NITI Aayog

Reuse of Treated Wastewater in Urban/Peri-Urban Agriculture in

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Reuse of Treated Wastewater in Urban/Peri-Urban Agriculture in India

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Preface

As the country steadfastly progresses to a multi-trillion dollar economy, water is the one of the key resources which can catalyze the growth. On the other hand, the very same resource – water – can hinder the growth if it is not managed judiciously. One of the least addressed aspects, despite being the most challenging, is the productive reuse of treated wastewater. Generation of wastewater is common to places where there is plenty of water, and where it is scarce. The impact of unmanaged wastewater is manifold as it pollutes freshwater sources in water plenty zones while it raises water security concerns in arid regions. However, it is a fact there are hardly any incentives or motivation to treat and reuse wastewater for productive purposes. As Hon'ble Prime Minister has urged in the State Water Ministers' conference, a vision on water is an important dimension of the journey of Amrit Kaal. Water Vision will not be complete unless the wastewater is given the due importance it deserves. It is in this context, NITI Aayog has decided to shed light on reuse of treated wastewater for productive purposes. Agriculture being the largest user of freshwater, it will be the most appropriate sector where treated wastewater could be impactful; and the urban and peri-urban areas are important because of the availability of wastewater.

This document highlights the scope of reuse of treated wastewater for urban/peri-urban agriculture, its challenges and the way forward. The potential of reusable treated wastewater keeps on increasing as the urban centers grow out to accommodate the fast pace of urbanization. Moreover, the Nitrogen and Phosphorous contained in treated wastewater gives it an advantage over the raw freshwater, while using for agriculture. It is heartening to observe that many States have been coming forward with specific policy for reuse of treated wastewater. This publication is expected to augment the ongoing efforts, and encourage interested stakeholders in making effective reuse of the valuable resource. Today, we have GIS tools and satellite images to make the planning easier and quicker. We have also presented a few examples in this direction.

I am thankful to Prof. Ramesh Chand, Hon'ble Member, NITI Aayog for his much valuable guidance, suggestions and directional inputs. Support and motivation by Shri. B.V.R. Subrahmanyam, CEO, NITI Aayog is deeply acknowledged. I appreciate my team members in NITI Aayog for their sincere efforts. Mr. Arunlal K., Associate has made remarkable contribution through wide research reflecting the technical know-how, and coordinating the works with other team members. Dr. Shikha Anand and Dr. Snigdha Goel, Young Professionals were instrumental throughout the preparation of this document, and have demonstrated their niche skills by providing significant inputs. I am also grateful to many who have helped me and team directly and indirectly.

I am confident that this document will trigger a new paradigm of thinking and practicing to make the maximum out of treated wastewater.

AVINASH MISHRA

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Introduction

As the nation progresses at a fast pace to achieve its development objectives, and strives to be a multi-trillion dollar economy in short span of time, the resources will be consumed at an equally vigorous rate. For leap-frogging in any sector, water is the first and foremost requirement amongst all the natural resources. Water has its footprint associated with all products right from the inception, throughout the life cycle and even after its useful life. Unlike other raw materials or resources, water is an integral element in all sectors of the economy with certain variations in the extent and way of utilization. The National Commission for Integrated Water Resources Development (NCIWRD) estimated India's water demand at a range of 973 to 1180 billion cubic metre (BCM) for the year 2050, while the utilizable fresh water remains pegged at around 1140 BCM. The commission, while submitting the report in 1999, has highlighted the importance of reducing water requirement to low demand scenario.

In India three major areas of fresh water use, in the order of volume of usage, are agriculture, domestic, and industry. The undesirable commonality among all types of use is the fact that water once used becomes "waste" and is being "thrown/flowed /flushed out" of the system. Agriculture sector bears the blame of diverting the single largest share of close to 90% of fresh water supplied at a significantly low efficiency less than 40%. However, besides the runoff from the fertilizer/pesticide mixed farms, a significant share of the water supplied for irrigating the farm land is still fit and available for uses, either as surface water in near-by water courses or in sub-surface water storages or as ground water. The major Indian industries are also water-conscious and most of them are meticulous in recycling and reusing, partly because of process efficiency and partly due to the wide acceptability of green-marketing. But the Indian urban centres that are growing at an annual rate of 2.38% (average during the period 2010-2021), and consuming about 28 BCM of water annually, discharges 80% of the fresh water supplied in used/waste/non-reusable forms. As per the estimates of Central Pollution Control Board (CPCB), based on population for the year 2020 and taking sewage generated per person per day as 148 litres (i.e. 80% of per capita water supply at a rate of 185 litres per day), Indian urban centers generate sewage of 72368 million litres per day (MLD) which works out to be 26.41 BCM annually.

Water availability and demand

Every year on an average, India receives nearly 4000 BCM of water through rainfall, of which about 1999 BCM forms available water resources in rivers, lakes, reservoir, ground water and glaciers. However, the distribution of this quantity is not uniform across the country; apparently some river basins are acutely drought prone, while some are frequently devastated by flood. For example, the most flood prone basin of Brahmaputra & Barak, have an annual average water availability of 614 BCM, drains its major share into Bay of Bengal. At the same time, basins like Cauvery and East Flowing Rivers (EFR) between Pennar and Kanyakumari are facing water deficiency (Avinash Mishra and Arunlal K., 2022). On the other hand, India's development requirements grow at an optimistically positive rate. Population growth is also not an exception. The UN's population projection for India by 2050, which was relied upon by the NCIWRD while assessing the water demand for 2050, was 1500 million. But, we are about to cross this figure in 2030 itself. In addition, there is a surge in migration to urban centres leading substantial growth in urban water demand.

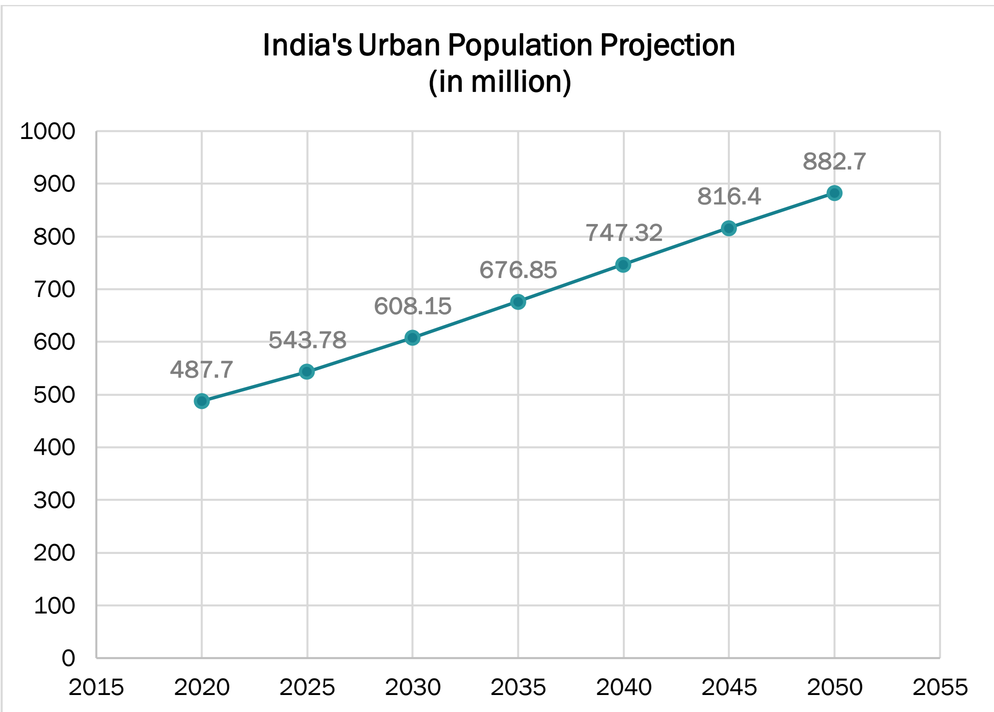

Figure 1: Projection of Indian Urban Population till 2050

Source: World Bank's DataBank
https://databank.worldbank.org/source/population-estimates-and-projections#

Studies show that urbanizing countries are rapidly converging to those diets which raise concerns such as greater use of land, water, and energy resources, greenhouse gas emissions, inequitable access to healthy food, and food security. Based on these trends and linkages, impending urbanization and associated dietary changes pose significant human health and environmental sustainability challenges (Pandey, B., 2020). Estimates suggest that percentage of urban population will grow from the current 35% to 36% to about 52% to 53% by 2050.

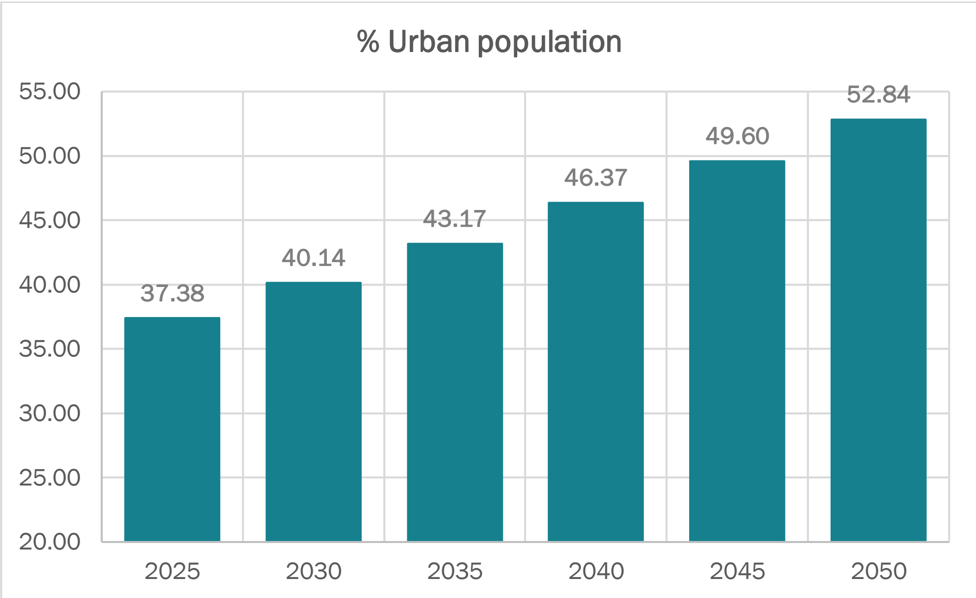

Figure 2: Projected percentage of urban population in India

Source: World Bank's DataBank
https://databank.worldbank.org/source/population-estimates-and-projections#

This indicates that the rise in urban population is not just because of the overall population growth, but contributed by migration to urban centres as well. Evidently, there will be a proportionate increase in water consumption by urban centres. Sometimes, urbanization comes at the cost of extinction of water bodies, shrinking of wet lands and disturbance of water balance. This often leads to long-hauling of fresh water from rural fresh water sources and subsequent conveyance losses.

Wastewater generation

The population projection data suggests that the wastewater generation will increase by about 75% to 80% in the next 25 years, which by volume works out to be 50000 MLD to 55000 MLD, and thus taking the total estimated wastewater generation to 1.3 lakh MLD. At this rate, about 0.8 BCM of wastewater will be generated additionally every year, and thus the total annual wastewater volume is expected to reach close to 48 BCM by 2050. This volume is about 3.5 times the existing installed treatment capacity, which testifies the necessity of scaling up of treatment capacity, robust system for wastewater collection, and a well-accepted framework for reusing the treated wastewater (TWW).

Table 1: Estimated wastewater generation till 2050

Year	Projected urban population (in million)	Estimated wastewater generation* (MLD)	Annually generated quantity (BCM)
2025	543.78	80479.44	29.37
2030	608.15	90006.2	32.85
2035	676.85	100173.8	36.56
2040	747.32	110603.36	40.37
2045	816.4	120827.2	44.10
2050	882.7	130639.6	47.68
*Estimated @ 145 lpcd (i.e. 80% of 185 lpcd fresh water supplied)			

Challenges in managing waste water

Managing wastewater is quite challenging in India on account of variety of reasons including mixing up of all kinds of used water, lack of sewage networks, issues related to improper/lack of maintenance, giving less importance than it deserves, and misconception on abundance on freshwater availability and many more. However, two most important challenges are the significant gap in existing treatment capacity, and the less penetration of advanced treatment technology.

Gap in treatment capacity

Owing to the gap in treatment capacity, only one third of this sewage load, i.e. 26869 MLD, is being treated, which works out to be 9.81 BCM annually. This scenario is going to aggravate as the water demand grows. Moreover, the treatment capacity is not growing in the same pace as that of urbanization, and there is significant gap between installed capacity and actual utilization. According to the United Nation's report, on average, high-income countries treat about 70% of the municipal and industrial wastewater they generate. That ratio drops to 38% in upper middle-income countries and to 28% in lower middle-income countries. In low-income countries, only 8% undergoes treatment of any kind. (UN WWD, 2017).

As of 2020, the country has 1469 STPs with total installed capacity of 31841 MLD. Further there are 162 STPs proposed with a capacity of 4827 MLD, which would bring the total installed capacity to 36668 MLD. Thus, we can treat volume of about 13.38 BCM annually, while the projected wastewater generation is 47.67 BCM as shown in Table 1. While analysing the treatment capacity between 2014 and 2020 it is seen that there is a growth of about 50% in the six-year period. Installed capacity grew from 22648 MLD at 2014 to 31841 MLD by 2020, that is an addition of 1532 MLD every year. But, to cope with the projected demand of 130639 MLD by 2050, annual growth rate should be 3132 MLD, which is double the existing pace.

The capital cost required to address the gap in the treatment capacity is justifiable. The benefits to society of managing human waste are considerable, for public health as well as for the environment. For every USD 1 spent on sanitation, the estimated return to society is USD 5.5 (UN WWD, 2017). The gap existing in the treatment capacity is the biggest challenge in effectively managing the wastewater. The un-treated water finds its way to freshwater sources or aquifer and thus adding stress to freshwater availability. It is also pertinent that even the installed capacity is not fully utilised. Out of the operational capacity of 26869 MLD actual utilization is 20235 MLD, and only capacity of 12200 MLD is complying with the consented norms prescribed by the SPCBs/PCCs (CPCB, 2021). In addition to this, lack of sewer network, issues in connectivity, problems associated with handling peak loads and improper maintenance affect efficacy of sewage collection.

Treatment technology

Next important parameter is the treatment technology used in STPs. Sequential Batch Reactor (SBR) and Activated Sludge Process (ASP) are the prevalent and adopted technologies all across the country. Various treatment technologies used in

India are tabulated in Table 2 and list of commonly used technologies across the globe and its potential usability for irrigation are mentioned in Table 3.

Table 2: Technologies used in the sewage treatments plants (STPs) in India

Technology	Technology type	Number	Capacity (in MLD)
Activated Sludge Process (ASP)	Conventional	321	9,486
Sequencing Batch Reactors (SBR)	Conventional	490	10,638
Extended Aeration (EA)	Advanced	30	474
Fluidized Aerobic Bed Reactor (FAB)	Advanced	21	242
Moving Bed Biofilm Reactor (MBBR)	Advanced	201	2,032
Upflow Anaerobic Sludge Blanket (UASB)	Advanced	76	3,562
Oxidation Pond (OP)	Natural	61	460
Waste Stabilization Pond (WSP)	Natural	67	789
Others (Aerated Lagoon (AL), Trickling Filter (TF), Bio-Tower, Electro Coagulation (EC) etc.)		364	8,497
Data Source: National Inventory of Sewage Treatment Plants, CPCB			

Table 3: Commonly used technologies and its potential usability for irrigation (Jean-Martin, 2022)

Technology	Restrictive uses (Fruit trees, industrial crops, cooked food crops)	Non-Restrictive use
Aerated lagoons	Fit	Requires disinfection
Single stage constructed wetlands	Fit	Not fit
Constructed wetlands hybrid	Fit	Not fit
Extended Aeration: Sequencing Batch Reactor	Fit	Requires disinfection (Filtration and disinfection for reuse by drip irrigation)
Trickling Filter (TF)	Fit	Requires disinfection
Rotating Bio-Contractor	Fit	Requires disinfection
UASB Followed by Waste stabilization pond	Fit for reuse	Fit Due to high algae production, use through drip irrigation requires filtration to remove the suspended solids.
UASB Followed by TF	Fit	Not fit
Disinfection with UV	Fit	Fit

Disinfection with Chlorine	Fit	Fit
Rotary Disc Filter	Fit	Requires disinfection
Fluidized Aerobic Bed Reactor (FAB)	Fit	Requires disinfection
Moving Bed Biofilm Reactor (MBBR)	Fit	Requires disinfection
Phytorid Technology[6]	Fit	Fit
UV photocatalysts[7]	Fit	Fit

Reuse of treated wastewater

The treated wastewater (TWW), in almost entirety, is either discharged to the watercourses or being used for irrigating parks, lawns or public places. Its reuse for non-potable purposes, such as crop irrigation, industrial processes, and groundwater recharge, is still relatively uncommon. Only a small fraction of treated wastewater finds its way back into productive use, representing an untapped resource that could alleviate water scarcity concerns. As inferred from the inventory of STPs published by CPCB, just less than 1000 MLD, which is about 3% of treated wastewater and 1% of wastewater generated, is being reused for some valuable purposes. Non-utilization of TWW is wastage of resource, capital cost of treatment facility, and the expense incurred in treating the used water.

Safe Reuse of Treated Wastewater (SRTW) is beneficial on multiple grounds. Firstly, on the water quality front, it curbs the issue of soil degradation and groundwater contamination. Secondly, it reduces human health hazards while dealing with contaminated water and consuming food items grown from untreated water. Thirdly, it could replace or supplement groundwater or surface water (or freshwater) irrigation and help to curb alarming issues such as the over-extraction of groundwater (NITI Aayog, 2022). While considering the options for reuse of TWW for valuable purposes, peri-urban agriculture stands first for various reasons. As cities continue to grow and consume more water, there is added pressure on elements for agricultural production such as water, land, energy. In parallel, climate change impacts are affecting the availability and distribution of water resources due to extreme floods and droughts. This implies urgent need to wisely use the water resources we have for productive purposes.

Reuse of treated wastewater in urban/peri-urban agriculture

FAO defines urban and peri-urban agriculture (UPA) as practices that yield food and other outputs through agricultural production and related processes (transformation, distribution, marketing, recycling etc), taking place on land and other spaces within cities and surrounding regions. It involves urban and peri-urban actors, communities, methods, places, policies, institutions, systems, ecologies and economies, largely using and regenerating local resources to meet changing needs of local populations while serving multiple goals and functions. UPA offers a fundamental strategy for building the resilience of a city's food supply.

Use of TWW for irrigation in farm fields in the proximity of treatment plants, which was otherwise being irrigated from a much farther water source, can reduce distribution losses. Further, the TWW could be clubbed with micro irrigation methods for horticulture crops. Thus, the actual saving on fresh water will be much more than the quantity of TUW used for irrigation.

There are varying estimates on the irrigation potential of treated wastewater from 6 ha per MLD to 90 ha per MLD as listed in Table 4

Table 4: Estimates on area that could be irrigated per unit of treated wastewater

<table>
<tr><th>Area per MLD</th><th>Source</th><th colspan="2">Remarks/Assumptions</th></tr>
<tr><td>6 ha</td><td rowspan="2">Adapted from Winrock International India; Institute for Studies and Transformations; Jadavpur University. Department of Economics; Eco Friends; Spatial Decisions; Youth for Unity and Voluntary Action (YUVA), 2006.</td><td colspan="2">Direct irrigation</td></tr>
<tr><td>39 ha</td><td colspan="2">Indirect irrigation after mixing with freshwater sources</td></tr>
<tr><td>45 ha</td><td>FAO</td><td colspan="2">8000 cum per ha</td></tr>
<tr><td>6.4 to 19.2 ha</td><td rowspan="2">Authors' estimate</td><td>80 to 200 ha/MCM</td><td>40% efficiency
240 days irrigation</td></tr>
<tr><td>90 to 40 ha</td><td colspan="2">Micro irrigation
4000 to 9000 cum per ha
(depending on crops)</td></tr>
</table>

According to FAO, 368 million ha of land are actually irrigated globally (AQUASTAT, 2020). Approximately 317 km^3 of municipal wastewater generated every year could potentially irrigate close to 40 million hectares (with approx. 8,000 m^3 per hectare), or 10% of all irrigated lands. The low percentage of wastewater that is being used by agriculture in a planned manner – and its unsafe application in most cases – confirms the vast potential for improving and increasing the application of used water (from municipal, industrial and agricultural sources) to meet the water demand for global food production. (UN WWD, 2017). In Indian context, the irrigated area is close to 100 million ha and the annual wastewater generation is about 29 km^3 which can irrigate 3.6 million ha. Considering a cost of INR 4 lakh per ha, the development cost per hectare of culturable command area in surface minor irrigation projects, it would cost INR 1.44 lakh crore (USD 18 billion) to create an irrigation potential of this extent.

Water erosion and other land degradation issues have depleted nutrients from the soil, thus reducing its quality. A majority of the states have soils deficient in macro nutrients such as NPK (nitrogen, phosphorous, potassium) and essential micro nutrients such as zinc. This causes crop yields to suffer and necessitates higher artificial fertiliser use (McKinsey, 2013). Nutrient rich treated wastewater can be carefully used to address this issue to some extent and thus offset chemical fertiliser use to a certain degree. Typical estimate of estimate ranges of nitrogen, phosphorus and organic carbon potentially contained in municipal wastewater globally is presented in **Table 5**.

Table 5: Typical composition of raw municipal wastewater of different strengths (Mateo-Sagasta and et.al., 2015)

Contaminants/resources	**Unit**	**Concentration**		
		Weak	**Medium**	**Strong**
Nitrogen (total as N)	mg/L	20	40	85
Phosphorus (total as P)	mg/L	4	8	15
Total organic carbon (TOC)	mg/L	80	160	290

Quantity of Nitrogen and Phosphorus contained in the wastewater generated in India in a year is given in Table 6. Consumption, Production and Import of Nitrogen and Phosphorus is presented in Table 7.

Table 6: Quantity of N&P contained in wastewater generated at present and projected in 2025 (in Lakh Tonnes)

Year	**Component**	Weak	Medium	Strong
2021	Nitrogen (total as N)	5.28	10.56	22.45
	Phosphorus (total as P)	1.06	2.11	3.96
2030 (Projected)	Nitrogen (total as N)	6.57	13.14	27.92
	Phosphorus (total as P)	1.31	2.63	4.93

Table 7: Consumption, Production and Import of N & P (in Lakh Tonnes)

Year	2018-19		2019-20		2020-21		Average	
Category	N	P	N	P	N	P	N	P
Consumption	179	69	191	77	204	90	191	78
Production	133	46	137	48	137	47	136	47
Import	47	32	52	24	56	25	52	27

Even for a weaker concentration sewage, the N and P contained is 10% and 4% of the import quantity respectively.

Examples of reuse of treated wastewater in agriculture

There are many countries which have included treated wastewater reuse as an important dimension of water resource planning, using high-cost technology for urban areas (such as activated sludge, membrane reactor) and low-cost ones for the rural areas (natural lagoon, constructed wetland etc.), taking into consideration the eco-friendly vision.

Reuse of treated waste water in Morocco (Adapted from UNESCO, 2020)

Morocco, a country known for its rapid population growth, urbanization and increasing economic growth, is suffering from water deficit and pressure on water resources. Water management is the key issue for Morocco as the country regularly faces extreme environmental events. In 2016, a sudden severe drought negatively impacted agricultural activity and production, during which the country's GDP decreased by 3.3%. According to the FAO, 83% of agricultural lands are not irrigated in Morocco, which is a percentage that needs to be reduced in the future. In addition, the country is suffering from significant variations in rainfall and droughts. One of the best alternatives to deal with this problem is treated wastewater reuse especially in agriculture. Forty-five percent (45%) of the total quantity of wastewater issued from wastewater treatment plants (WWTP) is now reused for agriculture in Morocco, which is a volume of 80 Mm^3 and could irrigate 4,000 hectares in 2020. The national water strategy (NWS), adopted by the Moroccan government in 2010, considers treated wastewater to have great potential in terms of facing water scarcity and facing the increasing demand for water, food and energy (UNESCO, 2020)

In 2004, only 8% of wastewater was treated, the rest was discharged directly into the sea (52%), the surface freshwater system (32%) and septic systems, causing serious pollution of the coastline, rivers and groundwater. This wastewater treatment rate was increased in 2012 to 28%. By 2009, over 100 WWTPs are installed, mainly in small and medium size towns in the interior of the Moroccan country.

The economic gain generated by the reuse of treated wastewater compared to irrigation with conventional water is reported to be very positive and attractive. This gain is due to the supply of treated water as an alternative water resource and to the nutrients provided by these waters. A 100 mm clean water slide (1,000 m3/ha) would provide crops with a fertigation equivalent of 40 kg of mineral nitrogen/ha, 11 kg of assimilable phosphorus/ha and 28 kg potassium/ha.

The Mas Pijoan Ranch, Spain (Adapted from Mateo-Sagasta, J. and et.al, 2010)

The Mas Pijoan Farm uses 0.137 Mm3/yr of reclaimed water. The farm is located in Solius, a community belonging to Santa Cristina d'Aro municipality. The farm has 300 cattle on 150 ha, 40 ha of which are irrigated for barley, rye, oats and corn for fodder. Until 2003, the farm irrigated 35 ha from the local aquifer. The yield of wells at the beginning of the summer could reach 150 m^3/h, but would decrease during the season to 20m^3/h, thus water could not be guaranteed at crucial crop growing stages. Competition for water in the area was always high. Managers of the nearby golf courses shifted in 1998 to the use of reclaimed water due to recurrent shortages in their groundwater supplies and the prohibition on the use of groundwater for irrigation. The Mas Pijoan Farm found that connecting to the reclaimed water pipeline of the Costa Brava Golf Course was a reasonable solution. The Golf Course irrigation is in operation from 9 pm to 7 am, and the water is supplied to agriculture during the rest of the day. The agreement between the golf course and the farmer includes the operation of a reversible pumping station to ensure that the golf course can be supplied from the storage pond of Mas Pijoan using well water if necessary. The arrangement has provided mutual reliability and flexibility to both users. The cost of connecting the existing pipeline to the storage pond was 70% funded by the European Agricultural Fund for Rural Development (EAFRD). Total private investment was 80,000 €. The farmer signed a 25-year service contract to share the use and associated operation and maintenance cost of the reclaimed water pipeline from the Golf course. Between 2003 and 2006 this arrangement enabled the farmer to increase total irrigated land from 35 ha to 41.6 ha, due to the reliability of the reclaimed water, amounting to 136,000 m^3/yr in 2006, or 65% of his water needs. The balance of water used by the farm is drawn from groundwater supplies. Overall, the ranch is irrigated partly with reclaimed water, partly with well water and partly with a mixture of the two.

There are examples within India, though in a relatively small scale, which reuse the treated wastewater for agriculture purposes.

Delhi

In 2016, New Delhi Municipal Council started promoting decentralised STPs to deal with the wastewater load in the city and promote recycling of used water for horticulture and irrigation. To supplement drinking water demand, Delhi Jal Board supplies around 89 MGD treated effluent for no drinking purposes i.e. irrigation, Horticulture, cooling of Power Plants and Industrial use etc. (Tyagi, 2022)

Chandigarh

Chandigarh is fully covered with sewerage facility and provided with the 100% sewerage treatment facility. As per 2020 estimates, utilizable treatment capacity of the city is 25% more than the quantity of sewage generated. Recognizing the importance of water, Chandigarh had, earlier in 1991, initiated tertiary treatment of wastewater at Diggian STP (45 MLD) and later supplied it for the non-potable uses such as irrigation of gardens, green belts & lawns, washing cars etc., to different sectors. Presently, the installed capacity for tertiary treatment is 90 MLD at Diggian STP which is treating 45 MLD water on average.

The Tertiary Treated (TT) Water SCADA project is being implemented to monitor the quantity and quality of recycled water to save the precious water resources being used for irrigation purposes in the city. Presently, the TT Water is being supplied to all the sectors without any automatic monitoring resulting in the non-equitable distribution of TT Water. The proposed SCADA system will include monitoring of BOD, COD, TSS, pH, DO, residual chlorine, as well as flow measurement, pressure measurement, etc. by installing various analyzing equipment and sensors (NIUA, 2023).

Policies, Standards and Regulations

In the absence of specific standards and guidelines, the wastewater reuse for irrigation is practiced informally in India. Local governments and industries in several parts of the country earn income by selling treated or untreated wastewater to local farmers. However, a lack of comprehensive standards and policy framework is hindering the development of a formal market, appropriate technology and sustainable business/financial models (Mahreen, 2022). Some states have already formulated policies on reuse of treated wastewater.

West Bengal has a policy titled “Treated wastewater re-use policy of urban West Bengal” published on June 2020. The policy highlights need of sustainable management of water resources by way of establishing an effective system of re-use of treated wastewater by the urban citizens of West Bengal thereby reducing dependency on fresh ground/surface water resources, and bringing reforms in the areas of Planning, Institution, Finance, Technology and Legal & Regulation. Advantage and need of reusing treated wastewater in agriculture is accepted in the document.

Gujarat’s “Policy for reuse of treated wastewater” (May, 2018) envisions to maximise the collection and treatment of sewage generated and sustainable reuse of treated water thereby reducing dependency on freshwater sources. The policy puts forward an ambitious target of reuse of 70% of treated wastewater by 2025, and 100% reuse by 2030.

In December 2017, Karnataka approved “Policy for urban wastewater reuse” with a goal to establish an enabling environment for the reuse of municipal wastewater to maximize efficient resource use, protect the environment, address water scarcity and enhance economic output. Agriculture is one of the major categories of reuse in this policy. Pricing of water and operational cost recovery of wastewater treatment plant are also outlined.

Chhattisgarh’s Urban Administration and Development Department has come up with Wastewater Recycle and Reuse policy with the objective of promoting reuse of treated wastewater with stipulated quality for non-drinking purpose. The document envisions that water reuse is for co-existence of domestic, agriculture and industrial sectors and for the growth of state to avoid any conflict with each other for precious water resources.

Jharkhand Wastewater Policy, 2017 considers wastewater as a perennial water source recognizes it as an integral part of renewable water resources. Policy urges that urban local bodies shall develop and manage wastewater systems, its treatment and reuse. However, there is cautious approach towards the reuse for agricultural purposes owing to the lack of wide social acceptance and apprehension of health risks.

The Department of Urban Development & Housing, Madhya Pradesh has prepared "Govt. of M.P. State Level Policy (2017) for Waste Water Recycle & Faecal Sludge Management (FSM)" to accomplish the objectives of 'The National Urban Sanitation Policy 2008' and 'Atal Mission for Rejuvenation and Urban Transformation Scheme'. Though the policy identifies agriculture as one of the potential areas for reuse, it limits the use in public parks, golf courses, urban green belts, freeway medians, cemeteries, and residential lawns citing that agriculture land is hardly available in urban area.

Andhra Pradesh's policy on wastewater reuse and recycle for urban local bodies encourages to substitute groundwater with treated wastewater. It also prioritizes use of reclaimed water for industry and agriculture as much as possible in order to save the fresh water for domestic uses. Policy also outlines institutional arrangements, participatory approach and legislative measures in this regard.

In 2016, Rajasthan's Local Self Government Department published State Sewerage and Wastewater Policy to ensure improved health status of urban population, especially the poor and under privileged, through the provision of sustainable sanitation services and protection of environment. As per the policy, treatment of wastewater shall be targeted towards producing an effluent fit for reuse in irrigation in accordance with WHO guidelines as a minimum requirement. Possible financial models and approach for incentivization are also included.

Haryana notified policy on reuse of treated wastewater in October 2019 keeping in view the limited availability of water resources in the State and also issues relating to quality of water. The priority of reuse in the decreasing order is Thermal Power Plants, Industrial Units, Construction Activities, Dual water supply system in houses/offices/business establishments, large commercial use, municipal use, and agriculture/irrigation. Policy specifies "TWW shall be used for agriculture/irrigation purposes provided surplus quantity is available after meeting the demands of the above-mentioned uses."

Punjab has notified Treated Wastewater Policy in 2017 which prioritizes agricultural reuse of treated effluent for unrestricted irrigation. Policy states that crops to be irrigated with treated effluent or blend thereof with freshwater resources shall selected to suit the irrigation water, soil type and chemistry, and the economics of the reuse operations.

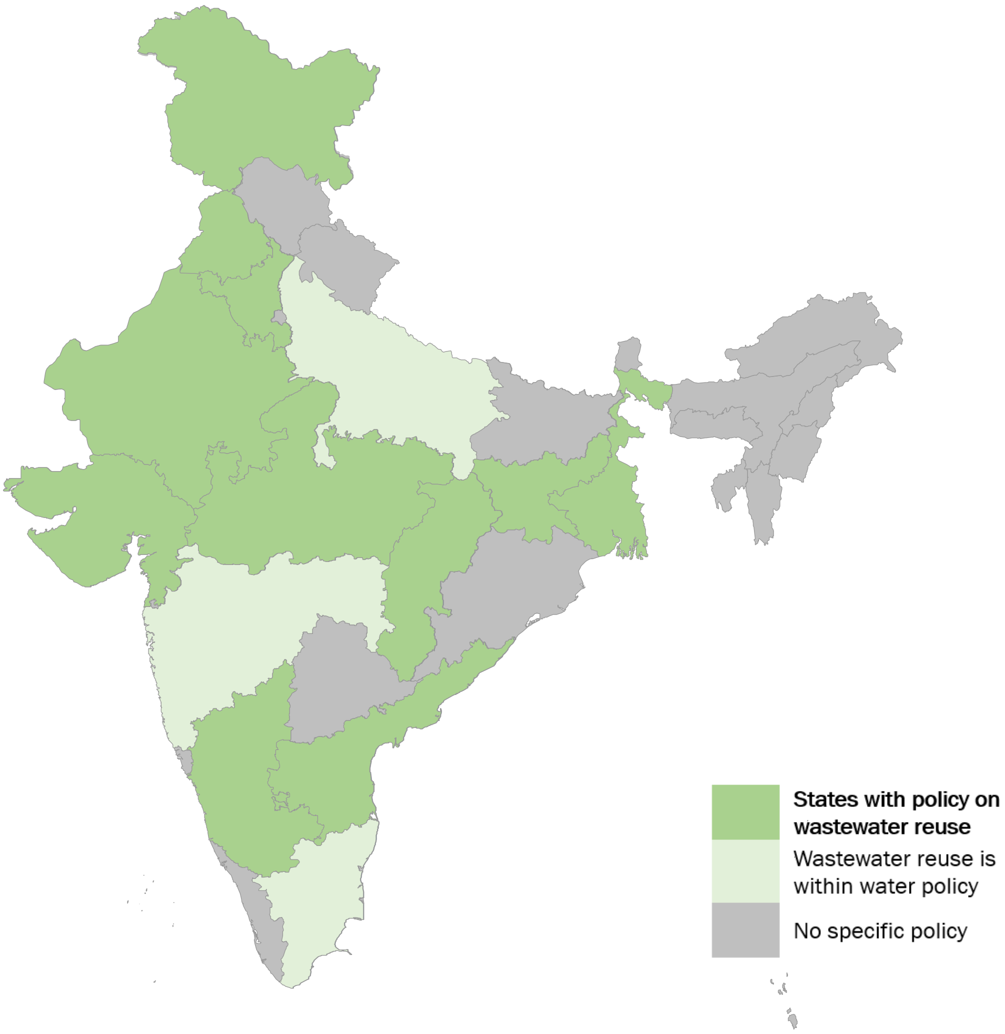

Figure 3: States having policy on reuse of treated water

Maharashtra's State Water Policy encourages recycling or reuse of treated wastewater and mandates penal action of the polluter of water resources. The policy considers that at least 80% of the water used for domestic purpose will be available for reuse.

Therefore, it is the obligation of local bodies to make available, entire quantity of generated sewage, for reuse after treating it to the standards prescribed by the Maharashtra Pollution Control Board (MPCB). There is no separate policy for wastewater reuse.

Tamil Nadu has policy to reuse treated waste water for industrial and agriculture uses. Memorandum of Understanding (MoUs) are signed between Urban Local Bodies and user agency for reuse of secondary treated effluent water. Jammu and Kashmir's "State Policy for Wastewater Reuse" was formulated in 2017 (before formation of UT of Ladakh and UT of J&K). Uttar Pradesh also has a draft policy on reuse of treated waste water.

National framework on reuse of treated waste water

National Mission for Clean Ganga (NMCG) has come up with a National Framework for Safe Reuse of Treated Wastewater, in November 2022, in consultation with NITI Aayog and various other organizations as part of India-European Union water partnership. The framework envisions that a sustainable circular economy approach is required for widespread and safe reuse of treated water to reduce pressure on surface water resources, pollution on the environment and risk of public health. It presents a brief information about existing polices and standards, and a model framework for State SRTW policy.

Way forward

Demand creation is the paramount in ensuring sustainability of reuse of treated wastewater. When the freshwater is almost free, it is very difficult to sell the treated wastewater at a price. There should be clearly visible and convincing advantages for using the TWW, or there should be a reasonable pricing for the freshwater. While the latter option may not be quite easy to implement, the former option could be tried out in select and specific areas where there is no bounty of free freshwater. Treated wastewater could be used in three ways.

1. Direct supply to the farm fields through pipes or existing channels
2. Discharge to a pond or surface body which is used as an irrigation source
3. Managed aquifer recharge

The indirect uses have certain disadvantages such as threat of polluting freshwater sources, repetitive consumption of energy consumed in pumping water from aquifer storage, non-quantifiable benefits etc. Moreover, it does not add to the productive use of treated wastewater. So, there should be some sort of incentivization for urban/peri-urban farmers to encourage the use of treated wastewater. The reuse of treated wastewater in agriculture may not be seen as a revenue recovery system, rather the primary agenda should be the effective utilization of the investments already made for treatment infrastructure, and operation and maintenance. However, the industries operating and drawing freshwater from the same hydrological unit may be asked to compensate the financial gap arising out of supplying treated wastewater to urban/peri-urban agriculture.

Economic feasibility of treated wastewater use could only be assessed from a broader perspective at river basin level or watershed level; it cannot be confined to a single sector such as agriculture. An integrated approach of water resource management (IWRM) that considers all water-related issues and their interdependencies, as far as possible, is required. (Mateo-Sagasta, J. and et.al., 2010).

Use of GIS tools in planning

Since each State/UT and each STPs location has unique advantages and limitations, the re-use strategy should be formulated to suit the local conditions. Site specific planning is essential to harness the full potential and to device customized strategies to address challenges. This could be done with the help of freely available and user friendly GIS tools to identify the potential farm fields around an STP which could be irrigated using the treated wastewater. On a conservative scale, an extent of 6 ha per MLD could be used for planning (the least value form Table 4: Estimates on area that could be irrigated per unit of treated wastewater). This will help to identify if there are potential scope of reuse of TWW in agriculture; distance to the prospective farm fields; need and extent of distribution infrastructure; extent of farm fields; proximity with market centres; further scope of expansion etc.

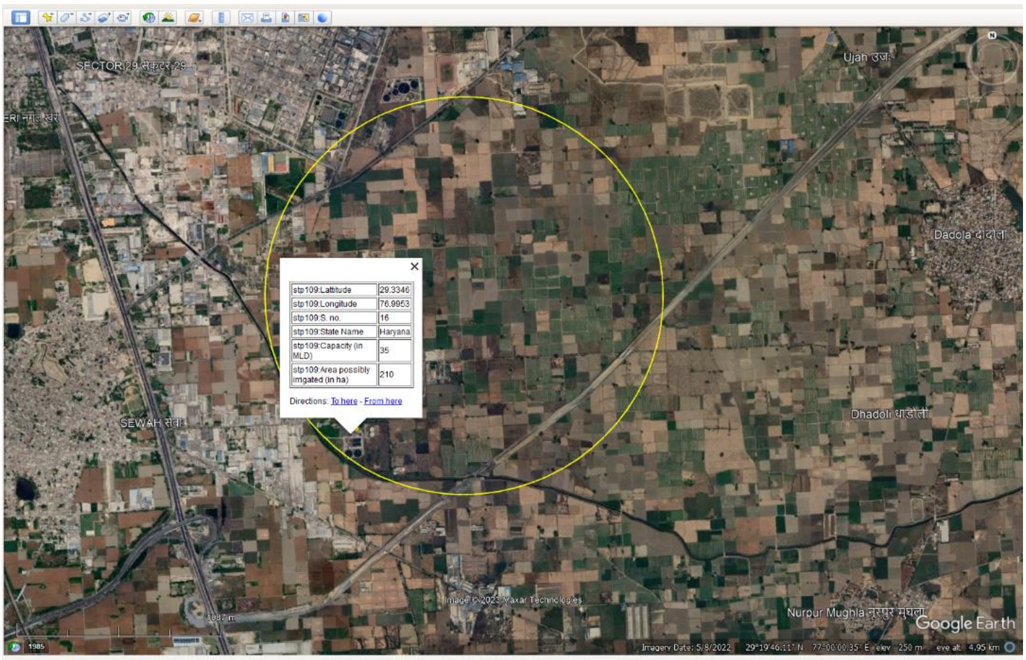

Figure 4 Google Earth image showing STP in Haryana and farm fields in its proximity

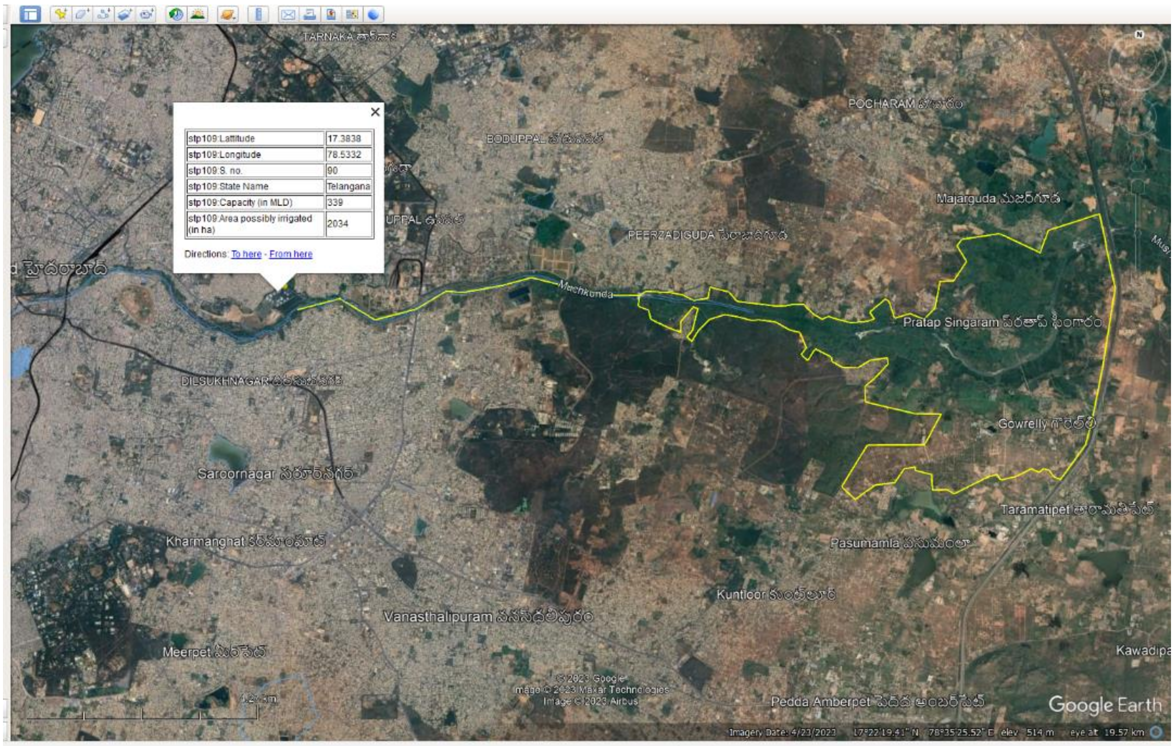

Figure 5 Google Earth image showing STP in Telangana and farm fields at a distance, at downstream of nearby river

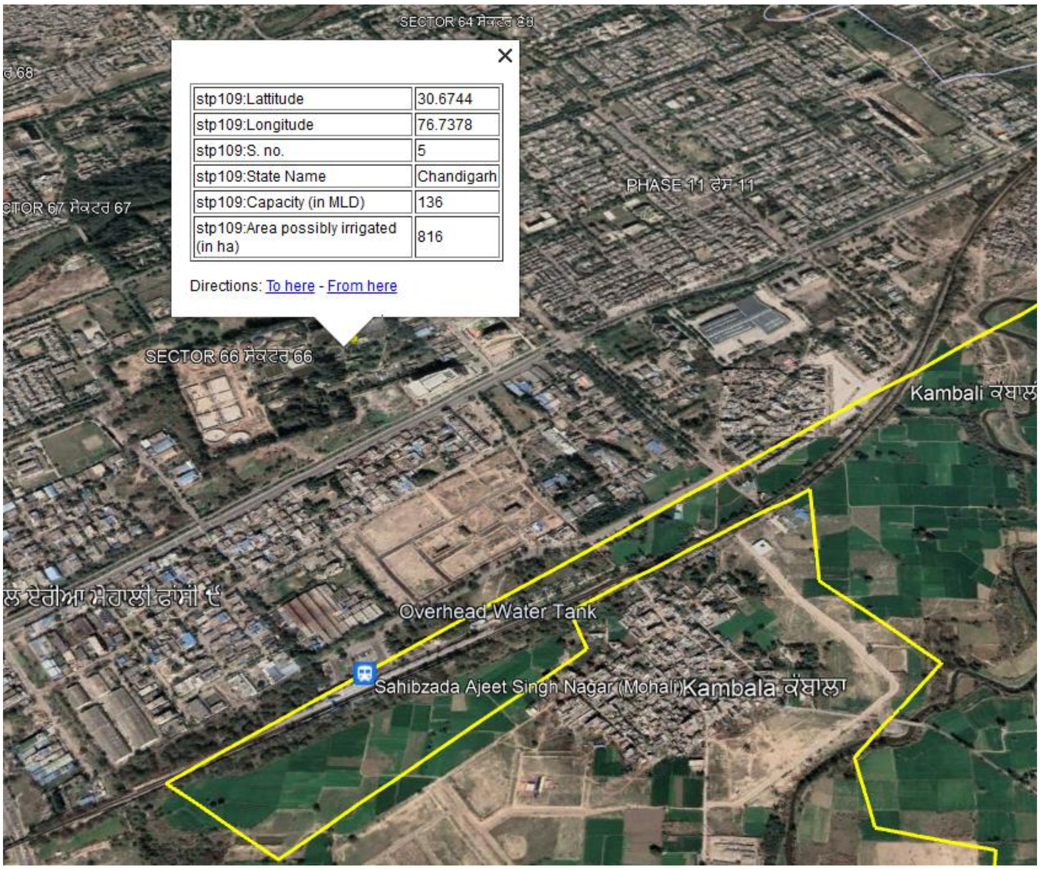

Figure 6 Information palette of STP and farm fields at distance of about 2 km

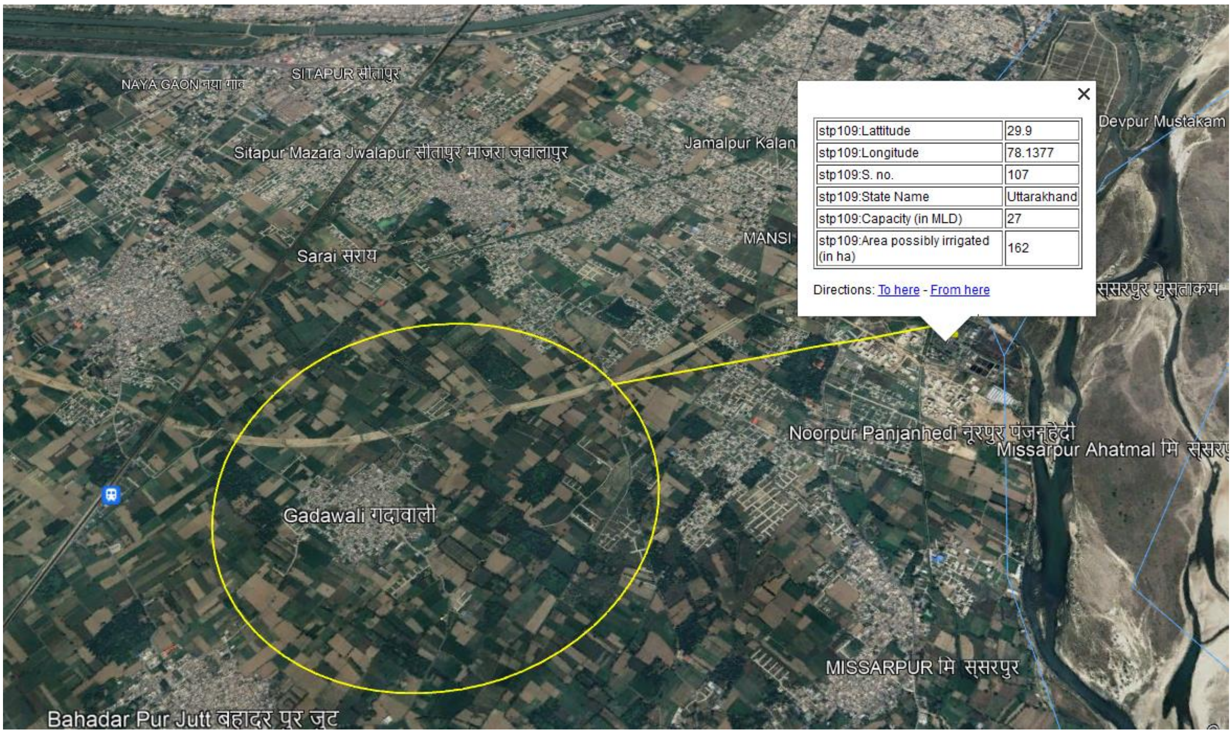

Figure 7: 27 MLD capacity STP in Uttarakhand, and prospective area at 1.5 km proximity

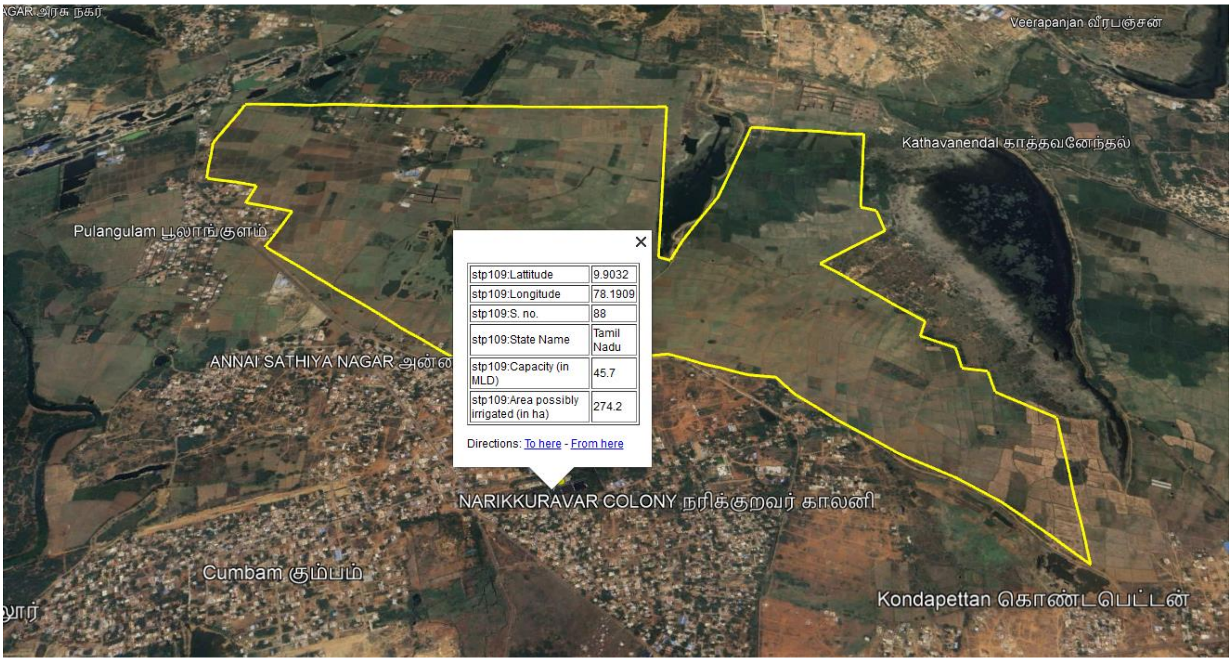

Figure 8: 45.7 MLD capacity STP in Tamil Nadu with potential irrigable area of 274.2 ha

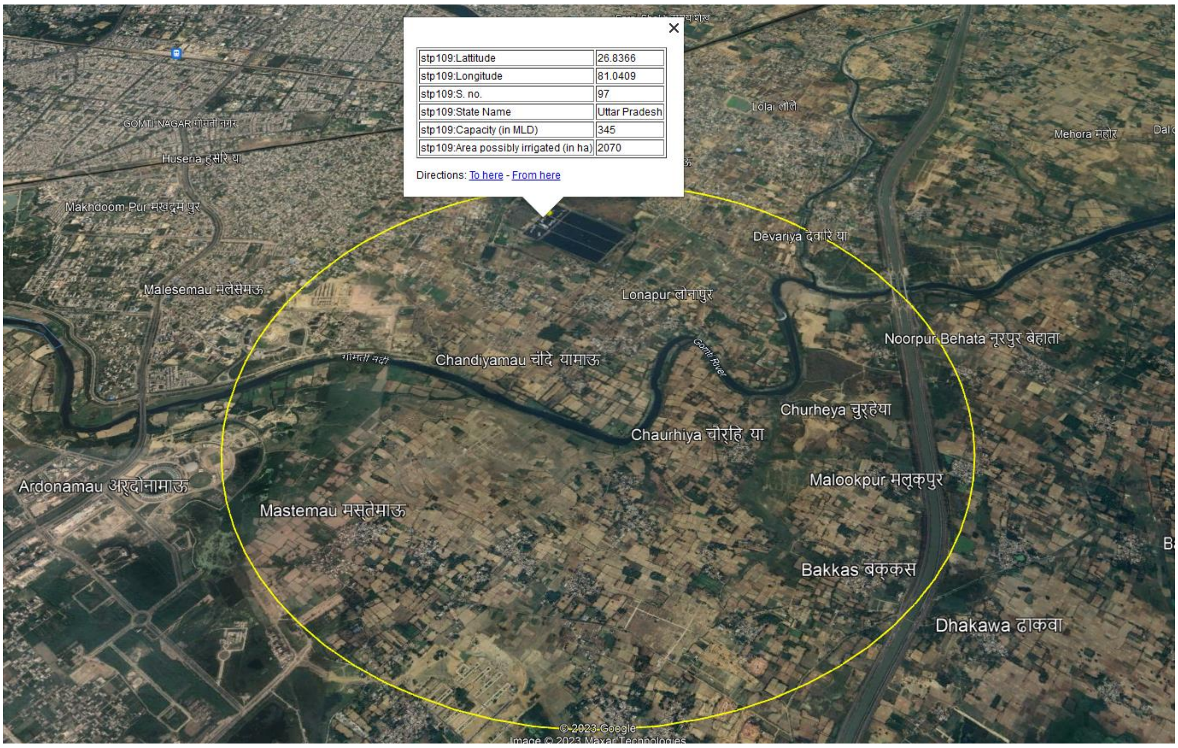

Figure 9: 345 MLD capacity in Uttar Pradesh with potential to irrigation 2070 ha area

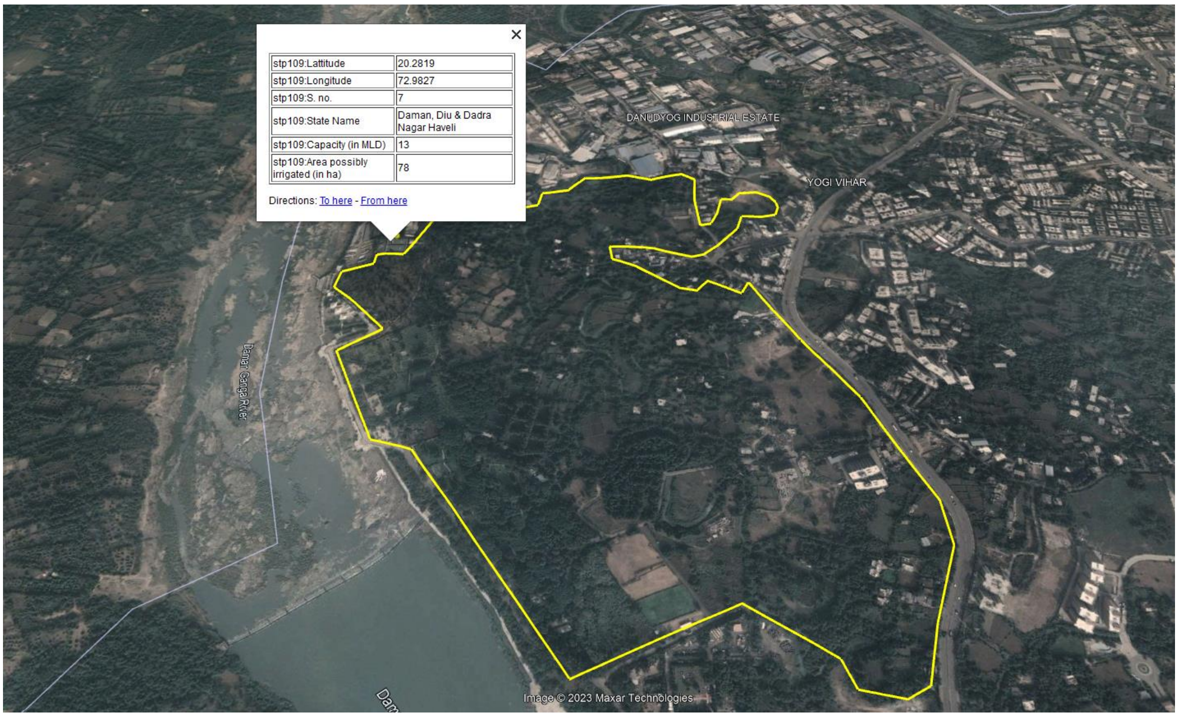

Figure 10: STP and potential area of reuse in Daman and Diu & Dadra and Nagar Haveli

Present fresh water irrigated area need not be converted to treated wastewater irrigation, while exploring the scope of reuse of TWW. The area deprived of irrigation should be the first priority to irrigate using treated wastewater, then the areas not having sufficient water for irrigation.

Use in conjunction with drip irrigation method is suitable since drip irrigation limits the direct contact with TWW as it is directly taken to the root zone area through pipe networks, and thereby reduces health risks to farmers to a great extent. This could be combined with precision farming/fertigation methods where farmer can customize the fertilizer to suit the characteristics of output water quality from the treatment plants.

The following points require attention while using the treated wastewater for irrigation:

i. Wastewater has relatively high sodium adsorption ratio (SAR) in comparison with fresh water. High SAR of irrigation water could have adverse impacts on crops and soil.
ii. Wastewater irrigation could lead to temporal and long-term salinization due to its salts (cations and anions) content. This can also cause an adverse impact on soil structure.
iii. Return water from farm fields: Since the quality of treated wastewater is dependent on the source of the water, type of usage and the treatment technology, the treated wastewater may still contain some pollutants or contaminants. This has the potential of polluting surface/ground water sources while flowing back from the farm fields.
iv. Risk of pathogen exposure: There are possibilities of pathogen being present even after treatment of waste water, if disinfection or advanced filtration treatment such as membranes are not part of the treatment system.
v. Bio accumulation: Heavy metals present in the waste water can accumulate in the environment and enter the food chain. Even at the low concentration levels, long term irrigation can pose risk for environment and human health.
vi. Weeds and mosquito: A rise in weeds is observed in fields using wastewater for agriculture, thereby, increasing the amount of pesticide applied. This can be reduced by using drip irrigation. Also, the practice of storing the wastewater

before applying to the fields creates breeding grounds for the disease carrying mosquitoes.

The presently treated wastewater, if reused for urban/peri-urban agriculture, is sufficient to irrigate a minimum extent of 1.23 lakh ha taking into account all losses, while it can go up to 9.25 lakh ha and beyond if distributed and used efficiently.

Table 8: States generating more than 1000 MLD and approximate irrigation potential

State	Sewage Load (MLD)	Treated quantity (MLD)	Irrigation potential (ha)	
			@ 6 ha/MLD	@ 45 ha/MLD
Andhra Pradesh	2882	309 (11%)	1854	13905
Gujarat	5013	2687 (54%)	16122	120915
Haryana	1816	1284 (71%)	7704	57780
Jharkhand	1510	15 (1%)	90	675
Karnataka	4458	2712 (60%)	16272	122040
Kerala	4256	47 (1%)	282	2115
Madhya Pradesh	3646	536 (15%)	3216	24120
Maharashtra	9107	4242 (47%)	25452	190890
NCT Delhi	3330	2412 (72%)	14472	108540
Odisha	1282	50 (4%)	300	2250
Punjab	1889	1360 (72%)	8160	61200
Rajasthan	3185	478 (15%)	2868	21510
Tamil Nadu	6421	995 (15%)	5970	44775
Telangana	2660	706 (27%)	4236	31770
Uttar Pradesh	8263	2510 (30%)	15060	112950
West Bengal	5457	213 (4%)	1278	9585
		Total	**123336**	**925020**
Data Source: CPCB, 2021				

Standards for reuse of treated wastewater

The essential step in implementing reuse of treated wastewater in agriculture is the formulation of standards. According to the International Organization for Standardization (ISO), the important concept in water reuse is the “fit-for-purpose” approach, which entails the production of reclaimed water quality that meets the needs of the intended end-users. The ISO has published guidelines for treated wastewater use for irrigation projects which provides guidance for healthy, hydrological, environmental and good operation, monitoring, and maintenance of water reuse projects for unrestricted and restricted irrigation of agricultural crops, gardens, and landscape areas using treated wastewater. ISO 16075:2020 specifies guidelines for treated wastewater use for irrigation projects intended to prevent public health risks within the population that has been in direct or indirect contact with the TWW or with any product that has come in contact with the TWW.

In order to expand the group of crops for irrigation purposes that can be irrigated with the different qualities of TWW, the concept of creating "barriers" has been developed. The barriers are methods to minimize the possibility of pathogens passing from the TWW to the vegetables or ingestion by the consumers. Irrigation barriers may be used to prevent contact between pathogens in TWW and humans who ingest irrigated food crops or may inhale aerosols produced during irrigation.

The barriers should include the following:

a. disinfection of the TWW;
b. appropriate physical separation of the TWW and the vegetables or the fruits;
c. installation of a physical barrier (such as a sun-resistant cover sheet) between the TWW and the fruit;
d. use of subsurface drip irrigation so that contaminated water does not ascend to the ground surface by capillary action;
e. irrigation under the foliage when the fruit is at an appropriate distance from the TWW.
f. cessation of irrigation ahead of harvesting to allow pathogen die-off.

The characteristics of crops that can be considered as preventing the pathogens from being ingested by the consumer should include the following:

a. fruit with an inedible skin (such as citrus fruits, banana, and nuts);
b. crops that are always cooked before consumption (such as potatoes);
c. fruit and cereals undergoing a very high-heat treatment prior to ingestion (such as wheat).

Relevant tables from ISO 16075:2020 depicting categories of treated wastewater quality according to chemical, physical and biological parameters, and the specified barriers are given in Appendix-A.

A set of proposed set of actions and timelines is presented in Table 9.

Table 9: Timeline and actions for implementation

Timelines	Steps/actions
Immediate (Within 2 months)	• Finalization of standards in consultation with CPCB • Testing of effluent water quality of all STPs

	• Identification of non-complying STPs
Short-term (Within 6 months)	• Retrofitting/modernization of non-complying STPs • Identification of STPs where urban/peri-urban agriculture is present/feasible within 10 km • Formation/revival of beneficiary associations • Estimation, feasibility analysis and site selection • Implementation and monitoring groups comprising of CPCB, Agriculture Dept, Irrigation Dept., Health Dept, FSSAI, and ULBs.
Mid-term (Within 1 year)	• Land acquisition wherever necessary • Laying of pipelines/construction of leading channels form STPs to farms • Establishing micro-irrigation infrastructure
Long-term/ continuous	• TWW quality monitoring (bi-weekly/monthly) • Health monitoring of farmers, farmworkers and surrounding population • Quality testing of agriculture produce • Sharing of monitoring reports with the implementation and monitoring groups

Conclusion

There is a wide consensus on the need, necessity and advantages of reusing the treated wastewater for productive purposes. Many States have devised policies in this direction with a vision on encouraging the reuse of treated wastewater. Though all policies are not quite encouraging about reuse of treated wastewater in agriculture, there is no blanket ban either. The significant addition of treatment capacity in the country and the growth of urbanisation underlines the importance of reuse of treated wastewater in urban/peri-urban agriculture. However, there needs to be a concerted effort to overcome the social stigma associated with this. This could be achieved only through forming quality standards for reuse of treated wastewater specific to the purpose it is meant for. Further to this, there should be a monitoring mechanism to ensure the quality of treated wastewater, and the quality of agricultural produce harvested from the crops irrigated using it. There could be provisions for third-party testing as well. The plans for reuse of TWW need to be tailor-made for each of the STPs with the help of GIS tools, wide consultation and clearly chalked-out plan for operation and maintenance. Treated wastewater is a wealth that none can ignore in the coming decade where water becomes scarce and the needs increase manifold.

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Appendix A: Relevant tables from ISO 16075:2020

Table A-1: Categories of treated wastewater quality according to chemical, physical and biological parameters

Cat.	Type of TWW	BOD mg/l		TSS mg/l		Turbidity NTU		Thermo-tolerant coliforms no./100 ml		Intestinal nematodes Egg/l		Potential uses without barriers	Potential corresponding treatment
		Avg.	Max	Avg.	Max	Avg.	Max	95 %ile	Max	Avg.	Max		
A	Very high quality TWW	≤5	10	≤5	10	≤3	6	≤10 or below the detection limit	100	–	–	Unrestricted urban irrigation and agricultural irrigation of food crops consumed raw	Secondary, contact filtration or membrane filtration and disinfection
B	High quality TWW	≤10	20	≤10	25	–	–	≤200	1000	–	–	Restricted urban irrigation and agricultural irrigation of processed food crops	Secondary, filtration and disinfection
C	Good quality TWW	≤20	35	≤30	50	–	–	≤1000	10000	≤1	–	Agricultural irrigation of non-food crops	Secondary and disinfection
D	Medium quality TWW	≤60	100	≤90	140	–	–	–	–	≤1	5	Restricted irrigation of industrial and seeded crops	Secondary or high-rate clarification with coagulation, flocculation
E	Extensively TWW	≤20	35	–	–	–	–	–	–	≤1	5	Restricted irrigation of industrial and seeded crops	stabilization ponds and wetlands

Source: ISO 16075-2:2020 - Guidelines for treated wastewater use for irrigation projects

Table A-2: Suggested number of barriers (degree of barriers) that are needed for irrigation with TWW according to their quality

Type of treated wastewater	Category	Irrigation of private gardens and gardens landscape with unrestricted public access	Irrigation of gardens and landscape with restricted public access	Irrigation of vegetables consumed raw	Irrigation of vegetables after processing and pastures	Irrigation of food crops other than vegetables (orchards, vineyards) and horticulture	Irrigation of fodder and seeded crops	Irrigation of industrial energy crops and in areas where the public has no access
Very high-quality treated wastewater	A	0	0	0	0	0	0	0
High quality treated wastewater	B	1	0	1	0	0	0	0
Good quality treated wastewater	C	Forbidden	1	3	2	1	0	0
Medium quality wastewater	D	Forbidden	2	forbidden	forbidden	3	1	0
Extensively treated wastewater	E	Forbidden	2	forbidden	2	2	0	0
Raw wastewater	—	Forbidden	forbidden	forbidden	forbidden	forbidden	forbidden	Forbidden

Source: ISO 16075-2:2020 - Guidelines for treated wastewater use for irrigation projects

Table A-3: Suggested types and accredited number of barriers

Type of barrier	Application	Pathogen reduction (log units)	Accredited number of barriers (Degree of barrier)
Irrigation and food crops			
Drip irrigation	Drip irrigation of low-growing crops such as 25 cm or more above from the ground	2	1
	Drip irrigation of high-growing crops such as 50 cm or more above from the ground	4	2
	Subsurface drip irrigation where water does not ascend by capillary action to the ground surface	6	3
Spray and sprinkler irrigation	Sprinkler and micro-sprinkler irrigation of low-growing crops such as 25 cm or more from the water jet	2	1
	Sprinkler and micro-sprinkler irrigation of fruit trees such as 50 cm or more from the water jet	4	2
Additional disinfection in field	Low level disinfection	2	1
	High level disinfection	4	2
Sun resistant cover sheet	In drip irrigation, where the sheet separates the irrigation from the vegetables	2 to 4	1
Pathogen die-off	Die-off support through irrigation cessation or interruption before harvest	0.5 to 2 /day	1 to 2
Produce washing before selling to the customers	Washing salad crops, vegetables, and fruits with drinking water	1	1
Produce disinfection before selling to the customers	Washing salad crops, vegetables, and fruits with a weak disinfectant solution and rinsing with drinking water	2	1
Irrigation of fodder and seeded crops			
Access control	Restricting entry into the irrigated field for 24 h and more after irrigation, for example, animal entering in pastures or entering of field workers	0.5 to 2	1
	Restricting entry into the irrigated field five days and more after irrigation	2 to 4	2
Sun drying of fodder crops	Fodder crops and other crops that are sun-dried and harvested before consumption	2 to 4	2
Irrigation of public gardens			
Access control	Irrigation by night when the public does not enter the irrigated parks, sport fields, and gardens	0.5 to 1	1
	Irrigation where the public has no access (Interchange on the side of the road)	2 to 4	2
Spray irrigation control	Spray irrigation at distances greater than 70 m from residential areas or places of public access	1	1

Note on log reduction: 0.5-log = 66.6%; 1-log = 90%; 2-log = 99%; 3-log = 99.9%; 4-log = 99.99%; 5-log = 99.999%

Source: ISO 16075-2:2020 - Guidelines for treated wastewater use for irrigation projects

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