Alternative On-Site Systems for Domestic Wastewater Treatment and Disposal: A Review

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***Abstract* - Sewage treatment and disposal is a major concern in many developing countries like India due to improper wastewater collection and treatment facilities. Safe, economic and effective disposal of domestic wastewater is one of the most challenging problems in today's civilization. Conventionally, septic tank is used for on-site treatment of domestic wastewater; but it causes groundwater pollution and incomplete action on contaminants. Recently other technologies have been developed such as Bio-filtration, Membrane bioreactors, Bio-towers, Sequential Batch Reactor, Fluidized Aerobic Bioreactor, Packed bed reactor, Submerged fixed film technology, Concentric chamber reactor and various combinations of aerobic and anaerobic processes which have given better performance than that of septic tank. This paper reviews the application of such technologies as alternatives for on-site treatment of domestic wastewater in various perspectives. The different types of reactors developed by researchers are also reviewed in order. This paper is concentrated on the review of treatment options for domestic wastewater generated at municipal level.**

Keywords: On-Site Treatment Systems, Domestic Wastewater, Decentralized System, Septic Tank.

INTRODUCTION

Well-designed water supply and sanitation facilities are key factors in protecting health of society. Inadequate domestic wastewater collection, treatment and disposal lead to pollution of surface and ground water bodies. This will cause major public health problems. Normally, the domestic wastewater is expected to collect through sewerage network and treat the same at centralized sewage treatment plant. In India, estimated 38,354 (MLD) sewage is generated in major cities of India, but the sewage treatment capacity is only of 11,786 MLD (~30%). Discharge of untreated sewage into water bodies has resulted in contamination of 75% of all surface water bodies across India (1). In class I and II cities of India, a sewage treatment capacity of only 6,190 million litres per day (MLD) has been installed against the total sewage generation of 29,129 MLD (3).

Centralized wastewater collection and treatment systems are costly to build and operate, especially in areas with low population densities and dispersed households. Developing countries lack both the funding to construct centralized facilities and the technical expertise to manage and operate them. Alternatively, the decentralized approach for wastewater treatment which employs a combination of onsite and/or cluster systems is gaining more attention (4). The decentralization concepts and technologies in wastewater management need to be systematically investigated, with focus on its development and practical implementation in India.

The most popularly used on-site treatment system is septic tank. But in reality the septic tank effluent has high solids content, high oxygen demand and characteristic putrid odor. Many researchers have developed various alternatives for the treatment of domestic wastewater on decentralised basis. The treatment can be carried out with the help of various reactor configurations. Various treatment combinations such as baffled septic tank followed by horizontal ground filter and polishing treatment or anaerobic filter in combination with constructed wetlands seem to be better options for the treatment.

ON-SITE WASTEWATER TREATMENT SYSTEMS IN INDIA

The centralized wastewater treatment systems in India are insufficient to treat the domestic wastewater generated in all parts (2). Government has passed new environmental regulations stipulating that dischargers of wastewater such as small and medium enterprises and housing estates will be held responsible for wastewater pollution and must therefore treat wastewater adequately on-site before it is discharged into the environment. Therefore, promoting decentralised waste water treatment systems both at individual and institutional levels can offset this problem to a greater extent. A few scientists have worked upon various treatment technologies for on-site wastewater treatment in India. Following is the review done on their contribution.

Murugesan Dhinadhayalanand Arvind Kumar Nema (2012) studied the performance of a unique decentralized sanitation system installed in a Tsunami rehabilitation colony. They presented results from experiments on the treatment of black water from toilet by septic tank with up-flow filter and subsequent treatment of blended wastewater by waste stabilization pond systems. The data showed that the septic tank with up-flow filter that treat black water, has the average COD removal efficiency of 61%, BOD of 69% and that of suspended solids (SS) 85%. This paper also documented the socio-techno-economic and environmental benefits for adoptability of the system in developing countries like India. The studies and the results obtained establish the present system as a possible combination of a decentralized on-site and a centralized off-site system. According to researchers, it is easier for adoption in settings of non-urban, rural and village locations where land availability for the pond system will not be a problem and the system can be a self-regulating one with no dependence on mechanical/electrical equipment.

Baetens (2000) has taken overview of Integrated Decentralized Waste Water Treatment Systems constructed during 1995-1998 at Auroville Centre for Scientific Research (CSR), Auroville, which is participated in a European Union funded project on Decentralised Wastewater Systems (DEWATS) The project was executed by BORDA (Bremen Overseas Research and Development Association). The system comprises of different devices covering primary, secondary and tertiary treatment stages. The settler is used for sedimentation as a pre-treatment phase, Anaerobic baffled tank for biological process as first treatment phase, anaerobic filter is used for second treatment phase and for the third treatment phase, a horizontal planted gravel filter is used. The pre-treatment (settler), first treatment (baffled tank) and second treatment (anaerobic filter) are constructed below ground level. After passing through this integrated anaerobic and aerobic treatment, the treated water is exposed to air in the polishing tank. The treated water has met the Central Pollution Control Board's (CPCB) standards and the wastewater can be, if required, safely used for infiltration into the soil and subsequently recharge the ground water table. As per study combination of aerobic n anaerobic treatment gives better results.

V. K. Raman et al (2014) assessed the performance of lab scale model of a compacted aerobic attached growth fix-film unit (termed Bio-cache) for treatment of small volume domestic wastewater. The study was carried out between July 2007 and June 2008, on the premises of department of Environmental Sciences, University of Pune, India Fig 1 shows that Schematic appearance of a Bio-cache attached growth treatment system. At the optimum hydraulic retention time (HRT) of 2 hrs, approximately 78% Chemical Oxygen Demand (COD), 88% Biological Oxygen Demand (BOD_5), 32% Total Dissolved Solids (TDS), 72% Total Suspended Solids (TSS), 9% Chlorides, 75% ammonia nitrogen (NH_3-N), 40% phosphate (PO_4-P), 93% most probable number (MPN) and 95% total viable count (TVC) reduction was achieved in the Bio-cache system. Study indicates that attached growth process increase removal efficiency of pollutants due to increase in microbial contact with pollutants.

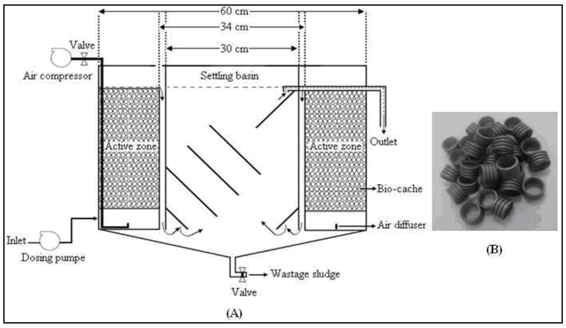

Fig. 1 Schematic appearance of a Bio-cache attached growth treatment system (A: Cross sectioning, B: Bio-cache media)

Bhuyar K. (2013) carried out studies on a laboratory-scale packed bed reactor treating domestic wastewater at different HRTs. The reactor is made up of cylindrical PVC pipe placed vertically, so that minimum floor area is required. The reactor has randomly packed with pieces of corrugated PVC plastic rings. Fig. 2 shows schematic diagram of the UAPB Bioreactor used for treatment of Domestic wastewater. The study demonstrated the influence of HRTs and suitability of UAPB reactor for treatment of domestic wastewater. The experiments were performed at hydraulic retention times of 1, 2 and 3 days based on empty reactor volume and the performance of the reactor was evaluated based on the removal of organic matter COD, SS, pH changes and biogas production. The average COD and SS removal efficiencies for Domestic wastewater were 63.87, 70.85, 75.92 % and 75.24, 84.55, 94.25 % respectively. It was concluded that one day HRT is the optimum for the bioreactor.

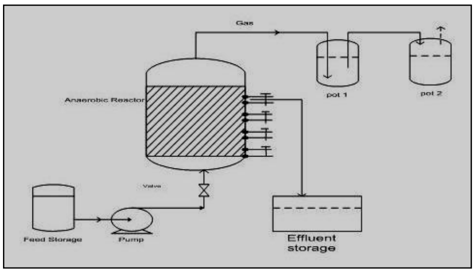

Fig. 2 Schematic diagram of the UAPB Bioreactor used for treatment of Domestic wastewater

ON-SITE WASTEWATER TREATMENT SYSTEMS IN DEVELOPED COUNTRIES

Sabry T. (2010) developed a full scale system consisting of modified upflow septic tank followed by anaerobic baffle reactor. Fig. 3 shows cross-sectional view in the modified septic tank system (USBR). The treatment system showed the average results at an average retention time of 20 h as 84% for the COD removal, 81% for the BOD removal, and 89% for the TSS removal. Results also showed that USBR has tolerance to the hydraulic shock loads. The BOD, COD, and TSS removal efficiencies have not been affected during the shock load periods due to system stability. From this study, it was concluded that the Upflow Septic Tank/Baffled Reactor system could become a promising alternative to the conventional treatment plants in rural developing countries.

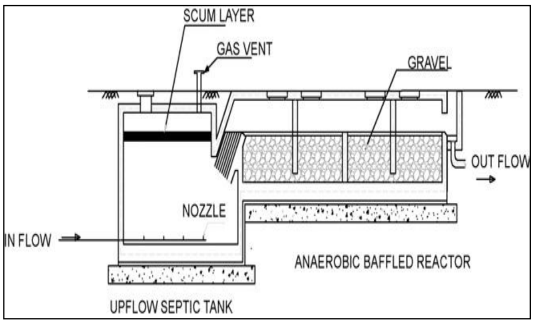

Fig. 3 Cross-sectional view in the modified septic tank system (USBR)

Pedros P.B. and W.K. Dobie (2006) in his study, described Amphidrome® process which is a submerged attached growth bioreactor (SAGB) that has been used for decentralized wastewater treatment systems ranging in size from 440 gpd to 150,000 gpd. The performance of system including loading and removal rates, at the four treatment plants is presented. The results indicated are 97% nitrification at an organic loading of 2.5 kg-BOD5/m3-day, and a nitrification rate of 0.427 kg-N/m3-day and a denitrification rate of 0.410 kg-N/m3-day each at a total ammonia loading of 0.434 kg-N/m3-day.

Mahmoud M. et al. (2010) conducted studies on pilot scale a down-flow hanging sponge (DHS) system for presettled municipal wastewater. The removal efficiencies of COD were 89, 80, and 56% at HRTs of 6, 4, and 2 h, respectively. Ammonia removal percentages of 99, 90, and 72% were achieved when the DHS system was operated at HRTs of 6, 4, and 2 hrs, respectively. The results suggested that the proposed system may be a competitive solution for municipal wastewater treatment under variable conditions.

Elmitwalli T. et al. (2002) used two-step anaerobic system to treat sewage. They tested the performance of the two up-flow-hybrid septic tanks which require high power input or high excavation depth due to that the two treatment steps exist in a vertical order. Mean removal efficiencies in the two-step anaerobic hybrid-septic tank at 5 days HRT and 13˚C were 94, 98, 74 and 78% for total COD, suspended COD, colloidal COD and dissolved COD respectively.

El-Gendy A. et al (2012) developed an on-site wastewater treatment system consisting of an up-flow anaerobic reactor; down-flow anaerobic packed-bed baffled reactor; a passive aeration and a biological filter system followed by a sedimentation tank. The average overall removal efficiencies up to 85%, 69%, 88%, 91% and 89% were achieved for COD Total, COD Soluble, BOD5, TSS and VSS, respectively. The integration of anaerobic and aerobic phases of the treatment can provide effluents with quality acceptable for disposal in agricultural drains with respect to COD Total, BOD5 and TSS.

Mendoza L. et al (2009) evaluated performance of a lab scale model of new cost effective reactor called gradual concentric chambers (GCC). Fig. 4 shows that layout of the lab-scale GCC reactor. The effluent quality of the GCC reactor was compared with that of an up-flow anaerobic sludge bed (UASB) reactor. Both reactors showed organic matter removal efficiencies of 90%; Average COD removal efficiency of 90 ± 2%. However, the elimination of nitrogen was higher in the GCC reactor. The economic analysis, the simplicity of design and the performance results revealed that the GCC technology can be of particular interest for sewage treatment in developing countries.

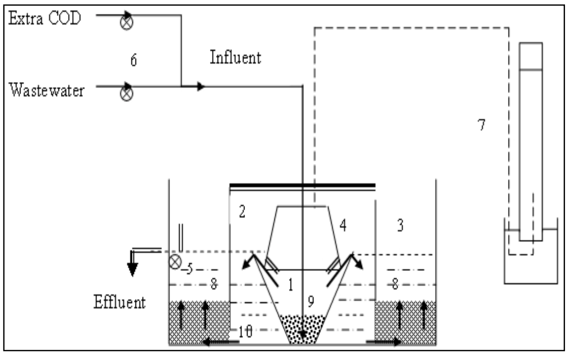

Fig. 4 Layout of the lab-scale GCC reactor. 1. Anaerobic compartment. 2. Headspace. 3. Aerobic compartment. 4. Gas deflector. 5. Water cycling pump. 6. Influent pumps. 7. Biogas collection system. 8. Gravel bed. 9. Sludge bed. 10. Anaerobic effluent.

DISCUSSION

It can be observed from the review that the efficient removal of suspended solids, organic matter and nutrients can be taken place by using low cost, energy efficient and compact treatment system. The research work on decentralized wastewater treatment systems for domestic wastewater is going on in India as well as in abroad. However, if the applicability of decentralised treatment system is concerned, India is quite behind as compared to western countries, more research is needed to mitigate pitfalls of conventional treatment and provide more concentration on decentralized treatment.

CONCLUSION

In India, presently septic tank is used as the on-site treatment system to treat domestic wastewater at almost all places. But the effluent from this system cannot meet the desired standards. The further research work on decentralized wastewater treatment systems for domestic wastewater is required. Decentralized treatment system can provide a low-cost, energy efficient and environmentally sustainable on-site wastewater treatment in India but modification is needed and recent concept should implement. Combination of aerobic and anaerobic treatment gives better results to treat sewage as well as attached growth process introduced more micro organism contact to reduce organic load so media introduction and combined aerobic and anaerobic process gives good quality of effluent. Physical parameter like dimensions, shape, type of rector etc also matter to treat wastewater so more attention required on it. These systems are proved to be efficient for decentralized wastewater treatment. From the review, it can be concluded that combination of aerobic and anaerobic treatment of sewage represents a low-cost and sustainable technology for domestic sewage treatment for community on-site.

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