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Wastewater treatment in CST using DEWAT System

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Abstract
With development of country and rapid increase in population, the demand for fresh water intakes has increased drastically. At the same time the production of kitchen and sewerage wastewater has increased proportionately. Therefore, the expenditure incurred due to fresh water supply and the disposal of wastewater has increased annually. Moreover, due to lack of proper wastewater treatment system, untreated wastewater has been discharged directly to the nearby environment polluting the environment and also posing the significant risk to the public health. Therefore these rapid urbanization has demanded for more sustainable and alternative methods of wastewater treatment system that can be implemented at a decentralized level besides the conventional and mechanized sewage treatment systems and septic tanks. This paper analysis the feasibility of Decentralized Wastewater Treatment System (DEWATS) to produce a highly efficient, viable, sustainable and eco-friendly, low cost solution for managing community wastewater in the hostel complex of the College of Science and Technology (CST) campus, Royal University of Bhutan.

Keywords: DEWATS, reed beds, college of science and technology, sustainability, ecofriendly wastewater, water reuse

1. Introduction

With rapid urbanization and growth of population in Bhutan, many communities are deprive of adequate water and sanitation services. This has been accompanied other challenges related to wastewater management. Discharging these untreated wastewater directly to the surrounding environment not only poses numerous threats public health due to presence infectious faecal matters and organic nutrients but also pollute our pristine natural environment and degrading the natural eco-system. Therefore, sustainable and ecological methods and strategies to treat these wastewater is needed urgently whereby the treated wastewater can be also reuse directly or indirectly.

It is estimated that Bhutan has been connected with 5% of sewer connections and 45% using septic tanks. It is also reported that 13% of the population lack access to improved sanitation facilities, thus safe management of waste water has become a concern in both rural and urban areas with grey water being discharged directly to drains without proper treatment [1]. Currently, in Bhutan, only 10 town out of 61 have proper municipal wastewater infrastructure connectivity and the rest depends on the onsite sanitation system like septic tank. The Urban areas like Thimphu and Phuentsholing have adopted waste stabilization ponds or lagoons, but these have become obsolete and undersized now due to continuous population growth in the cities. This undersize existing sewage treatment plants now became the source of undesirable odour in a places around it. It was found that, these treatments plants cater only a part of the city's population with its three stage waste stabilization lagoon system. Moreover it has been incurring lots of expenses due to operation and maintenance cost as it calls for frequent maintenance besides occupying huge area of land [2].

Amidst such challenges, Municipal authorities and concern agencies have now started to explore and develop a locally implement wastewater management systems like the Dojo-Joka system of Japanese origin to encourage integration of low energy intensive, DEWATS technologies. Such type of system is better suited for small-scale community or an individual household that deliver similar functions and performance as conventional wastewater management technologies [3]. Therefore, DEWATS has become an appropriate alternative sustainable solution for wastewater treatment with options for water reuse at community level in most of the developing countries [4, 5, 6].

2. Decentralized Wastewater Treatment System

DEWATS is combination systems used for collection, treatment of waste water collected from individual, clustered communities and industrial facilities and discharge it after proper treatment. The old method of decentralized systems when combined with new and advanced technology treat effluent to a high standard and making wastewater reusable for gardens and home as well [7]. These advanced DEWATS are grouped into four different categories namely the tanks systems, the pond system, filter system and root zone system. The tank system include of Septic, Imhoff and Baffled tanks whereas the pond system comprise of facultative pond and waste stabilization ponds. Among all, root zone system has now considered as efficient treatment system which is effective nutrients removal [8].

Due to its affordability and low-maintenance approach for the treatment of organic waste, it has become an alternative concepts for sustainable urban sanitation throughout Asia in recent decades, where the treated wastewater can be reuse in the community scale for irrigation of landscapes [3, 9]. In DEWATS, wastewater is treated very close to its source using individual modular system or collectively for a clustered settlement [6, 10]. These modular systems are more flexible and resilient that can be best suitable for rapidly developing regions with inadequate infrastructure development [11]. DEWATS can be configured in numerous ways, varying in the level of decentralization and layout that consequently varying in cost [12]. Studies have found that the DEWATS are 40% cheaper than centralized system for a town about 1500 people [13].

On the other hand, centralized wastewater treatment systems require sophisticated mechanized technologies and skilled manpower for its operation and maintenance (O&M) incurring huge amount of O&M costs beside its construction cost. Due to its financial constraints, it is less feasible to implement in areas with low population and dispersed community. Therefore, as discussed before DEWATS might be more advantageous especially in developing countries [14]. Due to its adaptability in different scale, DEWATS is not only used developing countries, but also in widely used in developed countries like Germany, where 10% to 30%of the population discharges their wastewater through DEWATS [15] and in United States of America, more 60 million people depend on such system [16]. Most of the DEWATS are executed with natural methods in the developing countries, although there are numerous types of intensive systems incorporated in conventional DEWATS like membrane filtration, sequencing batch reactor [14]. The advantages of such systems are as follow [17] beside financing advantages as discussed above.

- It is reliable and robust and increase the wastewater reuse;
- It does not require or less external energy is required;
- Minimum sludge production;
- Skilled professionals are not required for operation and maintenance work;
- Reduces the risks associated with system failure.

Studies have found out that DEWATS has the capacity to treat organic waste water from 1-1000 cu.m per day [3]. The basic treatment system consist, primary, secondary and tertiary treatment systems. In primary treatment, most of the sedimentation and floatation actions takes place where. In this system, the waste water is screened and collected. Suspended organic material and most of the total suspended solids are removed at this stage due to sedimentation. Most of the BOD are either gets settled or dissolved. The secondary anaerobic treatment in fixed bed reactors containing baffled upstream reactors or anaerobic filters. Here, the residual form of primary treatment are treated and segregated further by a constructed wetland or by artificial system that mimics the structure of natural wetlands to serve as a waste water filter. Lastly in Tertiary aerobic treatment in sub-surface flow filters. Here it removes dissolved materials which have survived the primary and secondary treatments. The treated water and sludge were used in the wet land as manure.

3. Constructed wetland/ Reed beds

Constructed wetland is a designed structure, such as pond where the natural ecological processes takes place. It encompasses of gravels and sands planted with reed species or floating plant species available in the site. The contaminated effluent is fed to the wetland which typically has a depth of 600 mm which passes through the filtering medium such as root zones, sand and gravels. Due to breakdown organic substance as and get filtered on the surface of root, gravel and sand. These substances are then used as the nutrients by reeds. Constructed wetlands are generally more suitable in warmer climate because biological decomposition rates increases with increase in temperature [18]. Constructed wetlands are generally used as an advanced treatment after secondary or tertiary treatment process, but it is not a wastewater treatment plant on its own. It is vital to conduct pre-treatment to wastewater to avoid excess accumulation of solid or sludge [19]. The treated waste water discharged from the reed bed can be reused for flushing water closet and landscape irrigation. The constructed wetland provide a wide range of benefits in waste water treatment in terms of energy consumption; provide more green areas and recreational spaces.

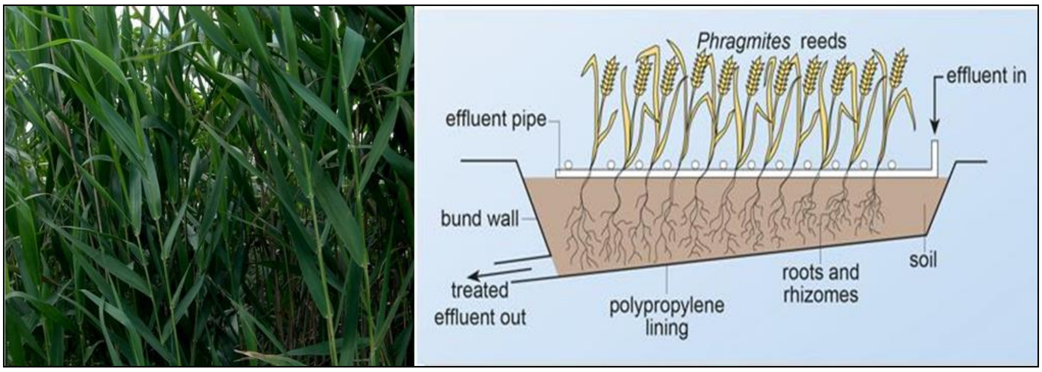

Fig 1: Common reed bed system

4. Site selection and existing condition

College of Science and Technology under Royal University of Bhutan is located in Phuentsholing, Bhutan with a Latitude of 26’49’’N to 26’54’’N and Longitude of 89’20’’E to 89’28’’E at an altitude of 293m above mean sea level [20]. The site experience hot and humid summer and warm and dry winter with an annual average temperature of 23˚C and humidity of 60% [21]. Currently, the hostel compex in the college uses an onsite conventional sanitation system of septic tank and soak pit. The drainage system has a segregated discharge for grey water and black water but while black water is treated through the septic tank, whereas the grey water is directly channeled through open drains into the environment without any treatment. Moreover, due to increasing population of students, the septic tank have now became undersized and required frequent maintenance. During Monsoon season, rear side of the hostel area sees a large number of formation of sewage pools with overflown faecal matter due to poor infiltration capacity and under sizing of the soak pit as shown in figure 2. This sewage ponds prove a nuisance to the residents and the Thimphu-Phuentsholing highway with foul smell and frequent clogging up of the road stretch behind the hostels, posing a great threat to the environment sanitary conditions of the residents.

Fig 2: Formation of sewage pond Grey water in Uncovered drains

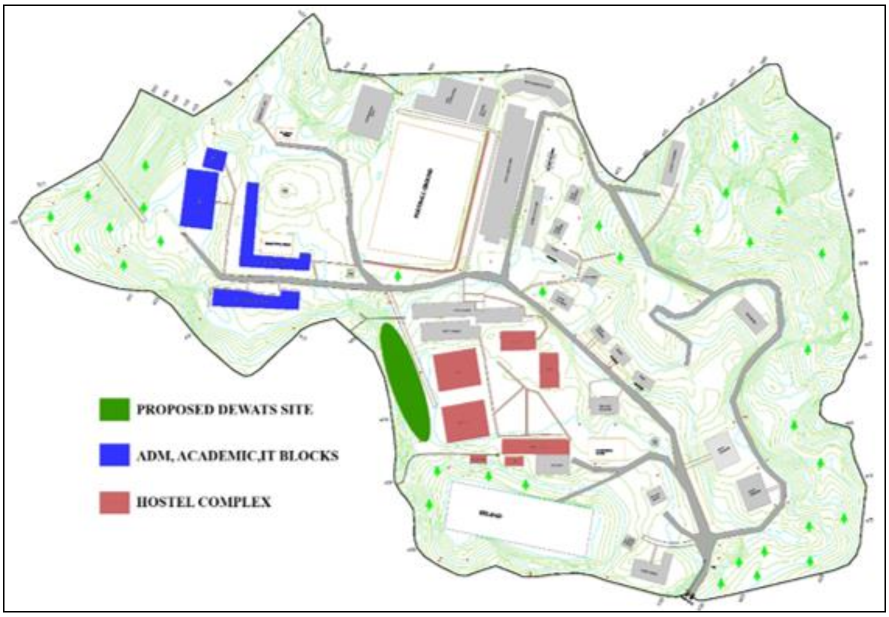

Fig 3: Map of CST campus

Similarly, college has also been facing shortage of water during peak summer season when there is heavy rainfall in the region, disturbing the water connection pipelines. Today, college management made huge expenditure on water supply from Phuentsholing using pump system. Therefore, the introduction of DEWATS and reusing the treated waste water in flushing toilet will ease the burden on management buy reducing expenses made related to fresh water supply and sewage management. Therefore this study the feasibility of implementing DEWATS between the Administration building and the Hostel complex where there will be a swift flow of wastewater due to gravity as Administration, academic and IT building complex lies about 6 meters lower to Hostel complex as shown in figure

5. Data Collection and Analysis

5.1 Waste water generation at site

The water demand in Bhutan is 150litres/person/day for a residentail buildings [22], however the water demand for boarding school and college is 135litres/person/day according to IS1172:1993 [23]. Therefore, in this study the average of two standard is considered, which is equal to 142.5litres/person/day. According to Ministry of Work and Human settlement, the wastewater generation is estimated about 80% of the water demand per person. Similarly this statement is considered in my studies by numerous researchers [24]. The total amount of water required per day is 100505 litres in the hostel complex is shown in table 1. The total amount of wastewater generated from the hostel complex is 80% of 100605 litres/day, which is equal to 80484 liters/ day. Studies have found that the efficiency of DEWATS system is 75% [25]. Therefore, the reusable amount of wastewater treated by DEWATS in the proposed site is about 60363 litres per day.

Table 1: Amount of water required per day in hostel complex

Sl.no	Buildings	No. of Rooms	No of Pupils (capacity)	Waster required (litres/day)
1.	Block A	41	82	11685
2.	Block B	41	82	11685
3.	Block C	41	82	11685
4.	Block D	41	82	11685
5.	Block E	45	90	12825
6.	RK block	96	288 (3 person/ room)	41040
Total		305	706	100605

5.2 Water Demand in ADM, Academic, IT block and Lecture hall complex

According to IS1172:1993, the water demand of day schools and offices are approximately 45litres per person per day [23]. Therefore the total amount of water required in the study areas is about 61965 liters per day as shown in table 2. The capacity of various spaces in the study area is based on the Neufert Architect's Data [26].

Table 2: Amount of water required in ADM, Academic, IT block and lecture halls

Sl.no.	Building	Spaces	Capacity	Water demand(liters/day)
1.	ADM building	Offices	62	2790
2	Academic Block	Class	414	19350
		Lab	16	
3	IT block	Office	12	28125
		Lab	341	
		Classes	272	
4.	Lecture hall complex	Class	260	11700
Total			1377	61965

The treated wastewater from DEWATS will reused for flushing the toilets and irrigation of landscape. Studies have found that only 28% of total water demand is required for flushing the toilets [27]. The estimated water requirement to flush the toilest in study area is about 17350 litres per day. Therefore the remainaing water about 43013 liters per day can be used to irrigate the landscape features in the campus.

6. Design and Layout of DEWATS

6.1 General Layout

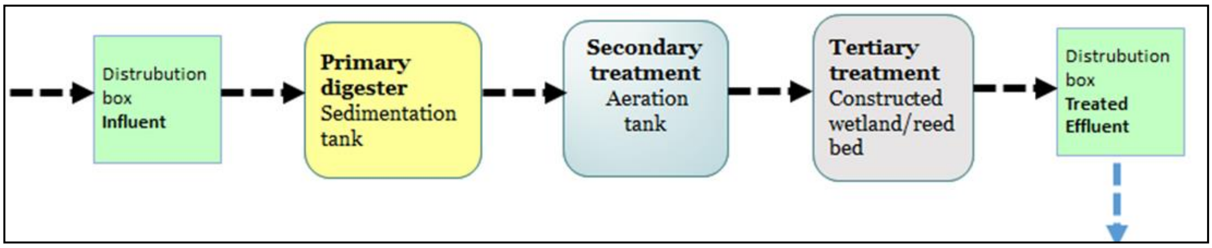

Fig 4: Flow chart of DEWATS

This study adopts the DEWATS coupled with a reed bed for better treated quality of the effluent. This anaerobic system provides the primary and secondary treatment options before discharging the treated effluent to the reed bed for tertiary treatment. The reed bed could serve the function of a polishing pond here to further treat the effluent water from the aeration tanks before being channeled out for redistribution and reuse in the ADM, IT and academic blocks beside irrigation of the college landscape.

6.2 Collection and distribution unit

It is the initial component of DEWATS which will help to collect and distribute the flow of sewage towards the sedimentation tanks. It also function as a physical stage of grit removal besides allowing the faecal matter to sediment. The plant is design based on the amount of waste water produced. The total capacity of the DEWATS plant is determined by flow per day in KLD x HRT [28].

Total capacity of the plant (V)
= flow per day in KLD x HRT
= 80.484 KLD x 9 days (8-10 days for the hot region)
= 724.35 KLD

This components is also known as the preliminary treatment. It reduces BOD of the waste water by about 15-30% [29]. According to Subbaian and group, 5% of the total design volume of the DEWATS is suggested for preliminary treatment system [28] as shown in table 3. A tank should be minimum of 1m depth for the settling of the suspended materials and the baffled is constructed with an opening at the bottom to facilitate effective solid-liquid separation. The minimum width of the tank required is 1.2m for easy operation and maintenance. Then length of the tank is calculated based on adopted width and depth. A free board of 0.30 to 0.45 m must be provided in addition to depth of the tank chosen. The breadth to length ratio is taken as 1:3.

Table 3: Design parameters for preliminary treatment

Sl.no.	Description	Suggested design parameters
1.	Capacity (V_1)	5% of total capacity of plant = 36.22 KLD
2.	Depth (D)	1.2 m + 0.45m(free board) = 1.65m
3.	Breadth (B)	3.2 m
4.	Length (l)	V1/(DXB) = 9.5m
5.	Baffles	1 no
6.	Opening between baffles	Bottom of the baffle

6.3 Primary treatment

The primary treatment of waste water is done in an anaerobic septic tank for anaerobic degradation of suspended and dissolved solids. A volume of 30% of the total design volume of the plant is required and about 15% of the grey water of the total design volume can be reduced. The standard depth of the tank should be 3m and width should be 1.2m [28]. The baffled wall is constructed in the center and the opening is provided in the middle which connects both the units. A 100mm diameter vent pipe with a cowl at the top is fixed over the tank slab in order to let out the gas generated due to digestion of the solids as shown in table 4. The width to length ratio is considered as 1:3.

Table 4: Design parameters for primary treatment (anaerobic septic tank)

Sl.no.	Description	Suggested design parameters
1.	Capacity (V2)	30% of total capacity of plant =217.305kld
2.	Depth	3 m
3.	Breadth (B)	4.9m
4.	Length (L)	V2/(DXB) =15m
5.	Baffles	1 no.
6.	Opening between baffles	At middle of the baffle

6.4 Secondary treatment

In this component, anaerobic baffled filter reactor is used in treatment process whereby non-settled and dissolved solids are made to interaction with remaining active bacterial mass. Similarly, in this stage, a tank of 30% of total capacity with 3 to 4 baffled wall separations is recommended [28]. The volume of the tank is further increased by the filter media which usually has a pore of 40% for the height of 2m as given in table 5. The length-width ration is considered as 3:1

Table 5: Design parameters for secondary treatment (anaerobic baffled-filter reactor)

Sl.no	Descriptions	Suggested design parameters
1.	Capacity (V_3)	30% of total capacity of plant= 217.305kld
2.	Depth	3 m
3.	Breadth (B)	5.8m
4.	Length (L)	$((V_3+(V_3 X 0.4))/(DXB))=17.5m$
5.	Baffles	3-4 nos. (equally spaced)
6.	Connection between baffles	PVC pipes positioned in baffles carry influent below the filter media
7.	Placement of filter media	2m thick placed above the bottom level of tank
8.	Filter media provided in tanks	Stones 20-30 cm size and Gravel (40mm and 20mm)

6.5 Tertiary treatment

This component of DEWATS is considered as natural treatment ecosystem where 30% of the volume is assigned to the planted bed filter which provides root zone treatment. The volume of planted bed filter is further adjusted to account for the loss of space occupied by the filter media. The percentage of volume lost due to filter media is normally estimated as 60% of the total volume [28]. In the design, planted bed filter of 1.2m depth and minimum width of 1.2m is suggested. The open tank bed is covered with graded gravel of 20-40mm and soil balls with a plant stem at each ball at top space. The ratio of length to width is taken as 3:1 as shown in table 6.

Table 6: Design parameters for tertiary treatment (planted bed filter)

Sl.no	Descriptions	Suggested design parameters
1.	Capacity (V4)	30% of total capacity of plant = 217.305kld
2.	Depth	1.2 m
3.	Breadth (B)	10m
4.	Length (L)	$(V_4+ V_4 X0.6)/(DxB)) = 30m$
5.	Filter media	Graded gravel (equal layers of 40 mm and 20mm thickness)
6.	Plant bed	Mud/soil balls of 20cm thick placed between the gravel layers. Each ball to contain a plant- root -zone
	Type of plants	Type of Reeds –Phragmites Kharka (native to Phuentsholing) at 300x300mm spacing

In this study, the *Phragmiteskarka* is used for Reed bed construction as, it is one of the native weeds of Phuentsholing and strength the native ecology. It also provide the consistent discharge quality as it has a superior capacity to meet the variations of effluent characteristics withstanding shock loadings without damage or disruption to treatment. Moreover, due to its extensive root system, it produce no sludge or other by-products [30].

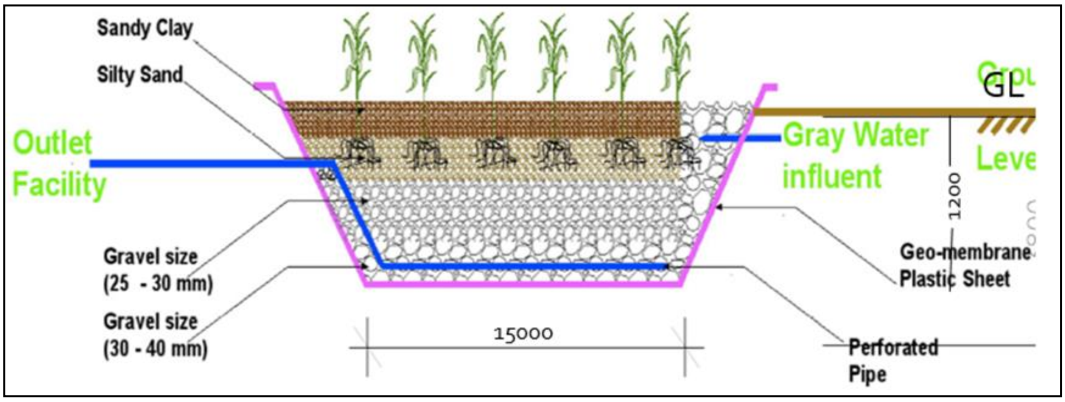

Fig 5: Reed bed filter pond

7. Result and Discussion

The total amount of land required for the construction of Preliminary, Primary, Secondary and Tertiary treatment system required around 681Sq.m, which is available between the two identified areas as shown in Figure 3. The proposed DEWATS in the college can treat 80484 liters of wastewater/day from hostel complex generating a reusable water about 60363 litres/day. At the same time the ADM, Academic, IT bock and lecture hall complex required a water of 17350 litres/day for flushing the toilets out of the total demand of 61965 litres/day.

Currently, the college management is paying about Nu.65000/month to Phuentsholing Municipal office for pumping about 60,000 litres of water/day to the college campus. The approximate cost of water is about Nu. 0.036/litre. The demand of water required for flushing toilet in species area can be meet by the treated wastewater of DEWATS saving the cost about Nu. 18736 per month. The remaining treated waste water of 43013litres/day can be used for landscape irrigation saving the cost of fresh water demand about Nu.45000 per month. Therefore the implementation of DEWATS in the campus could not only solve the issues related to health and sanitation but also generate income for future sustainability.

8. Conclusions

Bhutan has made a significant accomplishments on sanitation till date, however access to enhanced sanitation and hygiene is still low with 10% with sewer associations in urban territories and 62% of urban population still using septic tanks [1]. Today the management of wastewater from kitchen and bathrooms has become challenging for the municipal authorities and relevant agencies specifically with the draining of wastewater directly a nearby water body without treatment. This direct discharge of waste water pollutes both soil and water bodies destroying its ecosystem increasing the issues related to hygiene and sanitation. Moreover today, shortage of fresh water supply for both domestic use and agriculture purpose is still challenge in numerous communities in the country.

Therefore, such type of DEWATS are not only affordable but also protects the environment and human health and saves energy. The DEWATS is an effective alternative for treating raw sewage as it is one the sustainable and ecological method. This system has the capability of meeting the demand of the growing problem in a water scarce community that hinders the economic development, human livelihood and environmental quality. This study has found that, DEWATS can be the most suitable solution of the wastewater and water supply issues for small communities like CST, where it can save about 75% of cost incurred in water supply and wastewater transportation.

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