Tonca STP, Panaji
Co-treatment Case Study

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A. City Profile

Panaji, the capital of Goa, is located in Tiswadi taluka of North Goa district. Spread over an area of 7.5 km^2, Panaji had a population of 40,000 in 2011[1]. Panaji, along with seven Out-Growths (OGs) and four Census Towns (CTs), comprises the Panaji Urban Agglomeration (PUA)[2], which had a population of 114,759 in 2011. (Map of PUA attached as Annex I)

Panaji is a tourist hub attracting anywhere between 5,000 to 15,000 people as floating population every day[3], which is approximately 12-40 percent of the city's resident population. Over the last few decades, the city's population has remained in a narrow range of 40,000-43,000[4]. This demographic trend is expected to continue and it is projected that by 2041, the population of Panaji (area under the jurisdiction of City Corporation of Panaji-CCP) will be around 60,000 while that of the PUA (area under CCP and 7 OGs) will be around 181,453[5]. (Population details of Panaji and PUA is attached as Annex 2)

Access to toilets*:* As per the City Sanitation Plan (CSP) of Panaji (2015), 97 percent of the households within Panaji (area under CCP) have individual toilets and about 2 percent use community/public toilets[6]. To meet the sanitation needs of the floating population the city has 17 public toilets[7].

As per Census 2011, 87 percent of the households in PUA (CCP+7 OGs[8]) had access to individual toilets and 7 percent used public toilets.

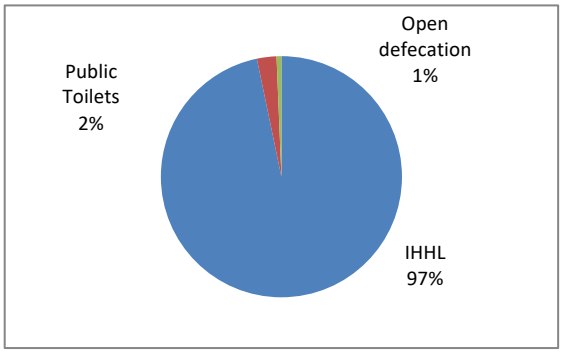


Figure 1: Access to sanitation in CCP area

Source: Panaji CSP, 2015

Sewage collection & conveyance system: As per CSP of Panaji, 61 percent of households in Panaji (area under CCP) were connected to piped sewer system while 39 percent had septic tanks (2015)[9]. (Table is presented as Annex 3) Multiple households are connected through one connection and the city has 2,727 connections for 5,987 households connected to piped sewer network[10]. With the recent (2014-16) expansion of the sewerage network in the erstwhile uncovered areas (including wards 1,2,3,4 and parts of ward 5) another 1,904 households have been added to the sewerage network taking coverage to 80 percent[11]. (Refer Annex 3) CCP is planning to cover the uncovered areas, including ward 29 and 30 in Ribander (across the Ourem Creek) and some pockets inhabited by migrants belonging to EWS/LIG sections. (Details on the city's sewerage system are presented in Annex 4).

[1] Source: Census 2011
[2] While Panaji is administered by the City Corporation of Panaji (CCP) the adjoining settlements are administered by their respective ULBs and Gram Panchayats.
[3] Source: City Sanitation Plan of Panaji, 2015. Available at http://ccpgoa.com/swachhbharat/uploads/download/13_down_Final_City_Sanitation_Plan_Panaji__June_2015.pdf
[4] Ibid
[5] Source: City Sanitation Plan of Panaji, 2015. CAGR of 1.36 percent for Panaji and 1.54 for the remaining parts of PUA.
[6] Of the total households (10158), 9826 (97 percent) had individual household toilets while 266 (2.4 percent) were using community/public toilets and 66 (0.6 percent) were found to be defecating in the open
[7] With 36 toilet seats for males and 37 seats for females. Source: City Sanitation Plan of Panaji, 2015
[8] Note: This doesn't include the 4 CTs
[9] Ibid
[10] Ibid
[11] 7882 households are connected to the sewers out of the total 9826 households with individual toilets

Further, of the 17 public toilets, while 12 are connected to the sewerage network, five are connected to septic tanks which are frequently emptied by CCP using the ULB owned vacuum tanker and the collected septage is discharged at the Tonca Sewage Treatment plant (STP).

In the surrounding 7 OGs majority of the households (74 percent) are connected to septic tanks and only 10 percent are connected to sewerage network[12]. (Table is presented as Annex 3) In the recent sewerage expansion project, most of the households in Taleigaon and Durgawadi have been covered by underground sewage system (UGSS).

A **typical septic tank** in the region is a two chamber construction with or without a soak pit/ drainage field[13]. In the past, septic tanks were not constructed in a scientific manner (taking into account the volume of wastewater, treatment efficiency, type of soil and its hydraulic capacity, eventual disposal of the supernatant/septage, etc.). However, in recent years the Public Health and Engineering (PHE) Department has taken a proactive role in regulating the construction of septic tanks in Panaji and adjoining areas and has prescribed a standard design for septic tanks. Households are required to adhere to the prescribed design and seek approval from PHE prior to construction.

Sewage treatment facilities: Sewage is either discharged into Outfall Sewers (OFS) or pumped to one of the two Sewage Treatment Plants (STPs), namely Patto and Tonca. The Patto STP services the north-eastern part of Panaji. Commissioned in 1992, the STP has an installed capacity of 0.6 MLD and is based on an Activated Sludge Process (ASP) technology. PHE plans to replace this plant with a 2 MLD plant based on Sequential Batch Reactor (SBR) technology.

The STP at Tonca was commissioned in 2005 and has an installed capacity of 12.5 MLD. The STP is based on Cyclic Activated Sludge Technology (C-Tech), an advanced Sequential Batch Reactor (SBR) technology. On the same location, PHE has constructed another STP with an installed capacity of 15 MLD based on C-Tech SBR technology for which trial runs have been ongoing.

The present combined installed capacity for sewage treatment in Panaji is 13.1 MLD, and it is expected to increase to 29.5 MLD. (**Error! Reference source not found.**) The projected waste water flow in 2041 is estimated to be around 22 MLD[14] which is well within the planned installed capacity of 29.5 MLD. Officials shared that the plan is to use the unutilised hydraulic capacity for treating septage from unsewered areas of PUA and even beyond across North Goa district as they lack sewage treatment facilities.

Table 1: Details of STPs in Panaji – Present and Planned[15]

Location	Year of commissioning	Installed capacity (MLD)	Waste Water Flow (MLD)	Technology
Patto	1992	0.6	1	ASP
Tonca	2005	12.5	9-10 (15 in monsoons)	C-Tech, Advanced Sequential Batch Reactor (SBR)
Current		**13.1**	**11 (16 in monsoons)**	
Tonca	2015	15	Trials are underway	C-Tech, SBR
Patto		2	Under Construction	SBR
Projected		**29.5**		

[12] Source: Census 2011
[13] Source: City Sanitation Plan of Panaji, 2015
[14] Based on 80% generation rate of water demand of 27 MLD for CCP in 2041
[15] Source: PHE

B. Co-treatment – Genesis

Co-treatment of septage at STP is being undertaken at only one location in Panaji, namely Tonca. The STP is located in the south eastern part and serves most of Panaji (area under CCP). As mentioned, above two treatment trains are located at Tonca, one with an installed capacity of 12.5 MLD and the other which is yet to be commissioned (and for which trial runs are ongoing) with an installed capacity of 15 MLD. The former serves approximately 12,000 households (through approximately 2,800 connections) while the latter will treat the waste water flows from the city's OGs. Co-treatment of septage at the 12.5 MLD plant was initiated soon after the plant was commissioned in 2005.

The main driver for initiating co-treatment was to end the practice of unauthorised dumping of septage into the region's open areas, storm water drains and water ways by private operators involved in desludging septic tanks that exist in areas that are not yet covered by UGSS. On account of the unutilised hydraulic capacity (approximately 2.5-3.5 MLD) at Tonca, PHE agreed to receive septage brought by private desludging operators and treat the same for a fee (INR 500 per trip per tanker). In addition, CCP also discharges septage collected from five public toilets in the city which are connected to septic tanks.

Geological conditions require frequent desludging of septic tanks: The presence of very shallow water table (only 1 to 1.5 m) and saturated top soil makes seepage of supernatant (or septic tank effluent) difficult which results in failure of typical soak pits[16] and malfunctioning of septic tanks. The septic tanks get infiltration of groundwater / rain water reducing the treatment capacity of the system and require frequent emptying of the tanks. The households thus need to desludge the septic tanks more frequently (once in 2 years) as compared to the normal time frame of 3-5 years.

Emergence of private desludging operators: The fact that the ULB (CCP) and other service providers (PHE) have limited specialised equipment/machines and vehicles[17] for desludging septic tanks has led to the emergence of private desludging operators who desludge septic tanks and transport septage to the Tonca STP for safe treatment and disposal for a fee (INR 3,000-3,500). These private desludging operators operate in areas across PUA and North Goa district. The vehicles are typically 4-8 kL capacity tankers with vacuum and pumping equipment and are licensed to operate by the State Transport Department. The operators also need to obtain annual approval / renewal for safety and roadworthiness of their vehicles.

Conducive Policy Framework: The Goa Public Health (Amendment) Rules, 2010[18] make provisions for protecting and advancing public health. Under the Act, some of the measures related to sanitation include closure of cesspools; prohibiting discharge of injurious refuse and solid waste into drains; providing sufficient number of public sanitary conveniences; *prohibiting discharge of sewage, poisonous and polluting liquid into water bodies[19]; safe disposal of sullage and sewage*, etc. This Act has ensured that the activity of septage disposal across the state has been regulated and the practice of indiscriminate discharge of septage into the sea, creeks, etc. has stopped.

High awareness, concern and commitment among the citizens: Higher level of education, awareness about legal provisions and an overall heightened concern for the environment is a

[16] Innovations in terms of soil mounds, long leach/ drainage fields, micro-wetlands, etc. to accelerate dissipation of effluent are not found in the region.
[17] The single tanker with CCP is used mainly for public establishments and its own public/ community toilets; while those of the PHE are used for cleaning of sewers rather than servicing septic tanks of private houses.
[18] Published in the Official Gazette, Series I No. 18 dated 29-7-2010
[19] Prohibits discharge of any solid or liquid sewage matter into any water-course, lake, tanks, sea-water within five kms. from the shore

characteristic of the Goan citizenry. This has ensured a check on illegal dumping of septage. The citizens proactively monitor illegal discharges which is a deterrent for private desludging operators.

C. Co-Treatment at Tonca STP

Plant Background

Tonca STP is located in the south eastern part of the city and serves majority of the area under the CCP. The STP was commissioned in 2005 and has an installed capacity of 12.5 MLD. The STP is based on Cyclic Activated Sludge Technology (C-Tech), an advanced Sequential Batch Reactor (SBR) technology.

The average waste water flow range from 9 to 10 MLD and peak flows of 15 MLD are observed during monsoon season (June to September). The officials shared that they manage the peak flows during monsoons by operating the plant for longer hours and by increasing the number of cycles. A typical treatment cycle lasts for 180 minutes. (For details on treatment cycle refer Box 1) Given that the STP was hydraulically under-loaded and had spare treatment capacity (2.5-3.5 MLD) enabled implementation of co-treatment of septage. (Tonca STP details are presented in **Error! Reference source not found.**)

Box 1: Description of a treatment cycle at the Tonca STP

> Complete biological operation of C-Tech system takes place in a batch reactor mode comprising of three basic phases i.e. (a) Filling, Aeration and Recirculation (b) Settling and Removal of sludge and c) Decanting. During the period of a cycle, the effluent is filled in the reactor to a set water level. Aeration blowers are started for aeration of the effluent. After the aeration cycle, the biomass settles under perfect settling conditions. Once settled, the supernatant is removed on the top using a decanter. Solids are wasted from the reactor during decanting phase. One cycle is fixed for completion in 180 minutes (90 minutes for fill aeration+ 45 minutes for settlement + 45 minutes for decanting).

There are plans to allow co-treatment of septage at the second plant (15 MLD) as well. The officials shared that no additional infrastructure provisions (in the form of decanting station) have been made as yet and that the necessary additions for co-treatment will be made once the plant is commissioned.

Within the area served by the Tonca STP there are ~44 km of main sewer lines and 9 intermediate Sewage Pumping Stations (SPS). There are 9 rising mains which convey sewage to the main SPS located outside the Tonca STP. (Details on the sewerage system in the area served by Tonca STP are presented in Annex 3)

The treated wastewater from the Tonca STP is discharged into St. Inez Creek which eventually drains into the Mandovi Estuary. A small part of the treated effluent (approximately 50 m^3) is being used by CCP and Forest Department for irrigation in and around Panaji. This water is supplied free of charge.

For sludge handling, the plant includes two lines of centrifuges and one belt filter press for sludge dewatering. The dewatered sludge is given away to farmers (typically used in coconut plantation) free of charge, used to fill low lying areas or stocked in the plant premises.

Planning and Implementation of Septage Co-treatment

Co-treatment of septage at Tonca STP was initiated soon after the plant was commissioned in 2005. Septage from areas not covered by UGSS in Panaji, OGs and CTs in PUA and also other parts in North

Goa is received and treated at this plant. Typical fees levied by private operators for desludging septic tanks ranges from INR 3,000 to 3,500 per septic tank.

Approximately 120 truckloads of septage are discharged at the plant on a daily basis, with desludging trucks (capacity of 4-8 kL) making multiple trips. The septage discharge is permitted only at the decanting facility located at the STP and not at any SPS in the city.

Volume and Quality of Septage

Typically 120 truckloads (capacity of 4-8 kL) are discharged daily at the plant which corresponds to about 0.48-0.96 MLD of septage, which is approximately 4 to 8 percent of the total volume of sewage received at the plant.

Comparison of the characteristics of sewage and septage: While the design influent BOD for the STP is 250 mg/l (BOD Normal condition 375 mg/l and BOD emergent condition 250 mg/l) the average influent BOD after mixing septage was found to be much higher across all months except July, August, September and October 2017 which corresponds to monsoon season (**Error! Reference source not found.**). The Suspended Solids (SS) in the influent after mixing septage were found to be within the design limit of 400 mg/l except for three months, namely, January, March and April as observed from the data for 2017 (**Error! Reference source not found.Error! Reference source not found.**). (The raw sewage characteristics considered for design of the 12.5 MLD plant are presented in Annex 5).

Officials shared that although the quality of treated effluent is presently within the prescribed limits (30 mg/l for BOD and 100 mg/l for SS) there is potential risk to plant performance and eventually the quality of treated effluent, if septage loads increase.

Infrastructure Investments and Operational Changes for Co-treatment

Decanting Station: A decanting station has been created at the Tonca STP to allow desludging trucks to discharge septage. The decanting station is located just outside the plant and has a high boundary wall. The decanting station was created at a cost of approximately INR 0.14 million[20]. The area inside the decanting station is paved.

The facility is a very basic set up comprising of a manhole into which the trucks discharge septage. The manhole is just upstream of the STP preliminary treatment works and the septage added to sewage at the manhole enters the STP through the main inlet and passes to the inlet chamber, prior to the preliminary treatment process and subsequently undergoes the entire treatment cycle. There is no equalization / storage tank for receiving septage, and septage discharge occurs based on the

Manhole created for discharge of Septage

A truck decanting at the manhole

frequency of trucks visiting the STP. The decanting station also has a small rudimentary cabin for a supervisor who monitors the entry and exit of trucks and maintains a register in which a record of the trucks using the facility is maintained.

The trucks are permitted entry between 9 am and 5 pm every day except on Sundays and government holidays. The decanting station can accommodate only two trucks at a time and only one truck can decant at a time. There is no parking available within the decanting station and this causes long queues of desludging tanks which park on both sides of the road close to the STP waiting for their turn to decant. Also the trucks use the space within the PHE office / STP complex to park.

Trucks parked on the load leading to STP

Trucks parked within PHE complex

Sampling and Monitoring Protocols*:* At present, regular sampling and analysis of septage is not being undertaken at the plant. While the septage discharged is largely from domestic sources (including households, hotels and institutions), the officials shared that there is a concern related to dumping of industrial sludge at the STP, however there is no control process in place to monitor or address this practice.

Retrofits or additions to the treatment process: Discussions with staff at the STP revealed that mixing of septage with sewage prior to treatment has not resulted in any adverse impact on the STP or necessitated any retrofits or additions to the treatment train or changes in O&M protocols. While septage characteristics from the site are not monitored and quality data to indicate pollution strength was not available, the prevalent practice of frequent emptying of septic tanks (which could often be as frequently as a few months) is expected to result in a relatively weaker strength septage which is more or less similar to sewage. The plant operators, however, had some concerns around higher organic loading of the plant as septage is concentrated organic sludge with high BOD and SS levels. In the future, as higher sewage flows are received at the plant, the loading may become exacerbated and this could become a concern for the plant operators. However, in the absence of any alternate treatment and disposal option for septage generated from unsewered areas, PHE officials and plant operators felt that there was no option but to accept and co-treat all the septage brought to the plant.

Record keeping protocols*:* The records related to decanting are maintained by a supervisor at the decanting station. He manages and supervises the entry and exit of vehicles at the decanting station. He maintains a register in which he records vehicle registration number, area from which the truck has collected septage and the payment receipt number.

Safety protocols*:* During the field visit it was observed that the staff of private operators (including drivers and helpers) involved in the process of discharging septage at the STP were not making use of protective safety gear and uniforms.

Financial Details

Capital Cost: The STP had to incur capital expenditure of about INR 0.14 million for creating a decanting facility for discharge of septage. This is a very basic set-up which is not recommended for large scale addition of septage, since there is no storage tank / screening provided for the septage. No additional retrofits or modifications requiring capital investment were made at the STP to enable co-treatment.

O&M Cost: Officials shared that no change has been observed in the plants O&M costs. The plant O&M has been outsourced and the details of the agency and contract amounts are presented in Annex 5.

Tipping Fee: Tipping fee of INR 500 is charged per trip by PHE towards the cost of treatment and safe disposal of septage. The truck owners deposit this amount with PHE usually in advance as a lump sum (for 10, 20 or 40 trips). The payment can be made either in cash or online and the operators are issued a receipt which they have to show to the supervisor for entry into the decanting facility. The tipping fee collections are approximately INR 18 million per annum[21]. (Table 2)

Table 2: Charges for co-treatment – Registration, User Fee and Households

Type of charge	Frequency	Rate (in INR)	Collections (approximate)
User Fee	Per trip	INR 500 per trip	Daily: INR 60,000
	Payment made in advance		Monthly: INR 1.5 million
			Yearly: INR 18 million

Performance Details

The treated water post co-treatment has BOD, TSS and faecal coliform levels well within range of the prescribed levels i.e., faecal coliform <100MPN/100ml (**Error! Reference source not found.**), BOD < 30 mg/l (**Error! Reference source not found.**) and TSS < 100 mg/l (**Error! Reference source not found.**).

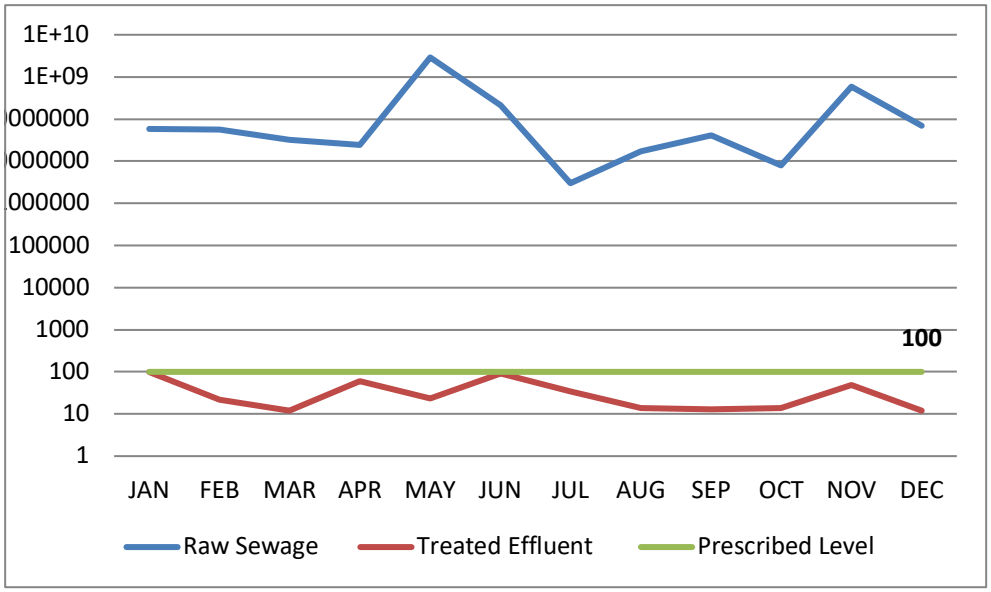


Figure 2: Faecal Coliform – Raw Sewage and Treated Effluent (MPN/100 ml)

[21] Based on ~120 trucks paying tipping fees of Rs. 500 / trip and operating for 300 days per year.

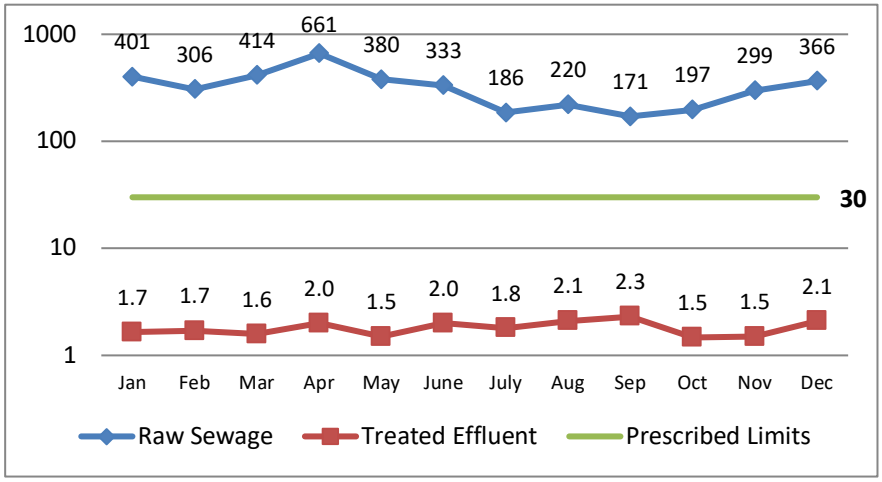


Figure 3: BOD Levels – Raw Sewage and Treated Water Levels (mg/l)

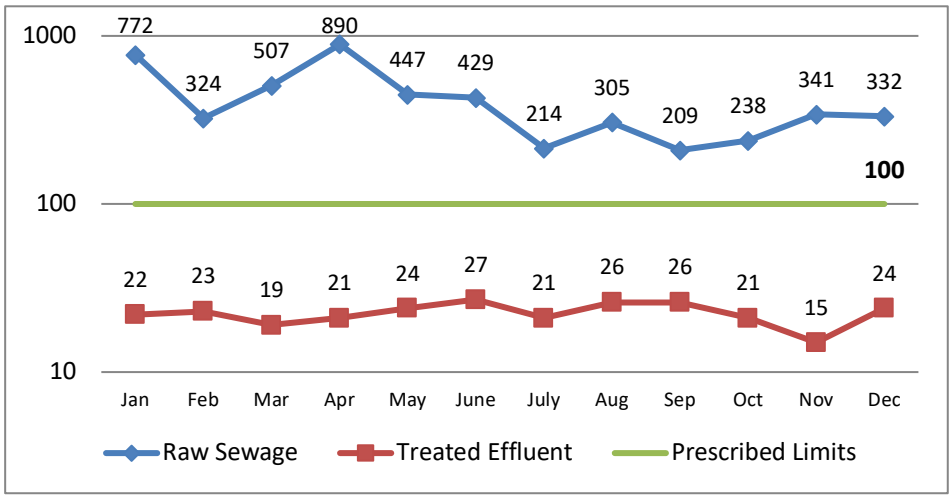


Figure 4: Suspended Solids (SS) - Raw Sewage and Treated Water (mg/l)

D. Impact of Co-treatment

Population being served by co-treatment: The initiative has been successful in serving the un-sewered parts of the PUA as well as many areas of North Goa district. Given that there are approximately 120 trips per day, it is estimated that the co-treatment of septage at Tonca is able to provide SEPTAGE treatment solution for between 0.11 – 0.23 million households with septic tanks[22]. In addition it also serves 5 Public toilets in Panaji which are based on septic tanks.

Regularisation of private desludging operators: The co-treatment at STP has provided private desludging operators operating in Panaji, PUA and the entire North Goa district with a safe and authorised place for discharging septage.

[22] Estimated based on number of households that can be serviced when septic tank sizes varies from 4 to 10 m^3, desludging truck sizes vary from 4 to 8 kL and when desludging is done once every 2 years.

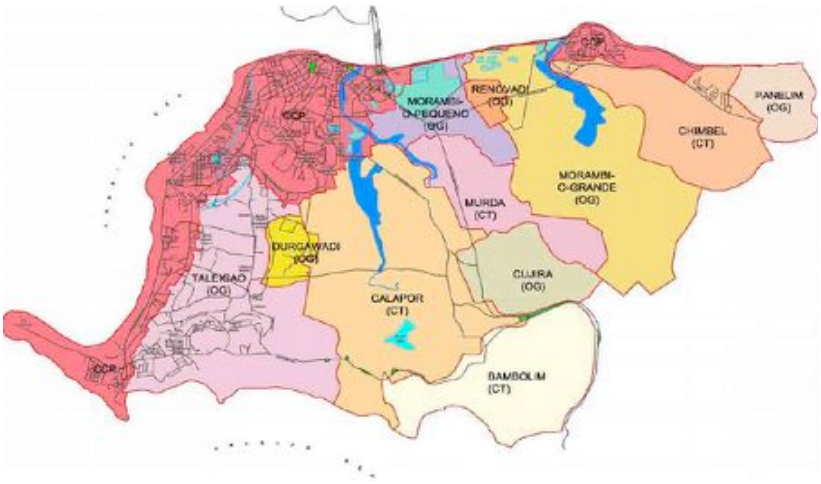
Environmental Impact: The initiative has discouraged and reduced the practice of unauthorised dumping of septage in the PUA and the North Goa district.

Source of Revenue for the STP: The user charges collected from private desludging operators / trucks is resulting in generating revenue to the tune of INR 18 million per year.

E. Key lessons and Practices

- The Goa Public Health (Amendment) Rules, 2010 which prohibit discharge of sewage, poisonous and polluting liquid into water bodies and recommend safe disposal of sullage and sewage, etc. has created an enabling policy environment for implementation of co-treatment.
- Co-treatment at Tonca STP is operating as a regional facility which is serving Panaji, PUA as well as the North Goa district. The unutilised hydraulic capacities of STPs, including that for the new plant under commissioning, can be utilised to treat septage from households connected to septic tanks in the entire urban region including the core city and the rapidly urbanising OGs.
- When a viable solution is provided, cost is not a deterrent for using that facility – this has emerged as a key learning from the co-treatment initiative at Tonca. When the private desludging operators were presented with a viable option for discharge of septage in the form of co-treatment facility at Tonca they patronised the same even when the tipping fee is as high as INR 500 per trip (much higher than the tipping fee in Chennai and Kanpur). They in turn are charging a higher fee from the households (INR 3000-3500).
- In order to ensure that industrial waste is not disposed at co-treatment facilities, there is a need to put in place random testing of the septage being discharged at the STP accompanied by strong penalties for violation to discourage dumping of industrial waste sludge (as is being implemented in Chennai). The STP may want to consider an instant analyser which can be made available at the decanting facility to ensure regular and rapid testing.
- The STP at Tonca receives a substantial amount of septage (almost 8% by volume of the current flows received at the STP). Observations from plant personnel and data on treated water available for 2017 indicates that there is no observed detrimental impact on the final effluent quality, and that the plant is able to handle and treat the additional load from septage without impacting unit operations. This indicates that the septage received does not add a significant organic load to the STP, and this should be tested in more detail to understand the characteristics of septage received. This finding is similar to the finding other STPs (Chennai – Nesapakkam) and lower septage pollution load may allow mixing of higher volumes and lower impact (and therefore lesser concern with co-treatment) on the overall STP performance.
- The plant receives septage without any storage to provide equalization. While there have been no reported process disruptions, the plant would be advised to create septage storage capacity at the decanting facility to a) intercept any unwanted loads from being discharged into the STP (by bypassing any suspect loads that may be industrial in nature) and b) avoid shock loading at the STP.
- The plant needs to consider means for institutionalising systems to ensure adherence to safety protocols so that the health and safety of the people transporting and handling septage is adequately addressed.

Annex I: Map of PUA



Panaji City and Panaji Urban Agglomeration (PUA)

Annex 2: Population of Panaji and PUA – 2011 and 2041 (projected)

Population of Panaji (CCP Area) and PUA – 2011 and projected 2041[23]

	2011	2041[24] (projected)
Panaji (CCP area)	40,017	60,000
Panaji Urban Agglomeration (CCP + 7 OGs)	70,991	112,246
Panaji Urban Agglomeration (CCP+ 7 OGs+ 4 CTs)	114,759	181,453

Annex 3: Collection, Conveyance and Disposal Mechanisms in CCP Area and 7 OGs of PUA[25] (2011 and 2015)

Collection, Conveyance and Disposal system	CCP Area[26]		7 OGs in PUA[27]	
	HHs	%	HH	%
Piped sewer	5978 (7882)	60.8 (80)	574	10.08
Septic Tank	3840	39.1	4190	73.55
Others[28]	8	0.1	933	16.38
Household (with Individual Toilets)	**9826**	**100.0**	**5697**	**100.00**

[23] Source: Census 2011 and City Sanitation Plan of Panaji, 2015
[24] Source: City Sanitation Plan of Panaji, 2015.
[25] Source: Census 2011 and City Sanitation Plan of Panaji, 2015
[26] Source: City Sanitation Plan of Panaji 2015
[27] Calculated from data available in Census 2011 after subtracting the details of the area under CCP
[28] Including other flush systems, pit with slab/VIP, without slab open pit, night solid disposed into open drain and night soil serviced by animal

Annex 4: Details on Sewerage System in Panaji

	Sewer Line (in kms)	**Coverage (Population)**	**STP (capacity)**	**Sewage Pumping Stations (SPS)**
Old Sewerage system				
Sewer-shed I	~44 km	30,000	Tonca STP (12.5 MLD)	9 SPS
Sewer Shed II			Patto STP (0.6 MLD) to be replaced by 2 MLD plant	1 SPS
New Sewerage System				
	~40 km	33,201	Tonca STP (15 MLD)	7 SPS within Panaji and 2 in the OGs

The city is divided into two sewer sheds, the first (Sewer shed-A) which lies to the west of the Ourem Creek covers a large part of the city and a smaller second (Sewer shed-B) one comprising Patto area is across the Creek on the eastern / north-eastern side. The old system comprises about ~44 km of main sewer lines within the city limits. Given the flat topography in most parts and the rather shallow groundwater table, the system requires pumping / lifting of sewage at several locations. Sewershed-A has 9 Intermediate Sewage Pumping Stations (SPS) while Sewer shed-B has one SPS. After the lift, sewage is either discharged into one of the 6/7 Outfall Sewers (OFS) or pumped directly to one of the Sewage Treatment Plants (STPs). In all there are 9 rising mains across the town which transmit sewage to one of the OFS or STPs. In addition to the 10 intermediate SPS, there is one main SPS right next to the STP at Tonca. In addition, there is one SPS for the final disposal of treated sewage at each of the two STPs (Tonca and Patto).

Sewage from Zone-I, II and III is pumped to the OFS which starts near the Panaji Residency in the north of the city. Sewage from Zone IV also reaches this OFS. From here sewage then flows by gravity to the SPS-5 in Zone–V. Zone-V comprises core city and commercial areas of Panaji and SPS-5 located here transmits sewage through a rising main to the OFS which starts near the St. Inez Church. Sewage from Zone VI, VII & VIII is also brought to this OFS. Thus this point receives cumulative flows from Zone I to VIII and the volume of sewage is significant. From here the combined sewage flows to the treatment plant at Tonca under gravity. From the southern and southwestern parts of the city sewage is brought through a combination of lifting, transmission and/or gravity flow through OFS. In the case of Sewer shed-B (Ward # 28) while earlier sewage used to be discharged into the Mondovi Estuary now a SPS has been constructed near Shram Shakti Bhawan which sends the collected sewage to the Patto STP. At Patto presently sewage flows are estimated to be 1 MLD.

In 2009, a new sewerage scheme was developed for some parts of the city and OGs including Taleigao, Donapaula and Caranzalem. This project included development of one STP of 15 MLD capacity (at Tonca) and laying of additional sewer network of ~40 km length. The new network has 7 SPS within the city and 2 SPS in the OGs viz. Taleigao and Durgawado.

Annex 5: Details of Tonca STP

The Tonca STP has an installed capacity of 12.5 MLD and was constructed under NRCP in 2005. C-Tech is the most advanced Cyclic Effluent Treatment process which is based on Activated Sludge Process adapted to Sequential Batch Reactor (SBR) technology.

Complete biological operation of C-Tech system takes place in a batch reactor mode comprising of three basic phases i.e. a) Fill - Aeration b) Settlement and c) Decanting. During the period of a cycle, the effluent is filled in the reactor to a set water level. Aeration blowers are started for aeration of the effluent. After the aeration cycle, the biomass settles under perfect settling conditions. Once settled, the supernatant is removed on the top using a decanter. Solids are wasted from the reactor during decanting phase. One cycle is fixed for completion in 180 minutes (90+45+45).

Complete system is capable of handling variable flow and load conditions. The system automatically adjusts to the new feed condition by changing cycle times, aeration intensity etc. Complete plant operation is controlled automatically through a PLC system, which is a major factor in reducing operating cost. All key functions like RAS, Sludge wasting, Aeration intensity, Cycle time control, Decanting rate etc. are automatically controlled as well as data logged. Mechanical grit removal system with rotating and reciprocating raking mechanism is found to be less effective due to high velocity of flow/less detention time in the grit chamber. Chlorination is being done for coliform removal. Treated effluent is being discharged into Mandovi River.

O&M of the plant has been outsourced. Details are presented in the table below:

Year	Agency	Costs
2005-2010	HN Bhatt and Engineers, Pune	
2010-2014 (extended till 2017)	SFC Environmental	@ INR 13.9 million /three years
2017-2020	SFC Environmental	@ INR 32.5 million /three years

The plant is designed for influent BOD and SS of 200 and 400 mg/l and effluent BOD and SS of 10 mg/l respectively.

Raw sewage characteristics – Design Parameters for the 12.5 MLD plant at Tonca

Parameter	**Unit**	**Raw Sewage (value)**
PH		7.4
BOD_5 Normal Condition	mg/l	275
BOD_5 Emergent condition	mg/l	375
Suspended Solids	mg/l	400
Faecal coliform	MPN/100 ml	$24x10^8$
COD	mg/l	462
Total Dissolved Solids	mg/l	8815
Total Solids	mg/l	8939
Volatile Solids	mg/l	692
Total Hardness (as $CaCo_3$)	mg/l	1500
Methyl / average alkalinity (as $CaCo_3$)	mg/l	750
Sulphate as SO_4	mg/l	550
Chlorides as Cl	mg/l	2400
Amonical Nitrogen	mg/l	90
Nitrogen (as NO_3)	mg/l	74
Grease	mg/l	86
Chlorides (as NaCl)	mg/l	1875
Temperature	^oC	28

Annex 6: List of officials met at Panaji

S. No.	Name, designation, organisation	Mobile	Email
1.	Mr. Dilip Dhavilakar Executive Engineer WD III, PHE North, PWD St. Inez, Panaji		
2.	Mr. Krishna Shetye Plant Engineer Tonca STP	9370694533	
3.	Mr. Charles In-charge of co-treatment, Tonca STP	9370694412	