NCGG Internship Report

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Internship report

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Contents

Abbreviations used

DWWT	Decentralised Wastewater Treatment
FFBT	Fixed-Film Bio-filter Technology
LiFE	Lifestyle for Environment
PPP	Public-Private Partnership
SRTU	Safe Re-Use of Treated Used water
SRTW	Safe Re-Use of Treated Wastewater
SBT	Soil Biotechnology
ULB	Urban Local Body

1. Introduction

The water challenges which India faces are not only diverse in as many senses, but multifaceted at the same time. It is therefore, not a surprise India to be ranked as 13th most water stressed country in the world, accounting for both surface and ground water (Pandey, 2019). An aspect of the diversity of the India's water challenge can be understood from the facts that almost 1/3rd of India's geographical region is prone to drought-like conditions and nearly a tenth is prone to floods (Lahiry, 2017); the monsoons which cover 80 percent the country's water supply from rainfall, have been deficit over 13 years in last 2 decades Panday, 2018); and therefore owing to such short period of rainfall, most of the water is lost to the run-offs (Chakraborti, 2019). Another aspect of the Indian water systems management is that it relies a lot on its aquifers to meet the demand for potable drinking water – be it through municipal distribution systems, or independent borewells. It accounts for around 40 percent of total supply. As a result, the water levels of the underground reserves across the country have been steadily depleting at an unsustainable rate, especially in the absence of adequate water replenishment for almost (NITI Aayog, 2019). In an assessment of 5,7,23 blocks or sub-districts in India, it was found that groundwater resources in 226 blocks are critical, for 550 blocks they are semi-critical and in case of 850 sub-districts they are over-exploited (Central Groundwater Board, 2019). Another aspect of the diverse issues with respect to India's water challenge stems from its population. India represents 17 percent of the world's population, and through 500 million livestock a 20 percent of world's livestock population. The spree of rapid urbanisation, industrialisation and population increase in India along with changing lifestyle, is adding to the water burden on an already water-stressed nation (ADRI, 2017).

The aforementioned economic and demographic changes are impacting the water demand and its usage intensity. Estimates suggest that irrigation sector would be requiring an additional 250 bcm of water by 2050, as opposed to additional 71 bcm of water usage increase by 2025, basing the comparison with 2010 figures (PIB, 2013). India being an agrarian economy, this is especially important. The total consumption of water tends to increase by 30 percent by 2050. (PIB, 2013).

Sector	Water demand in bcm					
	2010		2025		2050	
	High	Low	High	Low	High	Low
Irrigation	543	557	561	611	628	807
Drinking Water	42	43	55	62	90	111
Industry	37	37	67	67	81	81
Energy	18	19	31	33	63	70
Other	54	54	70	70	111	111
Total	694	710	784	843	973	1180

Water Requirement (High Demand Scenario) for Different Uses for the Years 2010, 2025 and 2050 (Source: PIB, 2013)

Since it has already been established that the groundwater recharge does not meet the water being extracted, over a long-term analysis of the pre-monsoon and post-monsoon seasons (ADRI, 2017), a large scale water deficit is soon to be a reality if no intervention is done to address the issue.

1.1 State of water availability in India

Following the findings from the study 'Reassessment of Water Availability in India using Space Inputs, 2019' by the Central Water Commission, it can be seen that the per capita annual water availability was assessed as 1486 cubic meter for 2021, and is estimated as 1367 cubic meter for 2031 (WRIS, 2021). According to the international norms, a country is recognised as water scarce when the availability is lower than 1000 m^3, and as water stressed when the availability goes below the 1700 m^3. The historic water availability in India between 1991 and 2001 were between 1900 and 2300 m3. The same was recorded in the year 2010 as 1588 m^3. Projections indicate water availability to reduce to 1200 m^3 by 2050 (WRIS, 2021).

Average estimates of annual rainfall indicate 4000 km^3, of which 1900 km^3 flows in river and is available as resource. Accounting for the constraints, a 1120 km^3 is accessible – 690 km^3 from surface water resources and 400 km^3 from underground water resources. The water demand by 2025 is likely to become 1100 km^3 (WRIS, 2021). The table below captures the water availability facts:

Area of the country as % of World Area	2.4%
Population as % of World Population	17.1%
Water as % of World Water	4%
Rank in per capita availability	132
Rank in water quality	122
Average annual rainfall	1160 mm (world average 1110 mm)
Range of distribution	150-11690 mm
Range Rainy days	5-150 days, Mostly during 15 days in 100 hrs
Range PET	1500-3500 mm
Per capita water availability (2010)	1588 m^3

Source: WRIS India, 2021

Average Annual Precipitation	3880 BCM
Average Annual Water Resources	1999.2 BCM
Estimated Utilizable Surface Water Resources	690 BCM
Total Annual Ground Water Resources (2017)	432 BCM
Total Annual Utilizable Water Resources	1122 BCM
Per Capita Water Availability (2011 Census)	1651 m^3/Year

Water resources in India Source: CWC, 2021

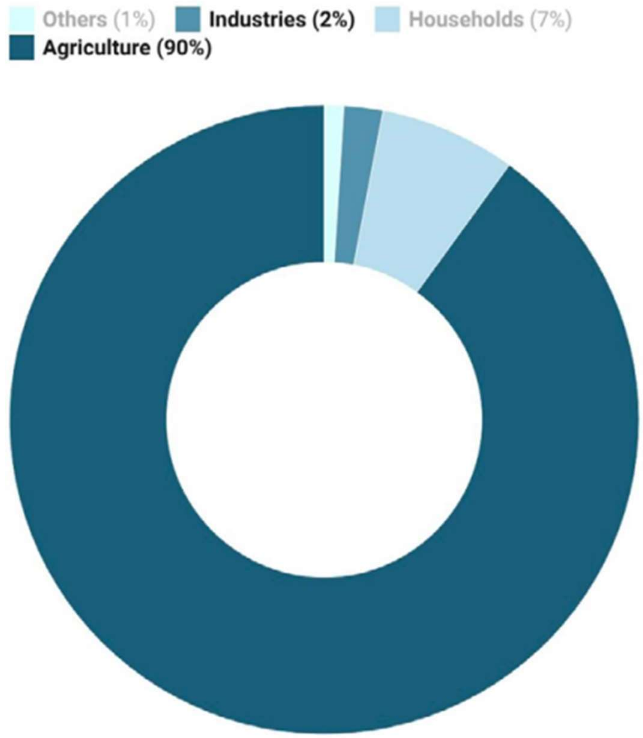
Sl.No.	Water Resource at a Glance	Quantity (km^3)	Percentage
1	**Annual precipitation (Including snowfall)**	4000	100
2	**Precipitation during monsoon**	3000	75
3	**Evaporation + Soil water**	2131	53.3
4	**Average annual potential flow in rivers**	1869	46.7
5	**Estimated utilizable water resources**	1123	28.1
	Surface water	690	17.3
	Replenishable groundwater	433	10.8
	Storage created of utilizable water	253.381	22.52
	Storage (under construction) of utilizable water	50.737	4.5
6	**Estimated water need in 2050**	1450	129
7	**Estimated deficit**	327	29
	Interlinking can give us	200	17.8

Source: WRIS India, 2021

1.2 The need for water conservation

Apart from the economic impacts that water shortage entails, the sociological impacts associated as well. The issue of water availability is highly gendered in India, and the rural-urban gender-based inequality is prone to worsen with incrementally reducing water availability. The associated socio-economic cost with this phenomenon is estimated at INR 1000 crores (or USD 133 million), accounting for 150 million days spent annually in water collection (ORF, 2021).

As apparent in the figure, the agriculture sector would be the worst affected, along with water-dependent industries such as food processing, leather, textile, to name a few. Estimates indicate a loss of 6 percent in GDP by 2050 (WRG 2030, 2009).



Water use across sectors in India (Source: Food and Agriculture Organisation of the United Nations, 2018)

1.3 T*he case for the Safe Re-Use of Treated Used Water*

Singapore serves as a model for countries across the world facing water crisis. It so happens that the water system model which Singapore adopted is how the brainstorming starts when deliberating on water solutions, and so for good reason. When Singapore restored its independence in 1965, it shortly-enough realised the shortage of water that had ensued. How far Singapore has come since, is a lesson and roadmap for nations struggling in establishing water sustainability and water security. The end of water treaty with Malaysia does not pose concern to Singapore's water independence. There are 4 water supply pipelines in Singapore, which indicate the extensive government intervention in water management – first, delivering incoming water from Malaysia (imported water), second carries desalinated sea water, third for locally obtained water from catchment, and lastly carrying treated wastewater (or, as Singapore branded it, New water).

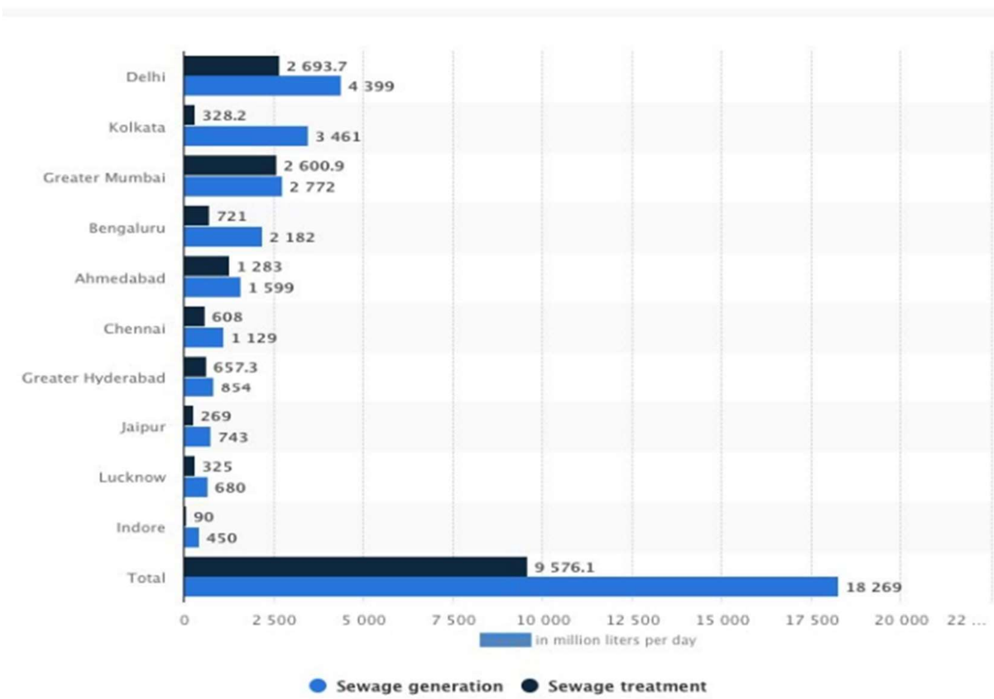
Hence, under the NITI Aayog's LiFE mission (NITI Ayog, 2022), there is the concept unfolding of 'Used water' borrowed from the New Water (Singapore's National Water Agency, 2018), to meet India's growing water demand. By employing technology-led, government-planned and incentive-led increase in the processing capacity or building of the treatment plants, the Government of India intends to install and build internal capacity at various level of administration (central, state, municipal, and local individual) to treat water, to required level depending upon use, and build resilience to water shortages and introduce sustainability to its water delivery.

The need for aforementioned intervention and pro-active governance comes from the urbanisation spree which India is experiencing. India is projected to have urban population growth to 40 percent by 2030 (NIUA, 2016). The effect of urbanisation in form of water shortages is more prominent in low and middle-income countries. And then there is the erratic seasonal change which further exacerbates the shortages of water owing to climate change. By harnessing wastewater, the municipal, agricultural and industrial water needs can be addressed; alongside addressing the water quality in natural water systems. By finding application of treated used water, not only water security is met, but the natural sources of water can be conserved simultaneously – such as underground water sources. By using treated wastewater, the water sources can be diversified. Diversification leads to water resilience.

The by-products obtained from the treating process can always be used in agricultural sector or horticulture, and hence, serves as a source of revenue to meet to some extent operating expenses.

In the current scenario in India, the potential which the wastewater has to provide fresh water has remained under-utilized. To give a sense, top 100 cities produce enough wastewater to make-up 75 percent of the industrial needs in India (IWMI, 2016). The quantity of domestic wastewater generated in India amounts to 62,000 million litres per day (or as is represented by MLD), and the current 920 sewage treatment plants depicting a capacity of treating 23,000 MLD, only address 37 percent of the treatment requirement (Singh, 2019). The portion of this treated wastewater used in various domains is way less. A comparison to the wastewater treatment and use of treated wastewater with the countries which are socio-economically similar to India is captured in the figure below.

Wastewater treatment and reuse in the developing countries comparable to India (Source: ORF, 2016)



Wastewater generation in major Indian cities (Source: Climate Centre for Cities, 2022)

1.4 Decentralised Wastewater Treatment System

Decentralized wastewater treatment (DWWT) systems are installed in a local set-up to treat the wastewater coming from either individual houses, community areas or buildings. The wastewater is treated close to the origin of the wastewater. The DWWT systems have aa definite geographic boundary identified wherefrom the wastewater is collected and sourced, and a low-cost collection system for wastewater and transfer of treated water, making the whole setup on-site for a given locality consisting of cluster of houses, individual houses, cluster of buildings, or communities.

As a result, a city or town may have more than such decentralised wastewater treatment systems. The case for choosing this system is made by: The treatment capacity required reduces, and the need for sewage lines and pipelines reduces, the whole setup becomes economically viable to be setup; the case for decentralised system is a good option when the institute or community is located far, significantly, from the centralised system; topographical challenges that may exist in setting up the required infrastructure and capacity for the transport, collection and disposal associated are also redressed; and since the cities are expanding, the newer establishments may not be feasible to connect to the central plant, or the central plant may not have the capacity to treat the newly incoming sewage. Such cases also call for this approach to treatment.

The advantages of Decentralised Wastewater Treatment systems are enumerated below (NIUA, 2019): -

a) Cost efficient

- The requirement for the underground sewer system is completely eliminated or partially required (within the settlement area from the household to the decentralised treatment system).
- Lower capital cost and O&M costs, due to absence of complex mechanical as well as electrical systems associated.

b) Environment Friendly

- Complete absence or lower electric consumption and hence power saving.
- Due or absence of underground sewer system, negligible possibility of ground water contamination.
- Odorless, hence can be built within a living habitat also.

c) High user acceptance

- Minimal O&M needs and costs as lower human resources capacity levels needed.

- Easy and efficient user involvement and participation (e.g. in decision making and O&M).

d) Flexibility in scale

- Can be built easily at remotest places, even by regularly skilled labour.
- Can be built for a scale fit for a household, cluster as well as community level or a town level.

2. Problem statement

India is a developing nation, and has been going through a spree of urbanisation involving a significant rate of urbanisation. The problem of water scarcity and water shortages is, but a foreseeable outcome, as has been experienced by all developing countries that have had their development streak preceding that of India. The water reclamation from the generated wastewater in India has been far low as compared to the comparable developing countries, which makes a strong case for investment and prioritising the used water treatment and imbibe the practice of the re-use of treated used water. The emerging climactic changes and shift in rainfall patterns has also made the water scarcity issues more complicated.

Hence, India as a nation needs to plan and encourage adoption of initiatives to boost wastewater treatment through its local urban bodies, and introduce the uptake of treated 'used' water in all probable and atleast non-potable application domains – such as industry, agriculture, horticulture, rejuvenation of natural ecosystems, outdoor washing and flushing.

The adoption of the said practice, in the end, lies with the urban local bodies in how pro-actively the ULBs invest in the outcome-based and impact-oriented plans pertaining to increasing or developing the wastewater treatment capacity and addressing water needs which remain unmet in industrial, agricultural and municipal setup. As a result, the Government of India and its domain-relevant think-tanks bodies need to invest in the capacity-training of the ULBs with the objective to help them ideate solutions to meet their area-specific challenges and water demands.

3. Objective

To conduct a study into and explore governance models and DWWT systems, which innovatively and successfully have addressed the then existent water availability issues, and thereby, cutting-down on associated challenges which may either be access to water, availability of water, economic aspects of water procurement or environmental impacts of untreated used water.

Such examples or case-studies can then be utilised through a documented training manual, in helping the urban local bodies with their capacity-building so to come up with solutions withstanding their set of local constraints, local needs and existing legacy infrastructure, conducted under the coordination and organisation of the National Institute of Urban Affairs.

4. Methodology

The each of the urban local bodies are better equipment to oversee the implementation of undertake initiatives to build or develop wastewater treatment capacity. Also, the urban local bodies are more equipped and well-positioned to account for and understand the local issues, challenges and demand, and carry-out the facilitate or undertake the required public interaction. Since, the ULBs can come any combination of limitations and scenarios, the approach followed for this report was to identify one case study for each of the implementation cases categorised based upon the area-wise scope of the population coverage for each model which is identified, across various scenarios of municipal, industrial and agricultural use. The methodology adopted accounts for the fact ULBs have different set of issues, implementation constraints pertaining to finance and existing infrastructure.

The focus of the report is upon collating the evidences of successful setup and demonstration of successful attempts at implemented decentralised wastewater treatment systems, without much emphasis on the technology used or costing involved. In the current marketplace, there are ample start-up introducing their share of technological innovation in the wastewater treatment domain technology.

As aforementioned, the selected case studies cater to the following categorisation of the scope of urban population coverage:

Case 1: Independent house level

Case 2: Building scale/Community centre

Case 3: Neighbourhood and community scale

Case 4: Organisational scale

Case 5: Industrial level

Case 6: Joint venture of Industrial and Municipal corporation

Case 7: Agriculture – Circular and climate resilient food systems

Case 8 and 9: Public-Private partnership

Case 10: Incentivised public spending

Case 11: Pilot program of a new governance model in agricultural sector

Case 12: Pilot program of new governance model in municipal setup

5. Case review

Case 1: Independent house level[1]

Case-study:

Residential Household Building, Sangli City (Maharashtra)

[1] Matto, M. et al. (2014)

Unique feature of the case study and the category:

Represents maximal localization in decentralised approach to wastewater treatment and re-use of wastewater.

Location:

Sangli city, Maharashtra

Objective:

The system treats locally-produced wastewater (both black and grey) using an in-house setup, 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

Scale:

People covered:	Family of 4
Treatment capacity:	1 KLD
Treatment water output:	0.5 KLD
Plant area:	2.8 sq. m.

Cost

Cost (per 2010 standards)	
Capital expenditure	INR 35,000
Operation and maintenance	INR 900 per annum

Technology:

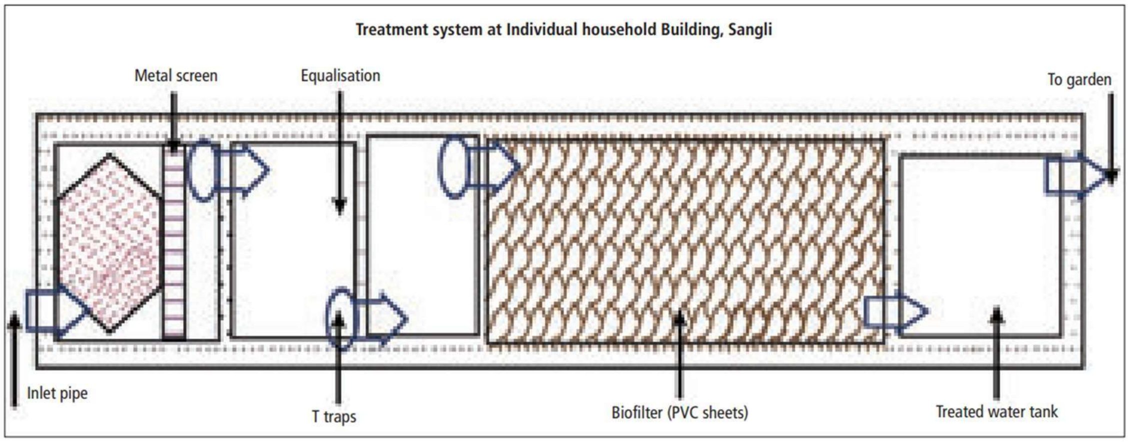
Name: Fixed Film Biofilter Technology (FFBT)

Brief:

- 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.

Illustration:



Graphical representation of fixed-film biofilter technology (Matto et al, 2014)

Size requirements:

- The four toilets, bathrooms and the kitchen wastewater enter 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.

Purpose use:

The treated wastewater is being used for in-house non-potable purposes, which include meeting horticultural water requirement of the household and for maintaining and landscaping a kitchen garden plantation over a 240 square metre area.

Cost benefit:

This represents the aspect where a remarkable outcome of implementing an in-house DWWT set-up was realised. The system allowed for a relatively free of charge supply of treated water fit for non-potable application, as an alternative to a water tanker of 8000 litres capacity costing Rs. 800 -1000/tanker. As a result, the annual 90 KL of treated water as output allowed for annual saving of INR 10,000.

Ecological benefits:

Since, the treated water is put to horticulture and landscaping usage, it adds to the groundwater recharge. The switch to treated water allows for non to lesser consumption of freshwater and aids in freshwater/groundwater conservation. The transport of water through tankers acts as a source of pollution, which to some extent is mitigated through local DWWT systems.

Case 2: Building scale/Community centre[2]

Case study:

Indradhanushya Center, Pune (public facility of Pune Municipal Corporation)

Unique feature:

Taking-in water from adjoining stream, treating it and using it, Discharging the water back into the stream post-treatment.

Objective:

Full-scale treatment system installed to treat wastewater flowing through an open stream alongside the Indradhanushya Environment Education and Citizenship Centre.

Location:

Indradhanushya Environment Education and Citizenship Centre (Rainbow Museum) Opposite Sachin Tendulkar Jogging Park, Anant Kanhere Path, Near Mahtre Bridge, Rajendranagar, Pune - 411030

Scale:

People covered:	250
Treatment capacity:	50 KLD, with 50 m3 /day

[2] Sayali, P. et al. (2015)

Treatment water output:	40 m3 /day

Cost:

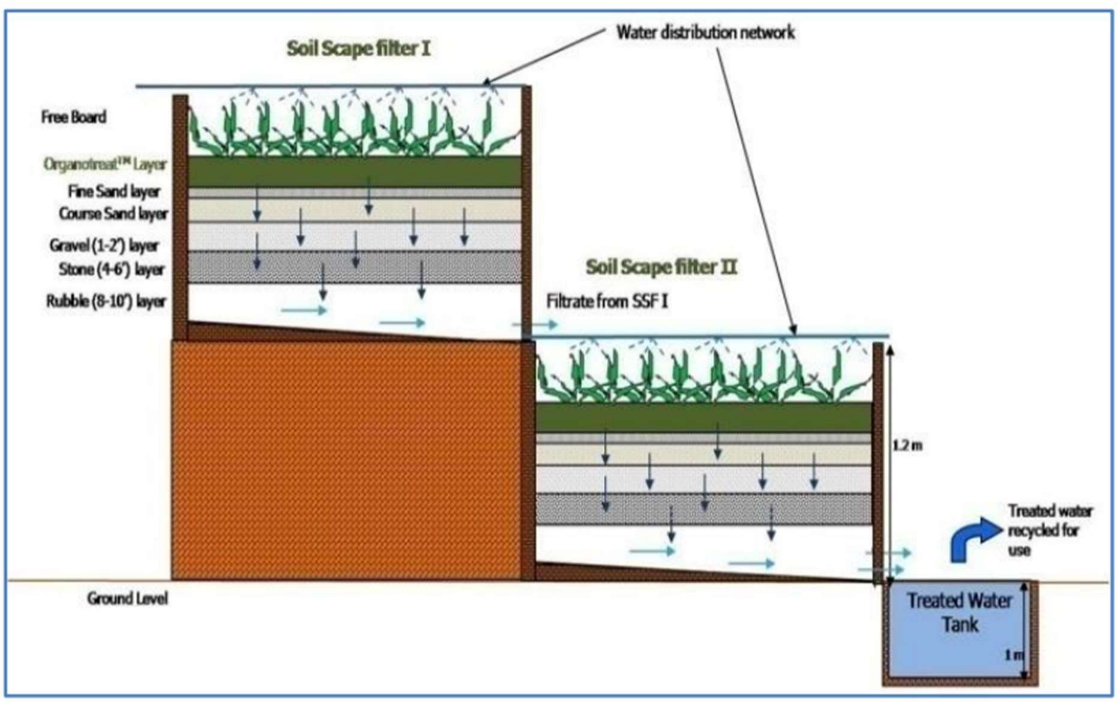
Capital	EUR 51,000
Operation and maintenance	INR 3,360 per annum

Technology

Name: Eco-filtration bank system

Brief: Eco-filtration bank (EFB) technology is a horizontal filtration technique, which is combined with medi-filter, mini–quay and a green pitching system. The maintenance requirements associated with the system are minimal, which are removal of debris from metal screens on a daily frequency, cleaning of intake well every 15 days, and uprooting of plantation every 2 to 3 months.

Illustration:



Graphical representation of Vertical Eco-filtration bank (Source: Sayali et al, 2015)

Size requirements:

Two linearly placed tanks, 25 m 2 surface area for each tank with effective depth of each tank being 1.2 m (10 m Length x 2.5 m Width and 1.2 m Depth of each SSF bed).

Purpose use:

The treated wastewater from the in-house treatment plant has sufficient output of water to meet with non-potable water requirements regarding gardening and maintenance of the campus' green cover, which constitutes water demand of 12 cubic metres/day, along with water requirement for maintaining Sachin Tendulkar jogging track (opposite to the Indradhanushya centre) amounting to 15 cubic metres/day. In addition, the treated water is also used for flushing purpose in washrooms within the campus.

Ecological benefits:

The ecological benefits of the project are manyfold. It directly contributes to the cleaning of Ambil stream, which acts as the water source. Not only the waste water produced from community centre treated before being released into the stream, the water in-take from the stream for usage also gets treated, hence adding to the clean water flowing within the stream. The project also strengthens the collective effort towards fresh water conservation, by supporting transition to safe re-use of treated water instead of freshwater for non-potable purposes.

The ecological impact of the same has been summarised as below:

	collection and transport			treatment			transport and reuse		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene	X			X				X	
• environmental and natural resources	X			X			X		
• technology and operation	X			X			X		
• finance and economics			X			X			X
• socio-cultural and institutional	X			X			X		

Source: Sayali et al, 2015

Case 3: Neighbourhood and community scale[3]

Case study:

Naval civilian housing colony, Kanjurmarg (Mumbai)

Unique feature:

The wastewater was treated in-house facility and used locally.

Unique feature:

- Fresh Water conservation.
- In-house treatment of waste water.
- Natural groundwater recharge through maintenance of green cover.

Objective being achieved:

The residential housing colony treats the domestic wastewater generated in its campus (both black and grey) by applying the Soil Biotechnology (SBT) which is a natural wastewater treatment method. The treated wastewater is used for meeting the landscaping water requirements within the colony campus, to maintain green areas. This approach is an example of effective Decentralized Waste Water Treatment (DWWT) in practice.

Location:

Kanjurmarg (Mumbai)

Wastewater scenario in the area:

There exists intermittent supply of water, on rotational basis to different wards. It has been common feature across the Mumbai. Of total sewage produced, upto 60-70 percent undergoes preliminary treatment before being disposed-off into the sea; which highlights the need for scaling up WW treatment. Also, the city of Mumbai has its water-wastewater facilities overstretched and unable to cater to the increasing demand-supply gap.

[3] Matto, M. et al. (2014)

Scale:

Waste generated:	7 Buildings x 24 Flats
Treatment capacity:	50 MLD
Plant area:	500 sq.m.
Treatment water output:	16.2 million litres/annum
Area irrigated:	2.2 acres

Cost:

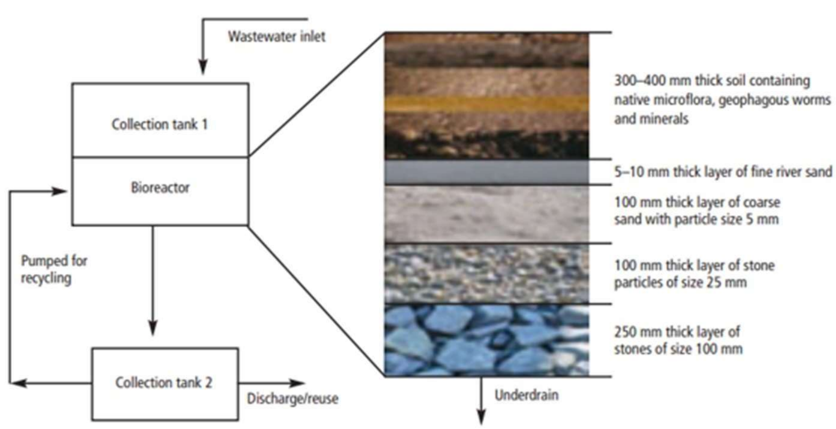
Capital cost	INR 7,00,000
Operation and maintenance cost	INR 1,000,000 per annum

Technology

Name: Soil biotechnology

Brief: 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

Illustration:



Schematics of Soil biotechnology and the bioreactor (Source: HS Shanker et al, Soil conditioning products from organic waste, Patent no. 760474282)

Area requirements:

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.

Application area and ecological benefits:

The clean water from the treatment unit is used for green cover maintenance and irrigation, instead of relying on freshwater sources for the purpose. This reduces the groundwater or freshwater from tankers consumption, and aids in freshwater conservation. The significant amount of treated water used in green cover maintenance makes way for groundwater recharge.

Cost benefit:

Prior to the implementation of DWWT system the water requirement for maintenance of green area and landscaping was dependent on municipal water tankers. Around 6 to 7 water tankers were required for landscaping water requirements in the neighbourhood. The average cost of water tanker (capacity being 8,000 litres) in Mumbai is Rs. 1200 per tanker. As a result, the administration was incurring a cost of INR 1.1 - 1.3 million per annum towards arranging water from tankers.

Case 4: Organisational scale

Case study:

National Environmental Engineering Research Institute (NEERI)[4]

[4] Matto, M. et al. (2014)

Unique feature:

Setting-up used water treatment facility in-hosue, and deploying the treated water for non-potable use within campus.

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 requirement

Location:

Worli, Mumba

Scale:

People covered:	100
Treatment capacity:	5 KLD
Treatment water output:	900 KLD
Green area irrigated:	550 sq. m.

Cost:

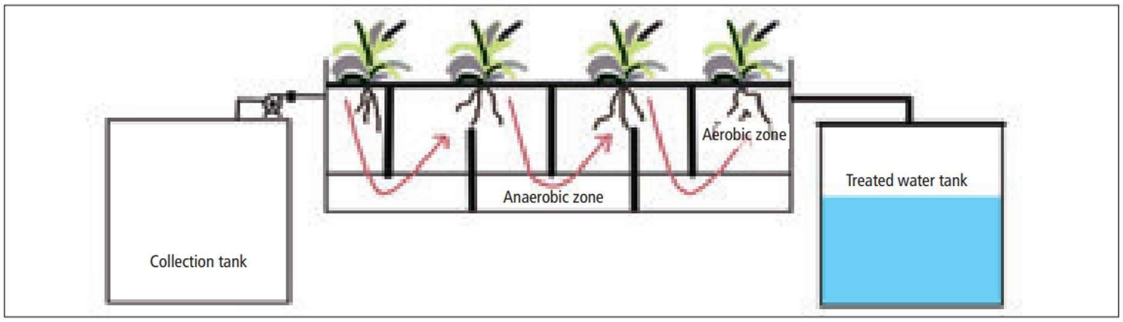
Capital	INR 14000 – Rs. 35000 per KLD
Operation and maintenance	INR 1,000-2,000 for a system of 50-100 KLD

Technology:

Name: Phytoid-based DWWT

Brief: Phytorid technology is a self-sustainable technology developed by NEERI, CSIR in 2005 for sewage treatment. 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. 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

Illustration:



Schematic representation of Phytoid-based DWWT (Source: Matto et al, 2014)

Purpose use:

The treated wastewater obtained from the treatment system is being locally applied to meet the green area water requirements, water requirement for car washing and as water in cleaning of the institutional parking space.

Cost benefit:

The average cost of water through a water tanker (of 8,000 litres) in Mumbai ranges from INR 1,000 to INR 1,200. Hence, by putting to use the treated water as alternative to water fetched using tanker, about INR .15 million are saved each year.

Ecological benefits:

The re-use of water with the help of locally implemented wastewater treatment facility, allows for freshwater conservation, and cuts the fossil fuel consumption in transport of water. The in-situ treatment and reuse of grey water upto 95 percent, helps to attract total of 5 credits on Indian Green Building Certification.

Case 5: Industrial level

Case study:

eMalahleni Water reclamation plant, eMalahleni, South Africa[5]

Unique feature:

Industrial plant is the sole consumer of municipal waste water. Successful PPP model.

Objective:

To create technology to treat used water from mines, local and others in the region, and meet the water requirements for industrial and municipality function, without relying on diminishing natural water sources.

Location:

Mpumalanga/eMalahlenni, South Africa

Scale:

People covered: The treatment plant is able to meet 20 percent of the city's potable needs, the total population of the city being 510,000 people

Wastewater generated:

Treatment capacity: 50 MI/day

Treatment water output:

- 30 m3/day potable quality, of which half is chlorinated.
- The water reclamation plant has treated 30 billion litres and supplied 22 billion litres to the eMalahleni Local Municipality.

Water scenario which forms the context:

The city is already struggling to meet the water demand by extracting 120m3 /day from the local Witbank Dam, exceeding the licensed withdrawal volume of 75 m 3 /day. This volume is set to increase to 180 m3 /day by 2030. Too little water on the

[5] Anglo American plc, 2007

surface is a problem for communities. Too much water underground is no less of a problem for a mining company.

The area around eMalahleni, however, contain approximately 140,000 megalitres (Ml) of wastewater from active and inactive mines, and continues to rise by over 25 Ml a day. Anglo American Thermal Coal invested a decade of research and development into mine water treatment technology. This was aligned with the central government mine closure and rehabilitation strategy, and the employment, development and environmental requirements of local authorities. By involving stakeholders, the WAPs provide links with other operational plans, including community development, social investment and biodiversity conservation programs.

Use case of the treated:

The treated water is of sufficiently pure quality to be used in meeting municipal drinking water needs, and need for water in cooling system for the mining industries.

Cost benefit:

The cost benefit of the project can be assessed from the fact that the project was examined by six of Anglo American's 10 thermal coal operations; and has been replicated by a private mining company Optimum Coal Holdings.

Social benefits:

- Daily by-product of the water reclamation of 200 tonnes consists gypsum-based solids, which is has been used in making bricks for affordable community houses. 66 affordable homes have been built from the gypsum waste for employees and it is hoped that it will soon be expanded to a total of 300 residential units.
- The local community has access to an additional source of drinking water for 60,000 people.
- The percentage of people without drinking water has been reduced from 14% to 2%, aiding the provincial government in meeting one of its Millennium Development Goals to ensure that no household goes without a potable, reliable and predictable water supply.

- The construction of the plant created almost 700 temporary jobs, two-thirds of which were filled by people from the local community. It now has 57 permanent employees - almost all of whom are local.

Ecological benefits:

- Conservation of fresh water, above and below the surface
- Reduction on strain on region potable water resource
- Habitat and industrial sustainability in the long run

Case 6: Joint venture of Industrial and Municipal corporation

Case study:

Ordinance factory, Nagpur[6]

Unique feature:

The excess treated water from the facility is used by the municipal corporation to meet its demand.

Scale:

People covered:	250 households (1000 people)
Treatment capacity:	100 cubic metre/day

Cost:

Capital	EUR 90,000
Operation and maintenance	EUR 9,000

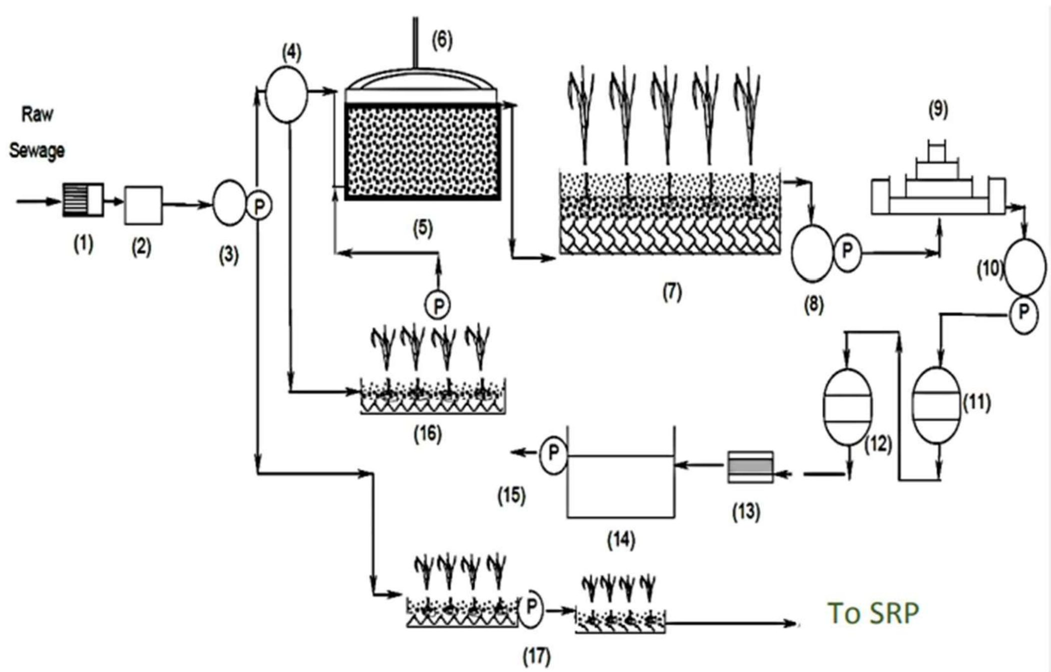
[6] World Bank, 2019

Technology:

Brief: The main treatment system consists of a bar screen chamber, oil and grease trap, inlet sump, primary clarifier, improved up-flow anaerobic filter followed by subsurface horizontal flow constructed wetland, cascade aerator, dual media and activated carbon columns and finally UV disinfection. The settled sludge from the primary clarifier will be treated in sludge drying reed beds, permitting the final reuse of the sludge as soil conditioner and avoiding any external disposal. The improved anaerobic filter ensures substantial removal of organic content. The filter media consists of poly propylene (PP) or high density poly ethylene (HDPE) material. The anaerobic reactor is filled with filter media 80% of total volume and provision is made for a biogas collection system, which is proposed to be utilised as fuel.

Treated effluents from the anaerobic filter are fed by gravity into two parallel sub-surface horizontal flow (HF) constructed wetlands planted with Typha latifolia and Canna indica. Horizontal flow constructed wetlands ensure the removal of remaining organics and nutrient reduction. Thereafter, treated wastewater is pumped to the cascade aerator to infuse dissolved oxygen and enhance the quality of effluent. The aerated wastewater is subsequently conveyed for tertiary treatment comprised of a dual media filter followed by granular activated carbon column for removal of colloidal solids and non-biodegradable organics & pharmaceutical and personal care products (PPCPs), respectively. Disinfection through UV is provided to the final treated effluent which is then ready to be recycled and reused for various non-potable uses of the community.

Illustration:



1)	Screen chamber	10)	Effluent collection tank
2)	Oil & Grease Trap	11)	Dual media (pressure) filters
3)	Raw Sewage Sump	12)	Activated carbon columns
4)	Primary Clarifier	13)	UV Disinfection
5)	Upflow attached growth anaerobic filter	14)	Treated effluent collection tank
6)	Bio-gas vent and collection	15)	Pumping & Piping for treated effluent reuse
7)	Subsurface flow constructed wetland	16)	Sludge Drying Reed Beds
8)	Holding Tank	17)	French Reed Beds – 1st & 2nd Stage, P – Pumps
9)	Cascade aeration		

Schematic treatment of wastewater treatment plant (Source: World Bank, 2019)

Size requirements:

Anaerobic filter and HF constructed wetland is 24 hours. The anaerobic filter consists of two tanks with the size of each tank being 4.5 x 4.5 x 2.5 m. Filter media of cylindrical shape with size of 37.5 – 50 mm and specific surface area of 150 m2 /m3 are provided. The size of the wetland beds is twice times 12.5 x 5 x 0.8 m

Purpose use:

The treated water finds application in horticulture for in-campus multi-purpose lawns and orchards.

Cost benefit:

Price of water is approx. €33/d per 100 m3 and costs incurred for generating non-potable recyclable water for 100 m3 is €14/d.

Net saving in respect to using recycled water would be €33/d – €14/d = €19/d. This would ensure savings of €19/d x 365 = €6,935 per annum from a 100 m3 /d capacity decentralised wastewater treatment plant.

Other benefits:

	Collection and transport			Treatment			Transport and reuse		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene		X		X			X		
• environmental and natural resources		X		X			X		
• technology and operation		X		X			X		
• finance and economics	X				X			X	
• socio-cultural and institutional		X		X			X		

Source: World Bank, 2019

Case 7: Agriculture - Circular and climate resilient food systems

Case study:

Sugar beet root factory Cosun in Dinteloord[7]

[7] Veraart, J. et al. (2020)

Unique feature:

Purified effluent water from mill is used as irrigation water for nearby greenhouse horticulture, and hence sustainable irrigation.

Location:

Dinteloord, Denmark

Water scenario in the area:

During a low river discharge and a high precipitation deficit, the freshwater supply cannot meet agricultural freshwater demand during the growing season, especially in rainfed agricultural areas in the southwestern part of the Netherlands that have no access to river water.

Hence, as a nature-based solution was ideated to address the challenge, ie. shortage of irrigation water. This was done through Aquifer storage and recovery (ASR) method, which involves using wells for the subsurface storage and recovery of excess freshwater to satisfy later periods of demand. The water is treated using reverse osmosis technology. The ASR-coastal is a special form of ASR in which several well screens are installed above each other in a single borehole, and can be independently operated. This enables the optimisation of the recovery of freshwater during ASR in aquifers with brackish groundwater. The buoyancy movement of the freshwater into the brackish groundwater can be overcome through deep infiltration and shallow recovery.

The treated water catered to the local farmers. The wastewater from the sugar factory served as the source for raw water that is then treated. The urban local body ULB is in the process of developing spatial plans to realize a climate resilient peri-urban catchment, on a larger scale, in cooperation with local food processing industry, farmers and owners of natural areas.

Size requirements:

A spread of individual 250 x 250 metres areas, each pertaining to single well, forms the entirety of space requirement for entirety of the set-up.

Purpose use:

Greenhouse horticulture needs irrigation water in spring/summer, purified waste water is stored within the aquifer (NBS solution) during winter and recovered in spring and summer. The intervention helps in ascertaining supply of water for irrigation to the local farmers, independent of the season which until were affecting water availability, hence adding to the climate resilience of the farming activity.

Ecological benefits:

The wastewater treatment helps in the rejuvenation of the groundwater, through manual aquifer recharge, which acts as water storage and aids in climate-resilient source of water for irrigation.

Case 8: Public Private Partnership

Case study 8:

Koradi Thermal Power Plant (operated by Maharashtra Generation Company)

Unique feature:

The Build-Operate-Transfer End-User Public-Private Partnership Model, where MahaGenCo was the only end-user of wastewater.

- Application areas: The project reduces net freshwater extractions by the power sector, freeing up freshwater resources for other uses (around 47 Mm3 per annum (Sharma, 2013)
- Increased urban wastewater treatment capacity results in cleaner and healthier water bodies, with the associated environmental and social benefit

Objective:

Diversifying the water supply sources by incorporating alternative sources (treated wastewater) and invest in sanitation and wastewater infrastructure for the city.

Location:

Nagpur

Brief: Mahagenco is first company in India to enter into an agreement with Nagpur Municipal corporation to treat and reuse wastewater from Nagpur Municipal Corporation's Bhandewadi Sewage project with view to minimize use of fresh water in power generation.

MahaGenCo and NMC partnership took the form of a build-operatetransfer (BOT) end-user contract with a 30-year concession, with the option for extension. NMC agreed to provide the raw wastewater, and MahaGeCo agreed to be in charge of the transportation and treatment needed to be able to reuse the wastewater effluent from the NMC sewerage system. The contract was developed to ensure a regular source of water to the power plant (the raw wastewater) while providing NMC with a constant stream of revenue from MahaGenCo (in the form of raw wastewater fees). The city would also reap the environmental, health and social benefits from the extra wastewater treatment.

Scale:

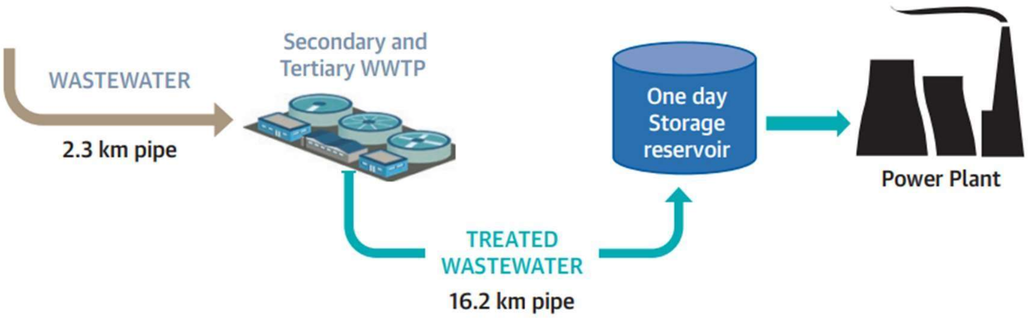
Treatment capacity: Stage 1 is 130 MLD, Stage 2 is 200 MLD

Cost:

Capital cost: INR 195 crores (inclusive of 90 cr. From NMC) + Land (from NMC)

Operation and maintenance cost: fixed amount of INR 15 crore (US$ 2.25 million) a year for the raw wastewater (110 million liters a day). For flows that exceeded the contracted amount, MahaGenCo agreed to pay NMC INR 2.03 per cubic meter of raw wastewater.

Illustration:



Source: MahaGenCo, 2022

Size requirements:

The land to set up the WWTP was 2.3 km from the drainage supplying waste water, and 16 km from the power plant.

Project highlight:

The fact that MahaGenCo was the only end-user of wastewater ensured strong project ownership and management, which were facilitated by regular communication and coordination with the municipal authority. There was no bidding process, because the MahaGenCo directly approached NMC and selection was done on a sole-source (nomination) basis. The collaboration between Nagpur municipal corporation and MahaGenCo ensured that the synergies of wastewater treatment and reuse were fully exploited through the contractual arrangement. An important aspect of this project is that MahaGenCo did not undertake the transport and treatment of the wastewater but instead selected an engineering, procurement, and construction contractor and an operations and maintenance operator through a single-stage competitive tender.

Cost benefit:

- The treatment and provision of water through this arrangement cost Mahagenco about INR 3.4 per cubic meter. Its costs would have been significantly higher if it had sourced fresh water from another municipal or irrigation project (about INR 9.6 per cubic meter for recent projects).

- The royalties from the sale of wastewater to MahaGenCo represent an extra revenue stream of nearly INR 400 crore over the concession period.

Ecological benefits:

- The project reduces net freshwater extractions by the power sector, freeing up freshwater resources for other uses, by around 47 mm^3 per annum.
- Increased urban wastewater treatment capacity results in cleaner and healthier water bodies, with the associated environmental and social benefit.

Case study 9: Public-Private model

Case study:

New Cairo Wastewater Treatment plant[8]

Unique feature:

Build–design–finance–operate–transfer (BDFOT) PPP model, with 20 years contractual period consisting of a construction period of two years and operation tenure of 18 years.

Location:

New Cairo, Egypt

Scale:

People covered: Close to 3 million people in New Cairo and the surrounding area will benefit

Treatment capacity: 250,000 cubic meters of wastewater per day

Use case scenario:

The treated water is directed to agricultural operations, reducing the demand for freshwater for agriculture and allowing that supply to be used by the city.

[8] World Bank (2018)

Cost:

Total private investment: USD 140 million

Project finance without recourse: USD 100 million

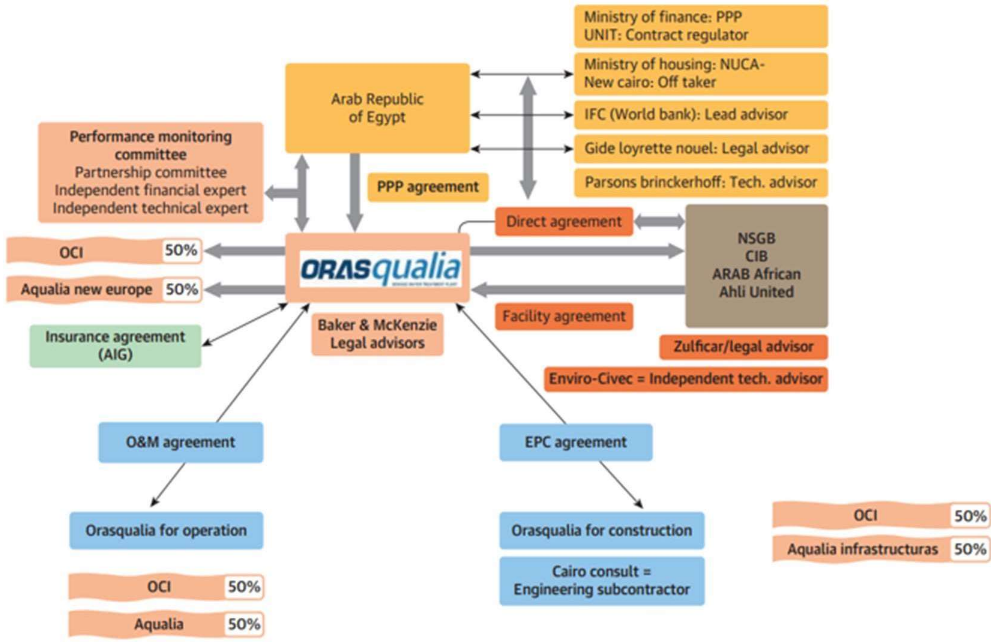
Equity: USD 40 million

Cost benefit:

- The compost from the wastewater sludge is sold to the cement industries located in the region, as fuel (which replaces coal, reducing greenhouse gas emissions). For the consortium, this is an extra revenue stream, although small, and avoids considerable sludge transport costs.
- The quality of the sludge is suitable to be used as agricultural fertilizer
- Plant reduces the volume of polluted water discharged into the river, bringing a significant improvement to human health and environmental quality.

Stakeholders:

The winning bid was made by a consortium of Orascom Construction Industries, an Egyptian firm, and Aqualia, a Spanish firm with international experience. The consortium provided the technical know-how associated with Aqualia, an international firm operating various water infrastructure projects around the world, and Orascom's knowledge of the Egyptian market, labor, and political conditions.



Source: World Bank, 2018

Benefits: -

- For city and environment:
  - Up to 3 million people benefited from the improved infrastructure and improved service quality
  - Increased availability of drinking water was achieved through substitution of treated water for irrigation and urban green areas in place of freshwater
  - Reduction in the pollutants being discharged into the river Nile
- For the private partner:
  - Knowledge transfer and higher visibility (for local private partner)
  - Some risk elements were taken by the Government of Egypt, including risks relating to inflation, interest rates, credit worthiness, and the supply of utilities
- For the utility and government:
  - Risk transfer such as financing, construction and operations and maintenance to the private partner. Foreign Exchange (ForEx) risk also assumed by the private sector.
  - Improved efficiency by bringing-in private sector
  - Reduction in pressure upon the public budget

- Knowledge transfer

❖ For the agricultural sector
  - Alternative source of irrigation water allows for potential increase in production in the surrounding area
  - Treated sludge (biosolids) can be used as fertilizer

Case 10: Incentivised public spending

Case study: Watershed Cleanup Program or Programa Descontaminación de Cuencas Hidrograficas [PRODES][9]

Unique feature:

The PRODES program is based on the idea of results-based financing (RBF). RBF is an alternative type of development financing and assistance method. In contrast to conventional development financing that focuses on disbursement of inputs such as grants, loans, or guarantees to be used in construction of infrastructure, RBF focuses on providing funding and incentives for achieved development outcomes and outputs.

Objective:

Reduce the level of contamination of watersheds by untreated wastewaters and motivate integrated water resource management systems and programs by creating and empowering watershed regulatory bodies and introducing charges for water use and water resource management plan.

Brief:

Under PRODES, the national water agency of Brazil (or ANA, as commonly referred to) agrees to a contract with an eligible WWTP owner, either public or private. Eligible WWTPs are located in river basins with legally established and operational river basin committees. Up to 50 percent of the investment costs for WWTPs can be reimbursed over five to seven years, provided that the quality of the

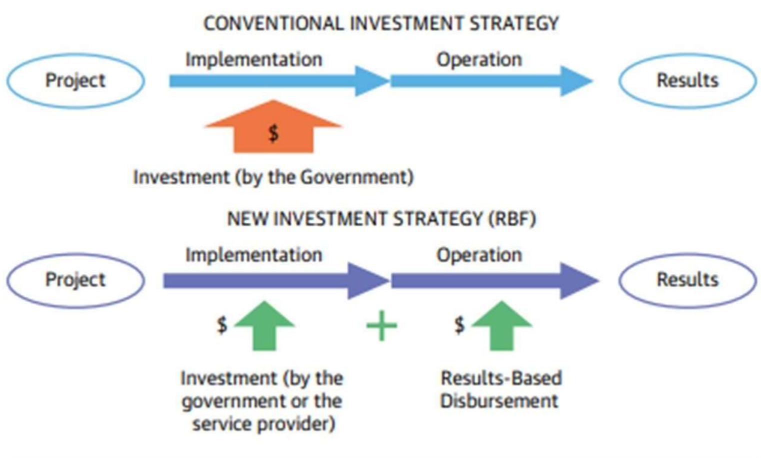
[9] World Bank, 2018

wastewater discharged meets the norms. The contracts move to new projects or upgrades in earlier ones.

Location:

Brazil

Illustration



Schematic representation of the incentivised public spending model (Source: World Bank, 2018)

The model establishes criteria set, which the interested WWTP entity must fulfil in order to be eligible. Said criteria are enumerated below:

Criterion	Maximum score
Population served and treatment efficiency	50
Existence of Basin Committee in operation	5
Location of the development in priority basin	15
Municipalities prioritized in the Atlas Brazil	5
Allocation of resources to PRODES by committees	10
Planned development in water resource plans, investment programs, etc.	5
Project situated in municipalities with criticality criterion 1 and 2 of Portaria 062 / ANA, and listed in Annex IV of Res. 601, dated May 28, 2015	10
Total maximum points	100

Source: World Bank, 2018

Benefits:

- For public entity:
    - Total contribution by ANA through contracts valued over INR 400 million, which has mobilized over Rs 1,597 million of investment by service providers
    - Operational risk is assigned to the service provider

- For private entity:
    - Enhances the financial viability of utilities and increases ability to access commercial or development credit
    - Partial payment of construction cost is borne by public sector
- Public and environment:
    - Increased provision of wastewater treatment leads to reduced pollution in the ecosystem
    - 7.49 million people are estimated to have benefited from improved water quality.

Case 11: Pilot program of a new governance model in agricultural sector

Case study

Water Solutions for Farmers by Milken innovation lab[10]

Location:

State of California, United States

Backdrop:

Farmers do not invest in buying the water resource to meet their field's water needs. Instead, the farmers simply drill for the water as per their needs. Such farmers, referred to as independent farmers, are not depended on the regulated sources of water. With the drilling for water becoming expensive on account of scarcity and shortage of water, and alternative in itself being a costly option where the unmet water demand has to be fulfilled through regulated water resources, the farmers either leave

[10] Milken Innovation Lab. (2016)

water needs unmet or the trees are removed to reduce the natural consumption of water to conserve it.

In light of aforementioned developing situation, ideating tools to help farmers use water as a resource efficiently by employing practices of precise irrigation and water recycling, to help such farmers find new sources of water, and along the way also repair the damage done to the aquifers, would go a long way. The design to devise a market for agriculture where government intervention ensures a market requirement, and partnership with leading tech companies which develop solutions for wastewater treatment creates opportunity to access the required technologies for the farmers at a more economic price, giving farmers an option to utilize their resources by exercising choice and alongside creating opportunity for restoration of the environment, forms the basis of the pilot project identified as the case study.

The model delineation of the aforementioned pilot project is described in the processes that take place, using a sequence of numbers, and subsequently depicted schematically in the figure:

1 - Farmers decide that they want to save water, reduce energy use, and save money.

2 - Farmers secure affordable financing from the state loan funds for agriculture producers. The local or state government may capitalize an agricultural revolving loan fund or a loan-loss reserve fund to provide lower-cost loans to small holder farms for eligible capital equipment purchase and installation.

3 - Farmers receive state tax credits to use themselves or to sell to tax credit investors. Tax credit investors could provide some of the capital needed to install new technologies, e.g., drips in alfalfa fields.

4 - Farmers contract with equipment providers to meet the farmers water savings needs. The technology providers have arranged a trade credit guarantee (where needed).

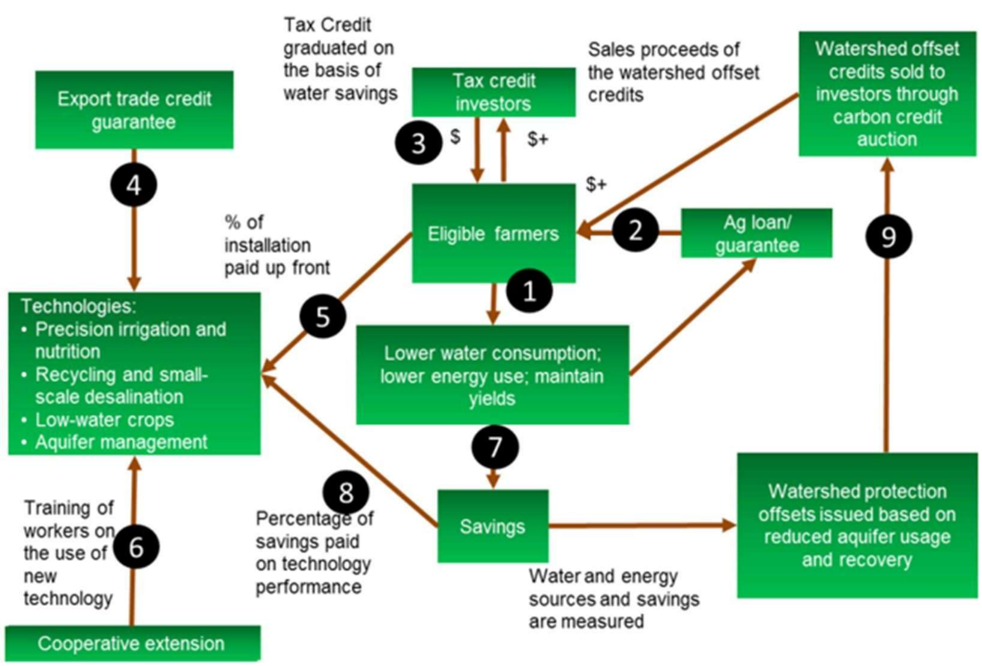
5 - A portion of the initial installation is paid by the farmer through the financing.

6 - The University of California's Cooperative Extension of its Division of Agricultural and Natural Resources could be deployed to train farmers in the use of the new water technologies.

7 - Savings from the deployment of the equipment and technologies would be measured

8 - Once the savings are realized, the farmer pays a portion of savings to the equipment and technology suppliers to reimburse the remainder of the capital costs plus a cost of capital and risk premium

9 - Savings would result in watershed savings credits issued by a "watershed district bank" and given to farmers. Farmers can sell watershed credits to investors or use "senior water rights" themselves



Schematic representation of the model (Source: Milken innovation lab, 2016)

Case 12: Pilot program of a new governance model in municipal sector

Case study:

Water Solutions for Farmers by Milken innovation lab[11]

Location:

State of California, United States

Highlight:

The model aims at setting-up an ecosystem through planned state intervention, which invites collaboration with the private sector in municipal context. The model delineation is as follows:

1-2 - The municipal water district decides what water savings technologies it wants to use.

3 - The municipality contracts with an environmental services company (structured as an ESCO) to bundle the technologies and solutions. The ESCO partnership would contract with an array of companies to provide a systems solution based on the needs of the water district.

4 - The ESCO raises investment capital to provide the needed funds to organize and deploy the technology solutions for the municipal water authority.

5 - The municipal water district would secure financing through existing (tax-exempt financing) or expanded programs (iBank's California Lending for Energy and Environmental Needs (CLEEN) targeted to water savings solutions.

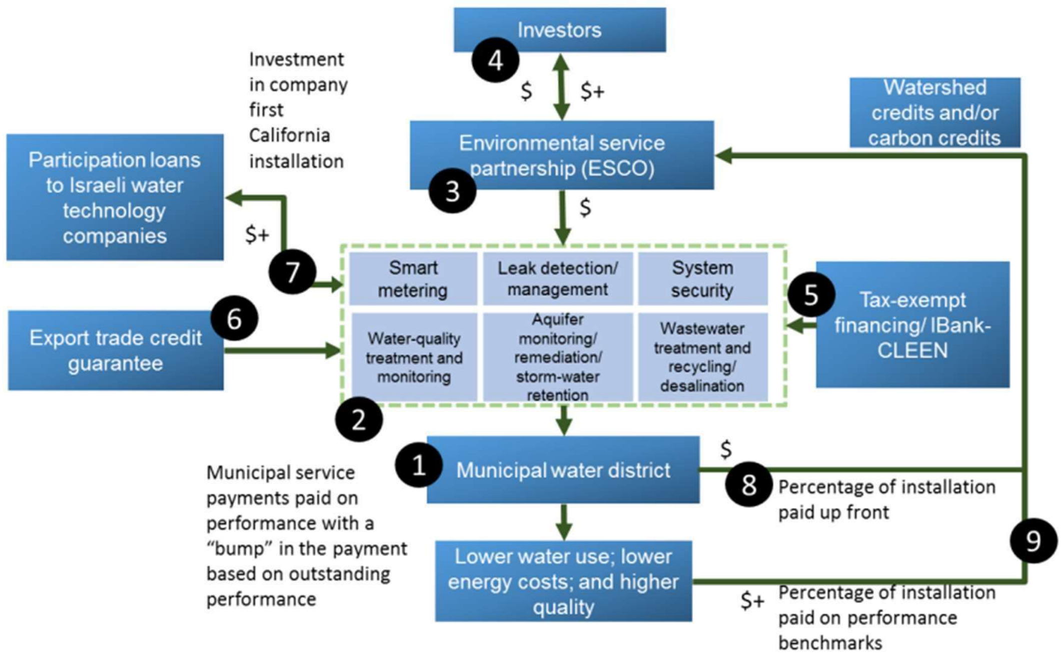
6 - The Israeli export trade office would provide trade guarantees to cover the credit on the Israeli companies' trade risks.

7 - The Israeli companies can apply for special export programs offered by the Israeli export trade office. The Israeli Office of the Chief Scientist would provide R&D investment to test innovations implemented in live beta sites (such a program exists in Israel and is considered to be significant in the implementation of new water technologies in municipal water systems.

[11] Milken Innovation Lab. (2016)

8 - The US water district partially pay capital costs up front and a contingent portion of the capital costs based on the “solution set” meeting successful outcomes.

9 - Additional service payments may be based on meeting savings outcomes, including a share of savings on high success thresholds being met.



Schematic representation of the model (Source: Milken innovation lab, 2016)

6. Learnings and Findings

6.1 Public-private partnership models

Wastewater treatment plants are capital-intensive owing to the construction costs and the technological equipment costs the revenue stream in case of the treatment may not be consistent, which in totality with the cost of the capital investment make the proposal for the private entities non-lucrative. This constraint makes a strong case for the public-private partnership approach to developing wastewater treatment capacities, as also seen in many of the world-over cases where wastewater treatment was made into business proposition for the private firms by government participating in tandem with them in matters of investment and easing the resource allocation.

Government participation lowers the over-all risk, make it easier the process of building and future procurement, and in some cases meeting the capital cost to some extent. The PPP model also benefits the government, for the availability of public funds in developing economies can hardly match such capital requirement.

Per the discussed case studies, some governance models or capacity development involved a PPP approach, where-in government side was represented by the urban local body or the municipal corporation and the other side by a private party which took a variety of role and function in the PPP arrangement. Hence below are some of the variations of arrangements, incontext wastewater treatment capacity building, which the involved parties agree to in a PPP agreement.

1. Build, Operate, Transfer (BOT): End-User PPP

This model the end user takes the risk of design, technology, construction. Municipal corporation ensures the availability and access to the land resource requirement for construction, and the timely availability of sewage and its quality. This is feasible option when the supply of raw sewage is meant for use by the industry as a whole.

2. Design, Build, Operate: PPP

The private entity designs, builds and operates (DBO) for the term of the project, of 30 years. Hence, Municipal Corporation funds the capital expenditure, provides land for the tertiary treatment plant and builds pipeline required for the transfer of water to the industry and for agriculture purpose, as deemed convenient. Municipality also bear demand off-take or revenue risk. Private entity bears the risk of technology, construction, and operation and maintenance. ULB have the liberty to decide the tariff. But private sector will bear the risk of timely payment even though work is completed on time.

3. BOT- Third Party Annuity

The private agency bears the risk of major capital expenditure, along with technology,construction and operation and maintenance risk. Municipality takes the risk of partial funding for capital expenditure, and annuity payment to ensure expected returns of theprivate operator. Demand off-take and thereby revenue risk is borne by the ULBs.

4. BOT- Third Party PPP (User Charge)

Risk of capital expenditure can be partially borne by municipality, but majority of capital expenditure has to be borne by private agency, along with that of technology, construction and operation and maintenance cost. However, the major risk of demand off-take and revenue has to be borne by private agency, and has therefore been the failure in most of the cases as demand off-take and revenue is often uncertain.

Observation

Most successful options in wastewater sector in India we find those cases are successful when revenue risk is taken by government. However, most successful options inwastewater sector in India we find those cases are successful when revenue risk is taken bygovernment (IWMI, 2020).

6.2 Application areas

i. The treated wastewater which is fit for the purpose of drinking or potable consumption has to be treated upto the tertiary level. But the treated water processed to a lower level – secondary or primary – is, nevertheless, fit for use or application in non-potable cases.

   Such a water resource can be directed for application in industries, in irrigation and other agricultural purposes such as horticulture, in community circles for landscaping and maintaining green cover, in commercial sector for purposes such as washing of coaches in metro depots, roads and parking spaces, watering public trees, and maintaining playgrounds and public parks, in individual houses for maintaining lawns and kitchen gardens, and in various other such opportunities of use.

The treated water as an alternative to freshwater, directly supports the conservation of natural water resources and conservation of water resources which supply potable water.

ii. Another major use of treated wastewater is in the natural rejuvenation of the ecological systems. By introducing treated wastewater into the streams, the overall quality of water flowing in the streams is improved through addition of water of relatively higher quality. Also, it reduces the instances where the polluted water is introduced into natural water or overall ecological systems.

Another aspect of introduction of treated wastewater in the natural ecosystems is creating catchment areas for this treated water, and allowing it to percolate underground and recharge the natural aquifers.

iii. The investment into development of capacity for treating more of the wastewater being generated close to agricultural land and farms, and extending the same to as well include water storage options and facilities for this water – maybe through artificial wells or man-made aquifers – and use this water during off-seasonal requirement of water in farms and agricultural lands, or to have reserved source of irrigation water to meet rainfall shifts or meet topographical challenges for certain 'farmable' areas.

6.3 Decentralised wastewater treatment systems

i. Decentralized wastewater treatment systems go a long way in developing economies, which have a common set of challenges all over the world. Such challenges include economic constraints when it comes to huge capital investments by public sector towards building infrastructure, or the steep rise in either size of urban areas/cities or the municipal requirements – where the legacy infrastructure either does not have the capacity to match the growing demands, or is unable to cover the geographical reach to cover the expanding cities.

ii. The DWWT systems require smaller investment – be it capital, land or capacity - and are not required to necessarily be undertaken by public sector. The topographical challenges which certain regions may pose to infrastructure development, are accounted for; and the newer areas which undergo development can be covered in a planned manner. The capital cost which is sunk, in the laying of the sewers and pipeline redundantly over long stretches, is also avoided, making this option more economic.

iii. The innovative approach to India's wastewater problem, water's efficient use as a resource problem, problem of water shortage and scarcity of potable problem, can be found and designed through making institutes, houses or communities individually capable to become self-sustainable and self-reliant in terms of meeting own needs to partially or full extent and meeting he obligations of environment friendliness.

This approach empowers individuals and communities by having them become self-reliant, and paves way for the building a diversified capacity to meet the water demand. Strategically speaking, such diversified sources of water reduce the threat and pressure upon the public sector in case of system failure.

7. Recommendations

i. Waste water treatment carries a huge market potential, if the treated water and the by-products from the process can be commercialised. The entry of the private sectors in the space will not only benefit the government through the influx of capital to develop state capacity, but aids directly in addressing the myriad of challenges which the country's different areas face pertaining to shortage of water and natural water sources conservation.

ii. The conventional technologies in the sector of wastewater treatment are very expensive, especially for the developing countries like India which are economically-strapped when it comes to huge capital investment. The leading private players in technology are based out of India, and the exchange rate does nothelp in the adoption of the foreign technology on a large scale. Therefore, the need to boost domestic start-ups which are geared towards innovations in the space of wastewater treatment is the need of the hour. Not only such enterprises help India build its capacity, they could potentially bring-in business from other developingeconomies.

iii. Indian government – Centre and of states, need to envisage or design plans and introduce the same as pilot projects in areas or domains that represent need for critical intervention. The plans would revolve around creating an ecosystem of polities and schemes to enable farmer or other water demanding entities to fulfil their needs and alongside re-align their usage system to meet the needs and goals of ecosystem preservation. The associated policies would ensure that there are incentives to the parties involved, and have financial support to adopt wastewater treatment technologies. The market can be attuned to provide additional benefit to the farmers and introduction of a credit system to monitor the progress made and involvement committed.

iv. The government needs to introduce a guideline through iteration in health, agricultural, urban, or related policies, focussing upon the measured to be adhered to when incorporating the use of treated used water which has not undergone tertiary treatment. Such water may or may not be purified enough to allow human contact. This is especially of concern since the farming activities in India are mostly undertaken through manual work. A set of guidelines can either delineate the purity levels that are safe for human contact, given the domains or purpose which for the treated water is being supplied; or can highlight the protective measures that should be undertaken.

v. Building state capacity in wastewater treatment should be followed up with building water reservoirs to cater to agricultural needs, especially when the treatment plants are close to the cultivation farmlands. Given the climatic shifts as are evident in Indian weather systems, and fact that weather pattern shift is prone to become severe, having a perennial source of water for irrigation needs would strengthen the Indian agriculture's resilience to climate change.

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