Centralized Versus Decentralized Wastewater Treatment And Reuse: A Feasibility Study For NITTTR Campus, Chandigarh

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Abstract : *In recent times we have witnessed the emergence of a water availability crisis due to scarcity and pollution of water resources. One of the major causes of water pollution is the widening gap between wastewater generation and treatment which has necessitated a paradigm shift from centralized to decentralized wastewater treatment and onsite reuse. The manuscript attempts to answer the question whether decentralization can be termed as an effective solution to deal with the limitations of centralized wastewater treatment. The scope of decentralization has been explored by means of a feasibility study of decentralized wastewater treatment and onsite reuse in NITTTR campus, Chandigarh. The feasibility study takes into consideration the guidelines, appropriate technology and potential reuse options associated with the adoption of decentralized wastewater management. The purpose of the feasibility study is to determine the saving in freshwater use that can result from adoption of decentralized waste water management and onsite reuse.*

Keywords: *Decentralized wastewater treatment; Feasibility study; Guidelines; Technology; Wastewater recycle and reuse*

INTRODUCTION

Water is widely accepted as a critical resource for ensuring a sustainable future. India is a "water rich" country which is facing a water crisis due to increasing urbanization (Cronin *et al.*, 2013). Wastewater treatment infrastructure is of paramount importance in such a scenario because when wastewater is left untreated, it contributes to improper sanitation which accounts for 80% of the diseases in India. It has been estimated that 80% savings can be made in the basic healthcare sector by an extra investment of 10% in wastewater treatment (Centre of Excellence in DWWM, 2012).

The management systems for wastewater can be classified as centralized and decentralized systems. A centralized facility is characterized by ownership of government agencies which plan, design, build, operate and maintain the facility. A centralized waste water management facility collects and treats huge volume of wastewater for the whole community. Tchobanoglous (1995) has defined decentralization as "the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation" Centralized wastewater treatment by Urban Local Bodies has been practiced effectively for several years; however, it has been found that the estimated sewage generation in India from Class I and Class II towns is 38,524 MLD (Million Litres per Day), which accounts for only 72% of the population, and for the total sewage generated, the treatment capacity available can suffice for only 30% of the total sewage generation (Central Pollution Control Board, 2013). Hence it is evident that in order to alleviate the water crisis situation, the centralized system of wastewater treatment needs to be augmented in terms of capacity

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and alternative wastewater treatment solutions need to be incorporated to bridge the gap between demand and supply of freshwater.

The geographic and economic constraints have caused a shift in focus from construction and management of regional sewage system to the development of decentralized wastewater management facilities (Tchobanoglous and Angelakis, 1996) Since alternate systems have disadvantages as well, a careful insight is needed to weigh the sustainability of different systems under varied circumstances before switching to decentralized management systems (Balkema *et al.*, 2002). To gain such an insight, a feasibility study has been performed to analyse the pros and cons of incorporating DWWM (Decentralized Waste Water Management) in NITTTR campus, Chandigarh.

GUIDELINES MANDATED BY AUTHORITIES FOR DECENTRALIZED WASTE WATER TREATMENT AND REUSE

The various policies for decentralized wastewater management are summarized in *Table 1.*

APPROPRIATE TECHNOLOGIES FOR PRACTICING DECENTRALIZED

Wastewater Management

There are two types of decentralized wastewater treatment units:

Package Type

This plant can be transported to the site in packaged form and it can be installed by trained personnel with minimal effort. It is a medium-capacity treatment plant and is suitable for standard facility.

Table 1: Guidelines Mandated For Decentralized Wastewater Treatment And Reuse

S. No.	Mandating Authority	Stipulated Guidelines For Decentralization
1.	Central Pollution Control Board of India(Central Pollution Control Board, 2015)	• Brand new houses should provide for appropriate treatment, recycling, reuse or disposal of the wastewater generated. • The piped water supply project for a new house should include the capacity of sewage treatment for Decentralization or augmentation of STP(Sewage Treatment Plant). • Municipal Byelaws and Municipal Act should develop special clauses for incorporation of DWWM (Decentralized Waste Water Management) • The designers and builders for sewerage/drainage systems are responsible for the treatment and utilization of wastewater on long-term basis. • The onus of meeting the O & M (Operation and Maintenance) costs for DWWM rests with public/people. Government should provide rebate in property/house.
2.	Manual on Norms and Standards for Environment Clearance of Large Construction Projects (Ministry of Environment and Forests,no date)	• Dual Plumbing has to be installed for use of water with different quality. • Treatment techniques suggested for Decentralization include SBT(Soil Bio Technology), INDIONmembrane bio reactor, INDION package STP, AKAR STP etc.
3.	Chandigarh Master Plan-2031	• It is compulsory to make use of recycled water for non-potable uses for houseswith an area greater than 2000m^2. • Dual plumbing arrangements are required for all apartments or group housing complexes with more than 20 tenements and commercial, institutional and industrial complexes with an area of more than 2000m^2. • All building plans and land development plans with an area of more than 2000 m^2 have to indicate the onsite waste water treatment and infrastructure for the same. Package treatment plants with FAB (Fluidized Aerobic Bed Reactor) technology should be used for DWWM.

Table 1: Guidelines Mandated For Decentralized Wastewater Treatment and Reuse (*Contd...*)

S. No.	Mandating Authority	Stipulated Guidelines For Decentralization
4.	Indian Green Building Council (IGBC Green Existing Buildings O & M Rating System (Pilot Version), 2013)	• On-site treatment system should be in place to treat 100% of waste water generated. Treated wastewater from the wastewater treatment plant has to be reused for irrigation/ cooling water / flushing water.
5.	Green Rating for Integrated Habitat Assessment (GRIHANational Rating System, 2008)	• It mentions the use of treatment techniques that incorporate biological processes such as artificial wetlands and reed bed systems. • Utilization of treated wastewater for applications in which MC (Municipal Corporation) potable water is normally used.
6.	Centre Of Excellence in Decentralized Wastewater Management , IIT Madras (Centre of Excellence in DWWM, 2012)	• Potential sites for installing a Decentralized treatment system have to be selected on the basis ofPopulation density, Land Availability, Topography, Reuse Potential as given in ranking list. • Overlapping with existing centralized facility is not recommended.

Civil Type

This type of plant has a high treatment capacity which makes it suitable for large setups. The installation requires on-site assembling and installation. Even though it allows for the parts to be transported, yet majority of the work is accomplished on site. It requires minimum maintenance.

The latest technologies used for wastewater treatment in the aforementioned STPs are:

Sequential Batch Reactor (SBR)

SBR is a modified activated-sludge treatment system. The processes involved in SBR and conventional activated sludge systems are similar. Both the systems rely on Aeration and sedimentation/clarification. The important difference is that the processes are carried out simultaneously in separate tanks in the conventional process, whereas in SBR operation, the processes are carried out sequentially in the same tank. It is suitable for treating domestic and industrial effluents.

Membrane Bio Reactor (MBR)

MBR is the latest technology for biological degradation of soluble organic impurities. MBR process is very similar to the conventional activated sludge process, since both have mixed liquor solids in

Figure 1: Typical Package Treatment Plant

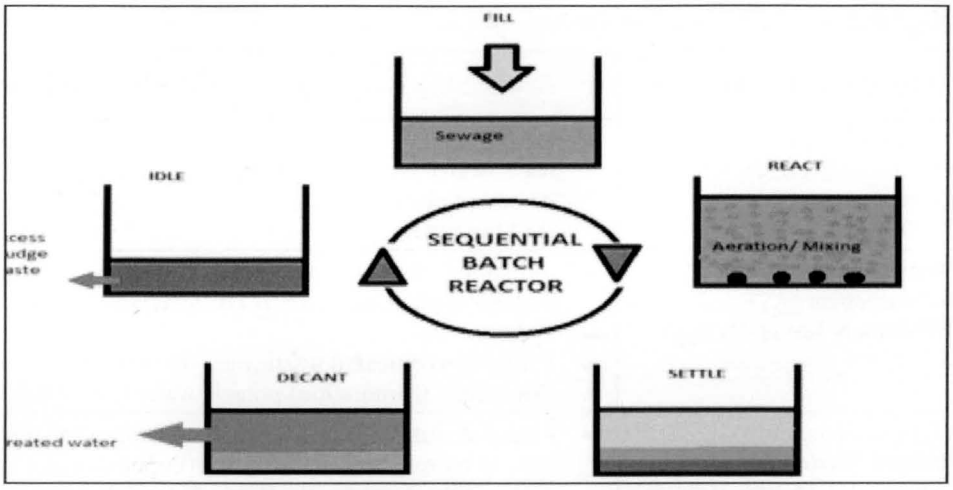

Figure 2: Typical Process Involved In SBR

suspension in an aeration tank. In the MBR process, the bio-solids are separated by means of a polymeric membrane based on microfiltration or ultrafiltration unit, as against the gravity settling process in the secondary clarifier in conventional activated sludge process.

MBR technology has been in extensive usage for treatment of domestic sewage, but for industrial waste treatment applications, its use has been somewhat limited.

Moving Bed Bio Film Reactor (MBBR)

MBBR process is based on the biofilm principle using polyethylene carrier elements. The carrier elements, which are less dense than water with a specific gravity of 0.93-0.95, provide a large protected surface for bacteria culture. MBBR provides advantages of Activated Sludge and Trickling Filter systems without their disadvantages.

Biofilm does not give odor and there is no infestation problem of snails or red worms as in the case of air phase fixed films. Performance analysis of plants using biofilm show no attrition of media and original media is still being used in plants which have been in service for more than 20 years.

Comparison of SBR, MBR and MBBR technologies has been done in *Table 2*.

FEASIBILITY STUDY OF DECENTRALIZED WASTEWATER TREATMENT AND REUSE FOR NITTTR CAMPUS

National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh is a premium institute in North India which was established in 1967.

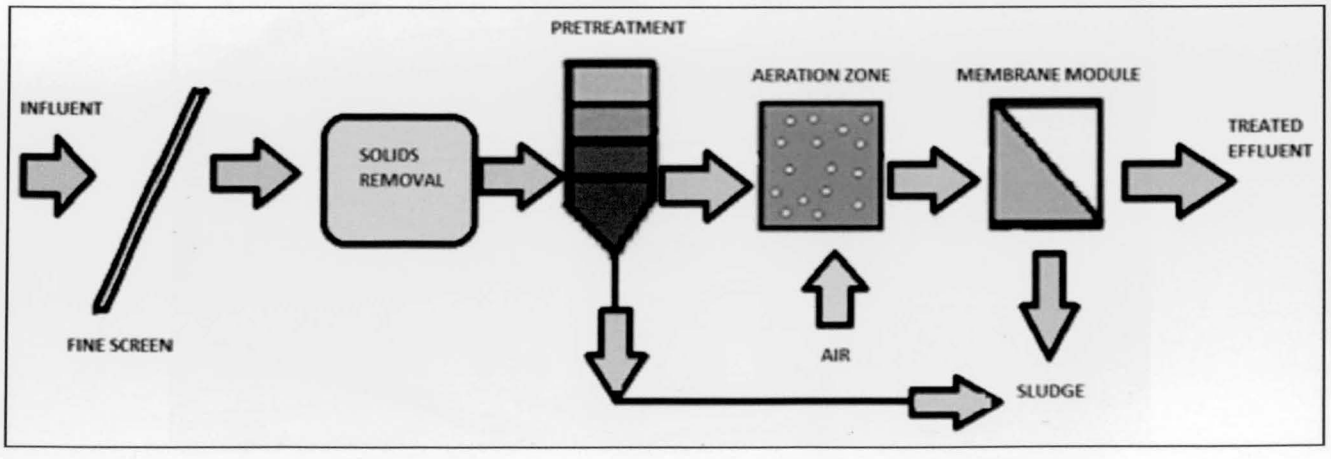

Figure 3: Typical Process Involved In The Use Of MBR Technology

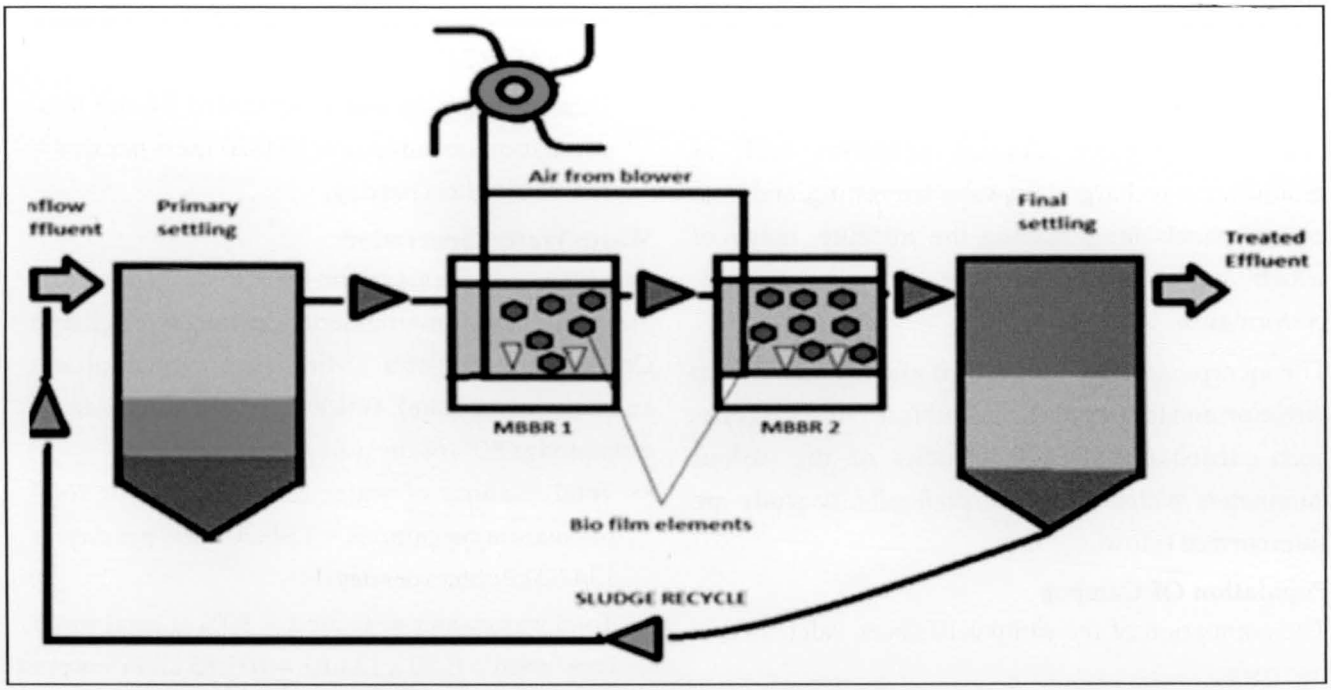

Figure 4: Typical Operating Sequence Involved In The Use Of MBBR Technology

Table 2: Comparative Analysis Of Various Technologies For Decentralized Waste Water Treatment

Sr. No	Type of Technology	Treatment Level for Bod (Mg/L)	Cost of Treatment For 200kld	Suitability	O &M	Space
1	SBR	< 10	50 lacs	High load municipal or industrial waters	Mostly automated therefore minimum O&M, intervention only needed for sludge disposal	Low
2	MBR	< 5 to 2	65 lacs	High end industries where cost is not an important factor and it is important to meet superior and stringent standards pertaining to outflow effluent	High	Low
3.	MBBR	< 20	30 lacs	Small to medium flows in congested location. Relieving existing STPs	No operational adjustment only equipment maintenance	Relatively high

Source: Compiled by Authors

The institute is spread over an area of 17 acres or 68796.62 m^2.

NITTTR administration has always been keen on incorporating green campus initiatives such as groundwater recharge, rain water harvesting, and solar energy panels for powering the institute, many of which are in place and have shown remarkable performance.

The incorporation of DWWM is another step in that direction and for this purpose a prefeasibility study has been carried out. Detailed studies of the various parameters which affect the prefeasibility study are summarized below:

Population Of Campus

The population of the campus has been calculated in two parts.

Estimation Of Permanent Residents On Campus

- Total number of hostels = 5
- Total occupancy of hostels = 590 students
- Tota number of faculty and staff residences = 61
- Total occupancy of faculty and staff residences @ 4 persons per house = 244 persons
- Total permanent residents on campus = 834 persons

Estimation Of Floating Population

- Total number office staff including faculty = 250 persons
- Total day scholar students = 44 students
- Average number of visitors in campus per day = 200 persons
- Total floating population on campus = 494 persons

Water Consumption

As per the provisions of IS 1172:1993 (Bureau of Indian Standards, 1993):

- Total quantity of water consumed by permanent residents on campus @135 lpcd (Litres per Capita per Day)(Occupancy x Quantity in lpcd) (834 x 135) = 112590litres per day.
- Total quantity of water consumed by floating population on campus @ 45 lpcd(Occupancy x Quantity in lpcd)
  (494 x 45) = 22230 litres per day.
- Total quantity of water consumed by the total population on campus = 134820 liters per day = 134.82 kiloliters per day.

Waste Water Generation

As per the provisions of the manual on 'Norms and Standards for Environment Clearance of Large Construction Projects' (Ministry of Environment and Forests, no date), wastewater generated can be estimated as 80% of the water consumed.

- Total quantity of water consumed by the total population on campus = 134820 liters per day = 134.82 kiloliters per day
- Total wastewater generated @ 80% of total water consumed = 0.80 x 134.82 = 107.85 kiloliters per day

Status of Waste Water Reuse and Recycle

The institute is availing TTW (Tertiary Treated Water) supply for meeting its landscape irrigation requirement since the last 3 years. The use of TTW in the campus reveals many shortcomings which are attached to TTW supply scheme of Chandigarh Administration. Even though TTW is being used for irrigating the landscape, yet it is not the only water being utilized for landscape irrigation. The TTW is supplied for only 5-6 hours per day and there is not enough pressure in the supply to ensure adequate water supply to meet the water demand for landscaping in the institute. Potable water is utilized in conjunction to TTW to meet the landscaping and horticulture requirement. The TTW is supplied on flat rate bimonthly basis and the amount of water is supplied on the basis of area of the campus.

Green Cover

The green area in the institute is nearly 2 acres or 8093.72 m^2.

Capacity Of Treatment Plant

Considering the population of the institute and the daily fluctuations, it is suggested that treatment plant

of 150 KLD (kiloliters per day) shall suffice. Considering the future growth anticipated in the institute it is safe to select the capacity of treatment plant as 200 KLD.

Collection Of Sewage Samples

The characteristics of sewage generated in the institute have been summed up in *Table 3*. The average value of BOD (Biochemical Oxygen Demand) for design purposes was selected as 95 mg/l.

End Use Applications of Recycled Water

There are several potential uses of recycled wastewater which have been identified to substitute freshwater for recycled wastewater in NITTTR:

- Landscaping: NITTTR has considerable demand for freshwater for the purpose of irrigation of landscape.
- Landscape Area = 8093.72 m^2
- Horticulture requirement @ 6 litres/m^2/day = 48.55 KLD
- BOD for disposal of treated water on land for landscape irrigation<10 mg/l (Central Pollution Control Board, 2015)

In this study it is assumed that the horticulture requirement in the institute is met solely by use of freshwater.

- Toilet Flushing: Surplus treated wastewater is available which can be directed towards toilet flushing in the hostels and residential area. This requires an elaborate dual plumbing network.
- Toilet flushing Requirement @ 45 lpcd as per IS 1172:1993 = 59.76 KLD
- Treated wastewater available for toilet flushing = 107.86 – 48.55 = 59.31 KLD

Most guidelines mention requirement of BOD<10 mg/l for toilet flushing yet experts in this field suggest that the BOD should further be reduced to less than 5 mg/l for sanitary purposes from the point of view of stench from the wastewater and storage in cisterns.

- Car washing: If surplus water is found after meeting the water requirement for landscaping and toilet flushing, it can be directed for car washing purposes.

Choice Of Technology

The best option available for treating the wastewater is by employing a package treatment plant due to lack of availability of land and quantity of wastewater to be treated. Package treatment plants are suitable for treating sewage quantity ranging from minimum 5KLD to 200 KLD.

The end user applications play a key role in determining the technology which has to be employed for treating the wastewater. In order to meet the requisite BOD disposal standard for the proposed end uses, the best option available is SBR technology, which gives consistent treatment results in spite of variable flow loads. Besides the cost factor, the choice of technology between SBR, MBR and MBBR depends on the characteristics of the treated sewage.

In this case, the treated sewage of BOD < 10 mg/l can be conveniently provided by SBR or MBR, with MBR providing more superior results than desired. SBR on the other hand can provide the same characteristics for

Table 3: Characteristics Of Sewage Sample Collected From NITTTR

Date Of Sampling	pH	TDS (mg/l)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)
1st May	6.3	152.3	111.2	187.9	95.3
2nd May	6.3	136.2	128.4	195.6	97.2
3rd May	6.5	110.4	100.5	180.3	91.5

* Total Dissolved Solids (TDS)
Total Suspended Solids (TSS)
Chemical Oxygen Demand (COD)

a more economical investment. In order to provide BOD<5 mg/l for toilet flushing, ultra filtration can be used which can be done for part of the treated effluent which arises after being treated by SBR. This results in saving money, resources and energy. Due to area restriction Filter press is recommended for Sludge digestion.

The process for incorporating DWWM in NITTTR is given in *Figure 4*.

Freshwater Saving

Decentralized wastewater treatment will lead to an increase in freshwater saving by diverting the treated wastewater for onsite reuse. The percentage saving in freshwater is illustrated in *Figure 5*:

- Total freshwater consumption (Domestic and Horticulture) = 156.4 KLD
- Total wastewater generation = 107.85KLD
- Total Horticulture Requirement@ 6 litres/m^2/day = 48 .55 KLD
- Total flushing requirement @45 lpcd= 59.76 KLD
- Saving in Freshwater use (Total freshwater substituted by wastewater for horticulture and flushing) = 107.85KLD
- Percentage saving in freshwater consumption (Saving in freshwater/ Total freshwater consumption) x 100= 68.95%

Analysis

It can be seen that nearly 68.95% of freshwater can be saved by incorporating decentralized waste water treatment and onsite reuse. NITTTR is a relatively small campus as compared to the other institutional campuses in the Union territory of Chandigarh. This in turn gives those institutes a larger advantage over NITTTR because this offers them a choice between civil type and package type treatment plant, hence they can treat a greater quantity of wastewater and use it onsite for varied end uses as suitable to the specific case.

CONCLUSION

Decentralized wastewater treatment and onsite reuse is the buzzword in sustainability. The major reason for adoption of decentralization is twofold, firstly it is a sustainable practice and secondly it helps to reduce the load on the centralized treatment facilities, thereby reducing the quantity of untreated sewage polluting water. Despite these reasons, procedure practice gaps have been identified which point towards a lack of will to adopt decentralization; the only way to deal with this issue is by formulation of national wastewater reutilization policy supported by a legal framework

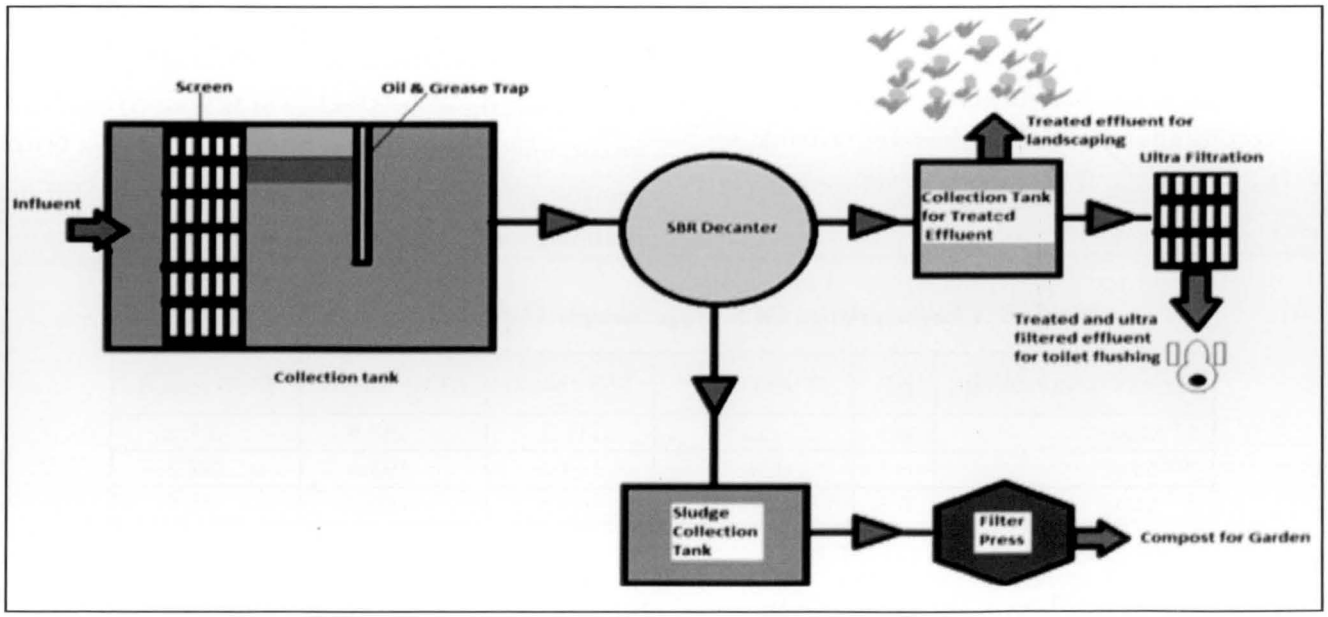

Figure 5: Process Diagram for DWWM in NITTTR

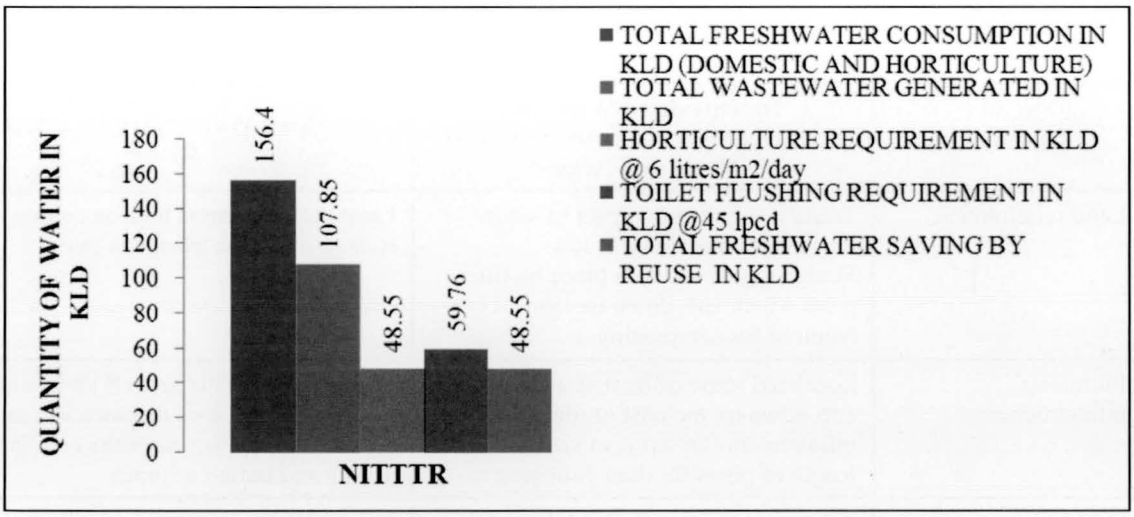

Figure 6: Extent Of Freshwater Savings Envisaged Through Decentralization

Table 4: Comparison Of Decentralized And Centralized Wastewater Treatment And Reuse For NITTTR

Sr. No.	Parameter	Decentralized Wastewater Treatment (By Package Treatment Plant) and Reuse	Centralized Wastewater Treatment a nd Reuse
1.	Cost of treatment unit	30 lacs to 65 lacs per 200 KLD of wastewater treated	31.5 crores to 44 crores for small sized treatment plant(2-5 MLD) (Pannirselvam R. and Gopalakrishnan A.N., 2015)
2.	Level of treatment	BOD<10 mg/l can be achieved through installation of single unit. Ultra filtration has to be adopted for BOD<5 mg/l.	These are capable of providing BOD< 10 mg/l. Special Treatment unit has to be constructed for reducing BOD <5 mg/l
3.	Energy requirement for treatment (pumping and treatment)	Minimal pumping is required due to localized treatment and reuse.	Minimal pumping is required for conveyance of sewage to treatment plant since treatment facility in Chandigarh has been designed by keeping the natural slope of land in mind. 10MGD (Million Gallons per Day) of Treated Wastewater has to be pumped back for reuse to the city which makes water reuse an energy intensive process.
4.	Diversity of reuse options	Can be designed for case specific reuse options such as landscaping water, toilet flushing, car washing and laundry.	Best suited for meeting horticulture water requirement as it is difficult to cater to case specific reuse.
5.	Complexity of treatment process	Treatment process is simple due to predetermined influent source which gives out wastewater of constant quality with only slight variation	Influent is received from domestic, industrial and other sources. Thus influent water quality is not consistent and makes the treatment process complex.
6.	Community participation	Requires community cooperation for O&M and acceptance of wastewater reuse. This sensitizes the community regarding its water use status and creates awareness.	Negligible community participation.

Table 4: Comparison Of Decentralized And Centralized Wastewater Treatment And Reuse For NITTTR (Contd...)

Sr. No.	Parameter	Decentralized Wastewater Treatment (By Package Treatment Plant) and Reuse	Centralized Wastewater Treatment a nd Reuse
7.	Land requirement	Treatment unit is compact in nature, thus land requirement is low. Sludge digestion takes place by filter press which cuts down on land required for composting.	Land requirement is high as quantity of wastewater to be treated is more.
8.	Plumbing infrastructure	Localized reuse of treated wastewater cuts down on the cost of plumbing infrastructure in terms of size and length of pipes for dual plumbing	Treated wastewater from STP has to be conveyed over large distance and in larger quantity which increases the cost in terms of size and length of pipes.
9.	O&M	It does not require skilled labour for SKADA operated automatic treatment unit. Labour is required only for removal of digested sludge from filter press.	It is manually operated by skilled manpower which is also required for operating the alternative energy source in case of electricity failure. Sludge is generated in large quantities and becomes difficult to manage.
10.	Customization of technology	Can be customized as per influent sewage characteristics and desired	Not possible since influent sewage characteristics are inconsistent.

Source: Complied by authors

which empowers municipal corporations and urban local bodies for enforcement of procedures with respect to decentralization.

By means of the feasibility study done on the institutional campus of NITTTR, Chandigarh it is clear that decentralization is a feasible option in order to reduce freshwater usage. Even though the wastewater quantity treated is far less than the large treatment operations carried out in the centralized treatment facilities of Chandigarh yet it is a start, which only means to encourage other large institutions in the city to adopt decentralization and thus collectively make a significant contribution in the reduction of treatment load in centralized facilities.

Through the comparative analysis of centralized and decentralized treatment facilities, it is clear that decentralized facilities are a long term investment and their major advantage is that they can be customized as per the incoming influent and desired outgoing effluent quality. Decentralized wastewater treatment is much more suited for wastewater reutilization than centralized facilities providing treated wastewater since it cuts down on the cost of conveyance of treated wastewater for reuse. Contrary to popular belief DWWM is not a money intensive operation, there is no denying that the installation of dual plumbing for conveying different quality of water for specific uses contributes to the initial cost of the system but it is a one-time investment which brings with it a promise of a sustainable future and reduced reliability on external sources for availability of water for inferior uses.

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