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SUSTAINABLE DECENTRALIZED WASTE MANAGEMENT IN URBAN RESIDENTIAL AREAS

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Abstract: Proper management of wastewater is a major challenge for a developing country like India. The scarcity of water in urban areas has given rise to the requirement of reuse of treated wastewater for secondary uses. Large number of treatment processes and operations can be used in various combinations to achieve the required effluent quality of treated wastewater and large numbers of studies have been carried out on this aspect. Most of the decentralized wastewater treatment processes are land or energy intensive both of which are in shortage in urban areas. The use of non-conventional energy for treatment of domestic wastewater has not been explored. Use of non-conventional energy sources would imply adequate energy for only part of the treatment time. Such a system can be developed using solar, wind or wave energy. A laboratory scale study was carried out using a modified septic tank, anaerobic baffled wall reactor, aerobic attached growth system and constructed wetland to find out the efficiency of black water/ domestic wastewater treatment. To simulate non-conventional energy sources, partial aeration was provided to the aerobic attached growth system. The reactors were subjected to an organic loading rate (OLR) of 1.2 kg/m^3/day and 24 hours HRT using synthetic wastewater. Individual reactors efficiency in terms of COD, TSS, total nitrogen, and total phosphate removal were analyzed. The reactors were placed in a sequence to depict a treatment system and the performance was evaluated based on above mentioned parameters. The performance of the wastewater treatment system was also validated using real wastewater. Pilot scale studies were carried out in an apartment block with 20-25 residents. The treatment system was meeting the effluent quality required for reuse as specified by CPHEEO. Overall, the study demonstrated that a sustainable onsite wastewater treatment using non-conventional energy source, i.e., solar power is a viable and efficient system

Keywords: Decentralized; Reuse; Modified septic tank; Baffled reactor; Aerobic attached growth; Solar Panels

1.Introduction

Water shortage, especially in urban areas having high density of population, has already been identified as a major problem and large numbers of steps are being taken to ensure availability of water. Water provided in urban households is consumed and the water resource is converted into wastewater 30-40% of potable water supplied to the household is used for toilet flushing while 50-80% of the potable water supplied forms part of greywater produced from the household (Omenka, 2012). This wastewater is sent along the sewage lines for treatment and discharge into the surface water streams and rivers. At present only 35% of the wastewater generated in class I cities and class II towns of India are treated (Manual on sewage and sewerage treatment, 2013). The rest of the wastewater contaminates the surface water and the ground water which are our water source. Present system of wastewater collection and disposal has been the norm since the 1920s when the honey wagon used to collect the household excreta for treatment and disposal in the urban areas. The water closet or the flush toilet increased the quantity of wastewater to be disposed and sewage transport system using pipes was evolved. This system has been doing well in developed nation but when the model is replicated in developing nations, it has not been found to be as successful (Omeka, 2012). With the scarcity of water increasing in urban areas, we need to start reuse of water by treating the wastewater to requisite level. A major hindrance in reuse of wastewater is the centralised wastewater treatment system in which the wastewater travels over large distances in sewer networks, usually by gravity, for treatment. To reuse the treated wastewater, pumping would have to be carried out. The cost of pumping it back to the user after treatment at the centralised treatment plant would be very high making this procedure uneconomical. Decentralised wastewater systems provides us with an option of reuse of treated wastewater for secondary tasks as well as ensure 'polluter-to-pay' system is followed. It also reduces the cost of infrastructure as 60-80% of the cost of a centralised wastewater system is expended in transportation of wastewater. A number of decentralised wastewater treatment systems are beings used all over the world. These systems vary from using technology intensive methods to low cost inexpensive methods of treatment. Treatment technologies like septic tank, anaerobic ponds, composting toilets are examples of low cost and low maintenance systems, but the wastewater requires further treatment to meet the reuse standards. Better effluent is available using treatment processes like trickling filter, up-flow anaerobic sludge blanket, anaerobic filter but high cost and maintenance are some of the disadvantages of such systems. Cities, like Beijing have an ambitious water reclamation systems but it was found that 80% of the systems failed during power-cuts. India, which suffers from power shortage, cannot afford a system which depends only on provision of electricity for the effective treatment of wastewater. The treated wastewater is being utilised for toilet flushing, landscaping, street cleaning, car washing and other secondary tasks. Each task has specific requirements of the quality of water and parameters for quality of treated water should be well defined in India. Control and maintenance of wastewater treatment system needs to be carried out as per the technology utilised. Expertise in operation and maintenance of such system is less and large number of systems does not function at their optimum efficiency and quite a few stop functioning within couple of years of installation (Omeka, 2012).

The payback time of cost of construction and operation and maintenance of a decentralised wastewater system is less when the gas generated from the system is utilised to gain economic benefits. Domestic wastewater has very less gas production due to the low organic loading of the domestic wastewater and high hydraulic loading which dissolves 23.5% of the gas. The gas recovery in domestic wastewater systems is found to be 23% of the COD load (Bal and Dhagat, 2001). This increases the payback time of the domestic decentralised wastewater system. With the scarcity of water in urban residential areas, the cost of water has increased. Reuse of wastewater for sundry task is now an economically viable option in class I cities and some class II towns. The treated wastewater can then be used as a resource to even sell water to water intensive industries and landscapes.

The decentralised or onsite treatment of wastewater would be best served if segregation of toilet wastewater (black water) and rest of the domestic wastewater (grey water). This will enable lesser treatment requirement for 70% of the wastewater (Manual on sewage and sewerage treatment, 2013) and consequently lesser power, cost and space requirements.

There has been a paradigm shift in the wastewater treatment system from centralised to decentralised and onsite wastewater treatment. Decentralised wastewater treatment can be defined as 'the collection, treatment, and disposal/reuse of wastewater at or near the point of wastewater generation' (Volkort and White, 2008). Thus, to achieve sustainable water and wastewater management, there is a need of developing appropriate methods to carry out wastewater management which allow onsite treatment and reuse, keeping in mind, the socio-culture, and economical as well as regional constraints.

Even though large amount of research has been carried out on onsite wastewater treatment, most of the systems in use require technical knowledge for proper functioning. Most systems suffer from inefficiency in operation and maintenance after the responsibility is passed on to the local community. A sustainable system should be robust and should have minimum dependency on electrical supply. It should rather depend on natural processes including non-conventional energy sources. Studies need to be carried out for the best possible configuration of various decentralised and onsite treatment process and operations providing low cost, sustainable wastewater treatment system which meets the requirement of the end user. Thus, there is a requirement to develop a sustainable onsite wastewater management system for the urban residential areas. The study will aim to develop a treatment system using a series of unit processes and unit operation so as to treat all OLRs of domestic wastewater. To provide a sustainable option, the present study focussed on developing a wastewater treatment and recycling system capable of operating using non-conventional energy source, i.e., solar power.

2. Materials and Methods

2.1 Experimental Set-up

The onsite wastewater treatment system was piloted in a single household at the outskirts of Chennai (Medavakkam), Tamil Nadu, India with the GPS coordinated as 12.9171° N, 80.1923° E. The location of the pilot site was shown in Fig. 1. The house that was chosen for the study had 25 inhabitants and the per capita water consumption is taken as 135 L per capita per day for design purposes

Fig. 1 Geographical View of the Medavakkam and Piloting site

The single household wastewater was collected and were treated in a battery of treatment units consisted of i) modified septic tank, ii) baffled reactor iii) aerobic attached growth system, iv) settler ,v) sand filter and vi) disinfection system . This sequence was arrived at based on laboratory scale studies. The flow diagram of the onsite wastewater treatment system is shown in Fig. 2.

Fig. 2 Sequential flow diagram of onsite wastewater treatment system

2.2 Reactors and Operation

The wastewater (both black water and greywater) generated from the 25 people house inmates were about 2000 L/ day, and the reactors were designed for this flow rate. The dimensions of the reactors are provided in Table 1. An appropriate location was chosen in the house to ease the flow from the source of generation to the treatment system by gravity. The photographs of the onsite treatment system are provided in Fig. 3. The treatment units were fabricated using fiber reinforced plastic material (FRP) with a thickness of 6 mm. The units after fabrication were transported to the site and were erected.

Table 1 : Dimension of the Reactors

S. No	Treatment Unit	Dimension (L x W x H in m)
1.	Modified Septic Tank	1.70 x 1.1 x 2.2
2.	Baffle Reactor	1.10 x 0.6 x 2.0
3.	Aerobic attached growth system	1.0 (Dia) x 1.50 height
4.	Sand filter	1.20 x 1.20 x 1.20
5.	Holding tank	1.80 x 0.45 x 0.90

To start the reactors, fresh anaerobic sludge (500 L) from Nessapakkam treatment plant was added into the modified septic tank (MST). The MST has two chambers connected vertically and has an inverted cone shaped structure (like UASB) that retains the biomass/solids escaping to the next reactor. In the baffle reactor, the baffles were placed perpendicularly to the flow of water to take a longer pathway (HRT of 24 h). In aerobic attached growth system, Fujino spirals were used as attachment medium, the diffused aerators were placed at the bottom of the reactor.

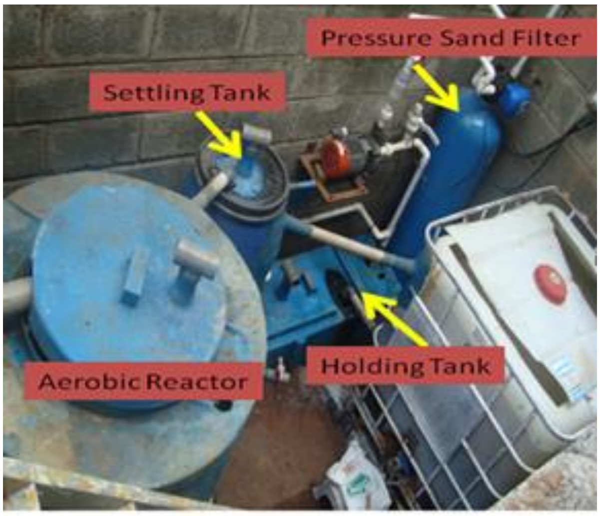

Fig. 3 Photographs of onsite wastewater treatment system

All the electrical/ mechanical devises were operated using DC. The energy required for the operation of the units was obtained from solar panels installed. During the start-up stage the wastewater load was gradually increased first one week with 25% flow and 24 hours aeration, next week with 50% flow and 24 hours of aeration, 3 week with 75% flow with 12 hours of aeration and 4th week with 100% flow and 12 hours of aeration.

2.3 Analysis

The samples were collected weekly from all the reactor outlets. Also raw and treated water samples also were collected. The collected samples were transferred to the laboratory and analyzed as per the standard methods provided by American public health association (APHA, 2005). pH of the raw and treated water from each units were measured using Eutech cyberscan PCD 650 multi parameter kit (Thermo scientific, Singapore). Chemical oxygen demand (COD) was measured using a closed reflux chromate titrimetric method (5220), Biochemical oxygen demand (BOD) was measured using the 5 day incubation method (5210-B). Suspended solids were measured using the gravimetric method (2540 D), and the fecal contamination was evaluated by most probable number test (9221).

3. Results and Discussion

3.1 Raw water Characteristics

The raw wastewater collected from the single household was characterized for various physic-chemical parameters and the results are presented in Table 2. The influent value shows a close similarity with the typical black water characteristics. It was observed that the concentrations of physico-chemical parameters were much higher than those mentioned by Metcalf and Eddy, 2003 for the high-strength wastewater. The average BOD to COD ratio of the influent was 0.52, which indicating its feasibility for biological treatment (Gallagher and Sharelle, 2011). The inlet wastewater characteristics showed a wide variation which is evident from the large standard deviation, especially for the parameters like COD, BOD and TSS.

The average concentrations of COD in the raw wastewater was 1366 ± 88 mg/L, BOD was found to 427.5 ± 39.6 mg/L and TSS was in the range of 345.2 ± 80.7 mg/L. The earlier reported values for typical black water were total COD 1712 ± 225 mg/L, BOD 997 ± 419 and TSS 1053 ± 571 (Kujawa – Roeleved et al., 2005; Sharma et al., 2016). The BOD values of the raw wastewater in present study were less than the reported values which might be due to presence of large quantity of detergents and surfactants.

3.2 Performance of various treatment units

3.2.1 Organics and Solids

The average removal efficiencies obtained for various treatment units during the study period are shown in Fig. 4. The data clearly demonstrates that despite of the high pollutant concentration in the wastewater, the treatment system was able to remove the organics and solids satisfactorily (Fig. 5).

Table 2 : Raw Wastewater Characteristics

S. No	Parameters	Raw sample values
1.	pH	7.45 – 8.58
2.	Biochemical oxygen demand (BOD) (mg/L)	427.5 ± 39.6
3.	Total chemical oxygen demand (T.COD) (mg/L)	1366 ± 88
4.	Total suspended solids (TSS) (mg/L)	345.2 ± 80.7
5.	Fecal Contamination (FC) (MPN / 100 mL)	1.8 x 10^7 – 9.8 x 10^7

The overall percentage removal of BOD was 88%, COD was 92%, TSS was 96%. It was also observed from the Fig. 5 that the pollutants concentrations were getting decreased as the wastewater flows from one unit to another unit. The average treated water quality was found to be 55.5 ± 36 mg/L for COD, 24.6 ± 9.6 mg/L for BOD and 10.6 ± 1.8 mg/L for TSS. It was observed that the performance of the system improved with respect to time, due to the increase in biomass attachment on the filter media and acclimatization of various biological systems with the wastewater.

Faecal Contamination

The most significant parameters concerning wastewater treatment and disposal are the pathogenic bacteria. The fecal coliforms bacteria (FC) provide the total spectrum of pathogenic bacteria present in the wastewater (Sharma et al., 2016). The average performance of the system in terms of coliform concentrations at steady-state is summarized in Table 3. The average influent concentrations of the FC were observed as 1.8 x 10^7 MPN/ 100 mL and treated effluent were found to be 62 MPN / 100 mL. Overall, the present onsite wastewater treatment system showed a significant coliform reduction capacity after the disinfection.

Table 3: Fecal Coliform concentration in the reactors

Reactors	FC (MPN / 100 mL)
Raw	1.8x 10^7
Modified septic tank	1.05x10^5
Anoxic baffle reactor	7.8 x10^4
Aerobic reactor	3.4 x10^3
Settling Tank	642.85
Treated water	22

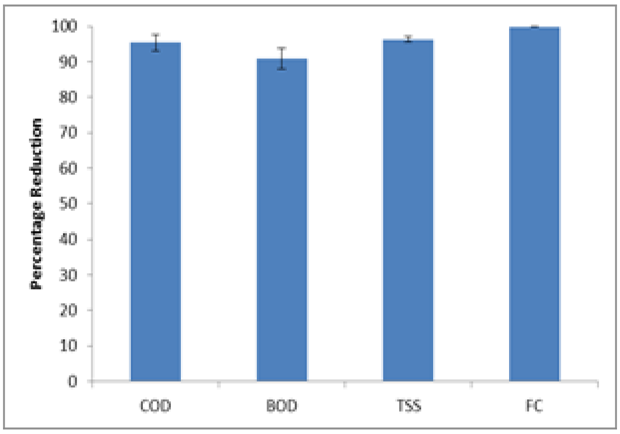

Fig. 4 The overall treatment efficiency of decentralised wastewater treatment system

4. Conclusion

The newly designed and field demonstrated wastewater showed a substantial potential for the on-site treatment of wastewater treatment. On the basis of easy design, trouble free operation and maintenance, longer de-sludging interval no grid dependence for power, and much better treatment efficiency compared to the conventional septic tank system, the developed system is an apt choice for onsite-wastewater treatment. The system achieved a very high BOD, COD, TSS and fecal coliform removal efficiency. The treated effluent values are 55.5 ± 36 mg/L for COD, 24.6 ± 9.6 mg/L for BOD and 10.6 ± 1.8 mg/L for TSS and 22 ± 12 MPN/ 100 mL. Therefore, the treated water can be reused for many secondary uses like flushing, gardening, car washing and floor washing. The present system can be a feasible alternative for application in the rural and peri-urban areas of the developing countries

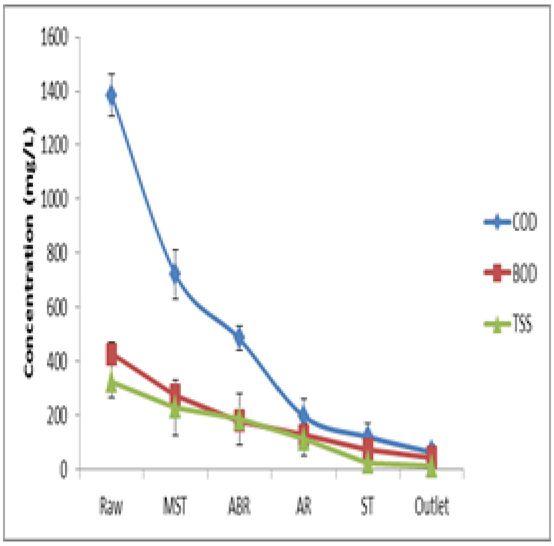

Fig. 5 Overall Performance of Individual Reactors (MST – modified septic tank; ABR – Anaerobic baffled reactor; AR – Aeration tank; ST – Settling tank outlet; Outlet – After filtration) (n = 8)

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