International Journal of Water Resources and Environmental Engineering Vol. 3(11), pp. 233-237, 8 November, 2011
Available online at http://www.academicjournals.org/IJWREE
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Process design for decentralized sewage treatment system with total natural resource management

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Accepted 14 October, 2011

In developing countries sewage disposal is still a major problem. Increase in population and less availability of natural resources makes sewage a major source of health hazard. With sprawling urban population sewage disposal has become a very serious problem. Under this circumstances, the decentralized sewage treatment system (DTS) for population varying from 1000 to 10,000 that is, 120 to 1200 Kl/day or more can play a major role in water pollution abetment with multifaceted benefits. In this paper a realistic and low maintenance process design of DTS with cost benefit analysis for a population of 3000 is discussed. This process with indigenous technology makes sewage a resource providing biogas as fuel, biofertilizer and manure rich water for irrigation purposes. The amount spent on this sewage treatment can be fully recovered within 8 to 10 years. Thus we can find solution to a formidable problem which either seems impossible and total natural resource management is possible through adopting it.

Key words: Decentralized sewage treatment system (DTS), natural resource management, sewage disposal.

INTRODUCTION

In developing countries the sewage disposal is not given proper priority so treatment and disposal of sewage is still area of major concern. Untreated sewage from cities and towns is the biggest source of pollution of water bodies in third world countries (CPCB Highlights, 2001). In India there are 211 Sewage Treatment Plants (STPs) in 112 of the 414 Class I cities and 31 STPs in 22 of the Class II towns (CPCB Highlights, 2005). Besides, 27 STPs are in 26 other smaller towns. In all there are 267 STPs, Including 231 operational and 38 are under construction. There remain 302 Class I cities and Class II towns together generate an estimated 29129 ml/day sewage (Nadeem et al., 2008). Against this, installed sewage treatment capacity is only 6190 ml/day. There remains a gap of 22939 ml/d between sewage generation and installed capacity. In percentage this gap is 78.7%. Another 1742.6 ml/day capacity is under planning or construction stage. If this is also added to existing capacity, even then there is gap of 21196 ml/day (equal to 72.2%) in total sewage treatment capacity. The untreated sewage causes many problems where it has been discharged. In India it is estimated that 75 to 80% of water pollution by volume is caused by domestic sewage. It pollutes the river streams, fertile land and ground water mainly besides causing odour nuisance Ministry of Environment and Forests, 2006. Untreated sewage is also a source of health hazards which manly affect children and poor people. Infectious diarrhoea makes the largest single contribution to the burden of disease associated with unsafe water, sanitation and hygiene (Pescod, 1992). The concept of Decentralized Sewage Treatment System (DTS) is quite effective to come over these major problems with unique solution. In present proposal the technology used for designing a DTS is very known and indigenous but the process design is new and widely applicable where sewage is a problem. In this paper we are proposing an improved concept of Sewage Treatment which is based on our earlier study of pilot scale by installing a Biogas digester of similar design at Gopeshwar (Uttarakhand) during 1984-1985 coupled with

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community latrines for population of 500 persons.

Untreated sewage causes dangerous effect on aquatic system because untreated sewage rich in contaminant (Central Pollution Control Board, 2005). Globally, the spread of Hepatitis-A and Cholera are mainly through untreated sewage. Consumption of marine food collected from such polluted waters cause Viral Hepatitis, cholera, Typhoid, and digestive problems Ministry of Environment and Forests, Government of India, Vision, 2003).

Decentralized sewage treatment system (DTS)

DTS is the system in which instead of collecting whole sewer of town at one place and treating it, it provides small treatment units on site at many places. DTS provides treatment of waste water flows from 120 to 1200 kl/d (kilo litre per day) or even more form domestic sources (CPHEEO, 1987). It is based on principal of anaerobic fermentation. The selection of which has been determined by its reliability, longevity, easy control and least maintenance. Actually in DTS the partial treatment is given to the sewage water as it can be utilized in urban agriculture irrigation purpose with drip or sprinkle irrigation technique instead of disposing it in to the streams (BORDA, 1998). So this small scale treatment plant can give real benefits in terms of money without polishing sewage with advance treatment like Activated Sludge Process etc. In this system a balance between the advantages of large scale treatment in terms of Economics of scale and individual Responsibility for domestic waste water treatment can be obtained by providing colony wise/sector wise treatment system. Demonstration plants using onsite DTS should be promoted throughout the developing nations for which not only Government Agencies and Non Governmental Organizations (NGOs) but also progressive builders and resident welfare association may show the way.

Total natural resource management

Natural resources include anything existing in nature that is capable of economic exploitation and management is to succeed with limited resources. Sewage can be a natural resource, if it is utilized for economic exploitation. This process design shows the way total possible natural resource management can be done and multifaceted benefits namely biogas, bio fertilizer and irrigable water rich in manure contents can be produced from sewage.

METHODOLOGY

Designing of sewage treatment procedure depends on the inlet quality of effluent. For sewage treatment generally biological process is adopted as it is congenital, cheap, and effective to meet prescribed standards. In general many treatment processes have been prescribed in the sewage treatment manuals and textbooks like screen chamber, grit chamber, clarifier, septic tank, Imhoff tank, anaerobic digester, UASB(Upflowing Anaerobic Sewage Blanket), baffled septic tank, anaerobic filter, trickling filter, constructed wetlands, aerobic ponds, horizontal gravel filter, sand filter, carbon filter, chlorination etc. However, from practical considerations we have adopted screening, clarifier cum digester (clari-gester), anaerobic up flow filter, chlorination, Sludge drying beds to get maximum benefit from compact and effective treatment.

Design criteria

This DTS is designed for population of 3000. The rate of sewage flow is considered 120 L/person/day. Inlet water quality is considered as BOD (Biological Oxygen Demand): 420 mg/l and SS (Suspended Solids): 500 mg/L. BOD (Biological Oxygen Demand) load is considered 50 mg/cap/day and SS (Suspended Solid) load is considered 60 g/cap/day including wet garbage.

Total process description

For flexibility of operation and maintenance two units of 180 kl/d capacities are provided, each for 1500 population. The water level in the inlet chamber and the water level in the outlet chamber will be kept at 20 cm difference to allow free fall with no electricity consumption.

Parts of DTS

(i) Screen chamber and V- Notch chamber
(ii) Clari- gester unit(Biogas plant)
(iii) Sludge Drying Beds
(iv) Up flow Anaerobic Filter
(v) Chlorinator and Sump

A screen chamber

The screen chamber is provided to remove floating solid material like paper, wooden straws, plastic wrappers, cloth pieces etc to avoid chocking and damage to the scheme.

V-Notch chamber

V-Notch Chamber is provided for measurement of sewage flow and to take samples of sewage entering the treatment unit.

Clari- gester unit (biogas plant)

As the prescribed process in compact, settling tank and digestion tank will be combined. This is called as Clari- gester (clarifier digester) unit (Figure 1) producing biogas and may be termed as biogas plant (Design of Biogas Plant on Human excreta, 1990). This is expected to remove up to 55% of BOD and about 60% of SS. Thus the Clari- gester Unit will perform 3 function (i) settling of solids, (ii) digestion of selected solid and (iii) storage of digested slurry till such time it is removed from the tank. The per-capita Biogas production is estimated as 0.03 m^3/day. Biogas is normally composed of 60 to 70% methane and 25 to 30% carbon dioxide by volume, with smaller quantities of other gases like H_2S, N_2, H_2, etc

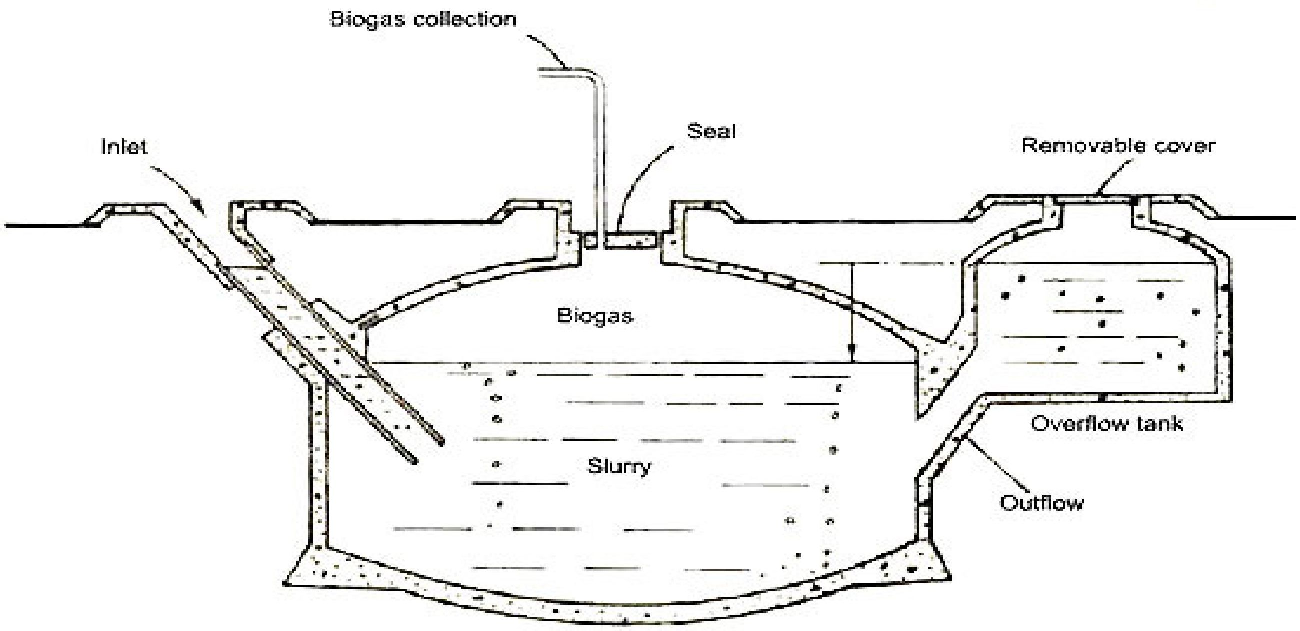

Figure 1. Clari- gester Unit (Biogas Plant).

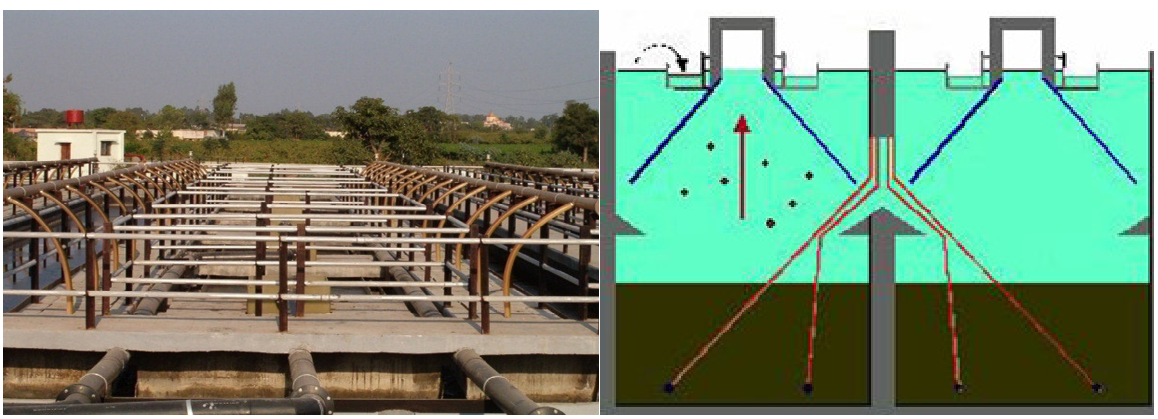

Figure 2. Top and Sectional Views of Up-flow Anaerobic Filter.

(Nadeem et al., 2008). The combustible constituent in the gas is primarily the methane. The fuel value of Biogas is about 4800 Kcal/m^3.

Up-flow anaerobic filter

Up-flow type of Filter (Reverse Filter) operating under submerged condition is a method of further treatment of biogas plant effluent where limited open land is available (Nadeem et.al). The expected removal of BOD (Biological Oxygen Demand) is 70% and SS 50% after this secondary treatment (Figure 2). The resulting effluent is clear and free from odour nuisance. The combined reduction of BOD is expected to above 90% and SS (Suspended Solid) above 80%.

Backwash system of anaerobic filter

The anaerobic filter will require back washing two to four times in a year for removal of excess of slime growth formed in the filtering media. Otherwise the system will get chocked up. For back washing the sluice valve provided on the backwash pipe and inlet pipe will be opened and the sluice valve on of the vertical operating pipeline will be closed. The effluent under this condition will directly flow into sump from the top that will flush out excess slime layers.

Chlorination

The treated water from anaerobic filter will be collected in storage

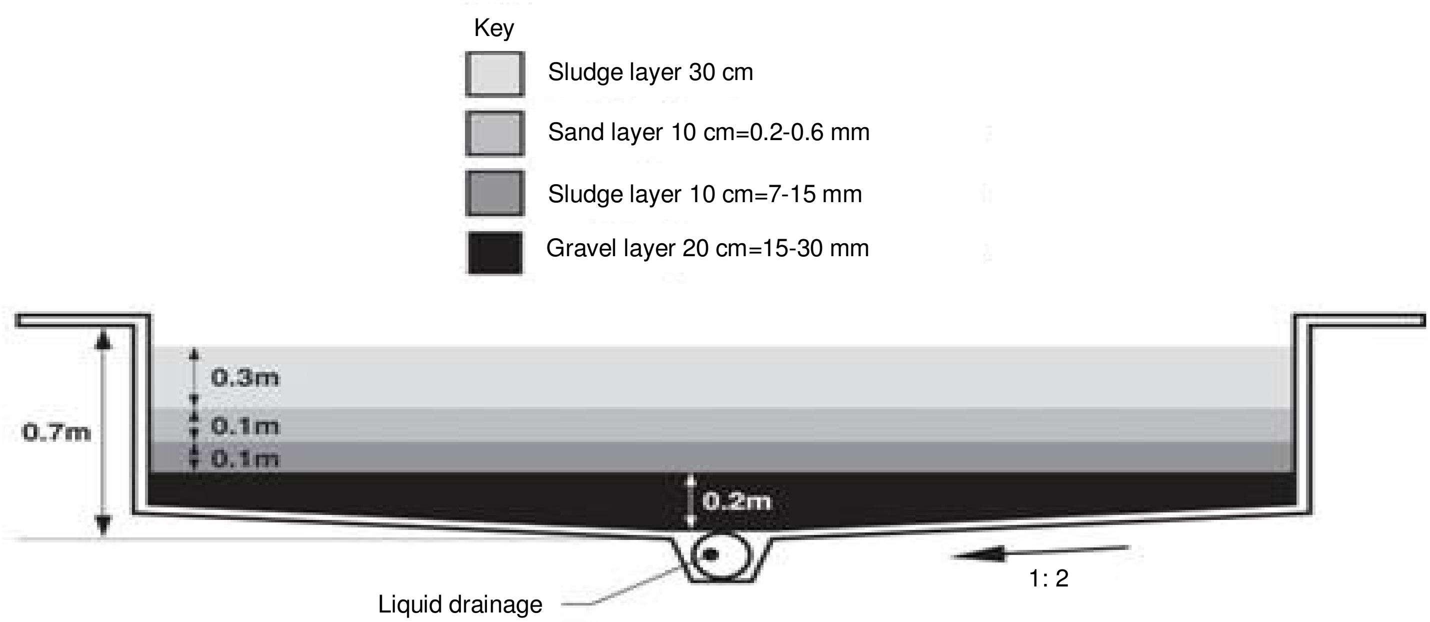

Figure 3. Sludge drying beds.

tank where drip type gravity feed chlorinator of 200 L capacity has been proposed. A dosage of 2 to 5 ppm (mg/L) of chlorine would be sufficient for safe use of treated water (Indian Standard Institution, 1985). A constant discharge chlorinator, having better control on dosage, is a good disinfector.

Sludge drying beds and manure production

The digested sludge which is in the form of slurry having about 90% water content is an innocuous substances, which should be removed at an interval of 15 days keeping as break of 3 months of rainy season. It is having highly drainable properties, can be easily dried on the solar sludge drying beds (Figure 3) producing high grade manure having about 5% nitrogen (as N_2), 3 to 4% phosphorous (as P_2O_5), 1.5% potash (as K_2O). It has high ammonia- nitrogen content which is readily available to plants. It is safe in handling after drying and it can be sold at the rate of Rs. 10/ kg at plant site. The manure contribution will be 4 kg / Person/ Year. So population of 3000 will produce 12000 kg manure per year.

Utilization of treated water

The quality of treated effluent in terms of BOD and SS will be 60 mg/l and 100 mg/L respectively. So it can be directly applied for irrigation purpose as per the guide lines of Central pollution Control Board (CPCB), India as the allowable limits for irrigation, BOD and SS are 100 mg/l and 200 mg/l respectively. Treated effluent can be used for drip irrigation so it can be pumped through high density polyethylene pipes as mains and laterals consisting of LDPE pipes which can be easily punctured so that drippers may be fixed and water is made available directly to the roots. Thus treated effluent can be utilized for growing trees without the touch of human hand (Encyclopedic Dictionary of Environmental change, 2003). Also by using sprinklers, water can be used for irrigating fields, parks and other purposes. Where soil and ground water conditions are favourable for artificial recharge of groundwater through infiltration basins, a high degree of upgrading can be achieved by allowing partially- treated sewage effluent to infiltrate into the soil and move down to the ground water. The unsaturated or "vedose" zone then acts as natural filter and can remove essentially all suspended solids, biodegradable materials, and microorganisms. Significant reductions in nitrogen, phosphorus, and heavy metals concentration can also be achieved.

RESULTS

Area required for sewage treatment of 360 kl/day

Length wise operational units:
Screen chamber 1.50 m + Biogas plant 8 m + up flow filter 6.5 m + sump cum pumping plant 4.5 m + extra place in between 9.5 = 30

Width wise operational units:
Sludge liquor sump 1.5 × 2 = 3 m + Sludge drying bed 5.5 × 2 = 11 m + biogas plant 8 × 2 = 16 + extra place in between 5 = 35 m

Economics of the scheme

Construction cost

The cost estimate is based on current Indian market rates for labor & materials using Uttarakhand PWD schedule of rates for the year 2007 to 2008. Thus the total cost of the sewage treatment works including gas connection network of 1000 m and drip irrigation system network of 7500 m works out to Rs.37.60 Lakhs.

Income estimates

The annually income will be Rs. 7,34,000 form irritation water (3Rs./1000 L of treated water) Rs. 3, 94, 000, From Sludge Cakes (10Rs./Kg) Rs 1, 20,000, from Bio gs (20 Rs. / $3m^3$) Rs 2,20, 000 respectively.

Maintenance expenditures

The annual expenditure on electricity works out to Rs. 60,000. The expenditure on wages of a worker would come to Rs. 40, 000. It may be noted that the system is designed that the operation and maintenance will be easy and could be handled by a single worker after some training. The routine worked that he has to do is lifting the screenings, opening and closing of some Valves, removing and packing of digested sludge, marking bleaching powder solution (for chlorination),etc. The expenditure on bleaching powder and some minor repairs shall come to Rs, 50,000 annually. Thus the total expenditure may not exceed Rs. 1,50,000/per year.

If the life of the project is taken as 20 years, the annuity on loan at 8% annual interest works out to 10% (approx.). If the entire cost of the project is loan; the annual instalment will work out to Rs. 3.76 Lakhs. This amount (maintenance + instalment) can be very well managed out of the income generated from the scheme.

Disposal of kitchen garbage

The problem of biodegradable solid waste can also be solved by this process if some mechanism is followed. The kitchen garbage can disposed of in sewer lines after crushed in to powdery form. The mechanical crushers like in sink erator are available in market. This practice is quite effective in urban areas where solid waste disposal is significant problem. Another benefit from this practice is increase in quantity of biogas and manure which gives direct economic benefit.

Conclusion

Unfortunately, in developing countries adequate attention is still not given on sewage treatment works with the fear that these are too costly. But as per present process design installation cost is just Rs. 1250 per capita including cost of drip irrigation system etc. Thus proposed DTS scheme will greatly serve many hidden intangible benefits than some mentioned tangible benefits. The actual implementation and maintenance of this scheme will give proper idea of process handling and actual benefits. The Central Pollution Control Board (CPCB), India and its state units are now quite keen to implementing DTS. The builders in the town will also obtaining good return out of their investments. So this is the right time when such project should get priority and cooperation from the state/district level administration as well as from privet sector for the implementations.

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