PERFORMANCE EVALUATION OF A THREE COMPARTMENT SEPTIC TANK WITH BIOMEDIA FILTERS

Mohammad J. Mowlaei, Dharma Dharmappa, Muttucumaru Sivakumar

Sustainable Earth Research Centre, School of Civil, Mining & Environmental Engineering, University of Wollongong, NSW, Australia

Abstract

Septic tanks are the most common form of on-site wastewater treatment technology in Australia and with more than 37% of new development utilising on-site wastewater treatment systems (EPA, 2000), it becomes increasingly evident that new technologies are needed to provide more efficient and cost effective solutions to the problem of wastewater treatment for non-urban areas. This paper examines and evaluates the performance of a three-compartment septic tank with biomedia filters. This experiment revealed that the addition of biomedia to the septic tank can improve the effluent quality drastically and can achieve up to 80% removal of BOD_5 and 85% removal of TSS.

Keywords

Biomedia filters, Three-compartment septic tank

1 Introduction

Centralised sewerage and pollution control plants are well suited in urban areas where the population density is high; However low population densities in rural, semi-rural and remote areas make centralised treatment systems economically infeasible. Under these circumstances, on-site wastewater management systems are suitable for residential dwellings as well as public and recreational facilities and commercial establishments.

On-site wastewater treatment systems are designed to be reliable, simple, compact, easy to operate and maintain and are a very low cost alternative for unsewered areas. They provide substantial cost saving over conventional systems by reducing or eliminating the costly sewer network (Newman and Mouritz, 1996). On-site wastewater management plays a significant role in maintaining a hygienic living environment, and protecting aquatic ecosystems and water resources from contamination and degradation (Khalife, 2000).

The objectives of this project were to:

- Investigate the performance of a three-compartment septic tank with biomedia filters
- Evaluate the septic tank's BOD and TSS removal efficiencies
- Determine appropriate design parameters for a three compartment septic tank

2 Experimental Method

A pilot scale three-compartment septic tank was set up at the University of Wollongong's Engineering Education and Innovation Centre at Coniston. Sedimentation of solids occurs in the first compartment, where they are gradually decomposed by bacteria. The second compartment is equipped with biomedia filter Accupac CF-1200, where anaerobic digestion takes place. In the third compartment aerobic treatment of wastewater occurs by using Biosphere media.

The pilot tank was made from 6 mm thick clear perspex of size 1000 mm (length), 500 mm (width) and 800 mm (depth). The first compartment receives primary settled wastewater collected from Wollongong Sewage Treatment Plant (WSTP). Wastewater flows upward into the second compartment through the Accupac CF-1200 anaerobic filter media, overflows to the third compartment and passes through the Biosphere aerobic filter media. The final effluent is collected at the bottom of the third compartment through a collection tap. Wastewater samples were collected twice weekly (Tuesdays and Fridays) from each compartment (see Figure 1). The dimensions of the septic tank are given in Table 1 and characteristics of the media, Accupac and Biosphere, in Table 2.

Figure 1: Schematic of the Three-Compartment Septic Tank

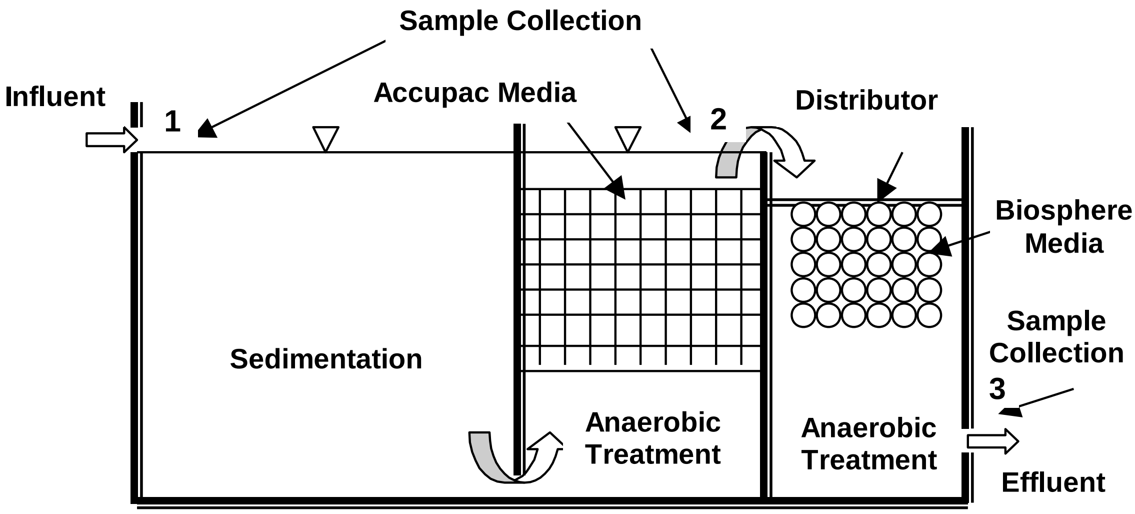

Table 1: Pilot tank dimensions, liquid volumes and flow rates

Dimensions	Pilot tank	Compartment		
		1st	2nd	3rd
Length (mm)	1000	550	250	200
Width (mm)	500	500	500	500
Depth (mm)	800	800	800	800
Depth of liquid (mm)	710	710	710	-
Volume of liquid (L)	284	195	89	-
Flow rate (mL/min)	150	150	150	150
HRT (hrs)	31.4	21.6	9.8	-

Table 2: Characteristics of Media used in the 2nd and 3rd Compartment of Pilot Tank

Parameter	Accupac CF-1200	Biosphere
Packing size (mm)	250x500x300	200x500x600
Packing size (mm)	250x500x300	200x500x600
Unit size of media (mm)	1830x300x300	34 (diameter)
Weight	185 kg/m^3	5.8-6.8 g/ball
Specific surface area (m^2/m^3)	226	1160-1260
Quantity (per m^3)	-	30,000
Void space (%)	95	93-96
Cost (AUD/m^3)	500	4000

3 Results And Discussion

Samples were analysed over five months for six wastewater quality parameters, temperature, dissolved oxygen (DO), pH, turbidity, suspended solids (TSS) and biochemical oxygen demand (BOD_5). Table 3 shows the variation in influent and effluent wastewater parameters with their minimum, maximum and average values during the sampling period. The results obtained compared with the performance data obtained for conventional septic tank systems by Khalife (2000). The primary difference was the efficiency of organic matter removal.

Table 3: Influent- Effluent Wastewater Quality Parameters

Parameter	Present Study						Khalife, 2000	
	Influent			Effluent			Influent	Effluent
	Min.	Max.	Aver.	Min.	Max.	Aver.	Max.	Aver.
Temperature (°C)	14	22	18	13	19	16	22	22
DO (mg/L)	0.3	0.9	0.6	1.0	3.0	2.0	1.1	4.0
pH	6.0	9.0	7.5	6.5	7.5	7.0	7.3	7.4
Turbidity (NTU)	22	64	43	10	30	20	54	12
SS (mg/L)	64	262	163	23	75	49	289	42
BOD5 (mg/L)	80	196	138	28	66	47	324	185

Variations of individual wastewater quality parameters of the influent, 2nd compartment and effluent are discussed in the following section.

3.1 Dissolved oxygen (DO)

Comparing the average influent DO (0.6 mg/L) with the average effluent DO (2 mg/L) indicates that aerobic activity had taken place in the septic tank particularly in the 3rd compartment. Figure 3 indicates that the DO of effluent improved towards the end of the sampling period, due to better distribution of wastewater over the biosphere in the 3rd compartment. The variations in the influent, 2nd compartment and effluent DO are shown in Figure 3 and the aerobic and anaerobic treatment fluctuations are clearly shown on the graph.

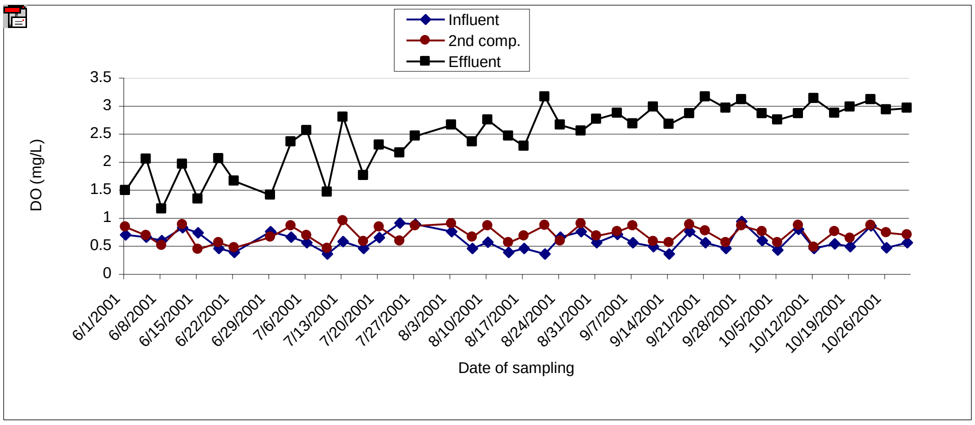

Figure 3: Influent, 2nd compartment and effluent DO variations

3.2 pH

The pH of the effluent wastewater varied between 6.5 and 7.5 for the duration of sampling. This is an indication of optimal performance, since a pH of 7 is the optimum condition for biological activities (Peavy et al., 1985). Figure 4 indicates that the aerobic filter in the 3rd compartment contributed more to the reduction of acidity than did the anaerobic filter in the 2nd compartment. The pH variations of influent, 2nd compartment and effluent are shown in Figure 4.

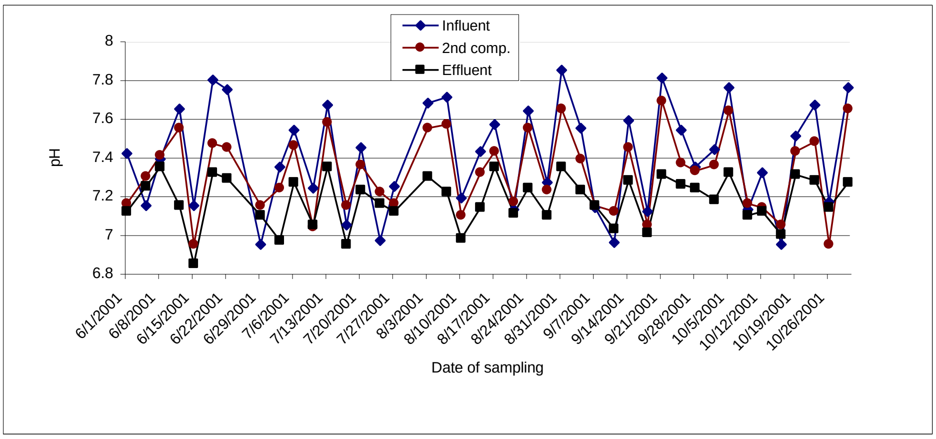

Figure 4: Influent, 2nd compartment and effluent pH variations

3.3 Turbidity

The turbidity variation of influent wastewater varied between 22 to 64 NTU. Comparing the average influent turbidity of 43 NTU with the average turbidity of 30 NTU in the 2nd compartment indicates that the anaerobic filter contributes to turbidity reduction. The turbidity of the effluent wastewater varied from 10 to 30 NTU, which indicates up to 72% removal efficiency. The average effluent turbidity of 20 NTU indicates that the colloidal matters were reduced significantly due to the treatment of wastewater by Accupac trickling filter in the 2nd compartment and by biosphere media as an aerobic filter in the 3rd compartment. The turbidity variations of influent, 2nd compartment and effluent are illustrated in Figure 5, and the turbidity removal efficiencies summarised in Table 4.

Table 4: Turbidity removal efficiencies

Compartments	Turbidity removal efficiency (%)			(Khalife, 2000)
	Minimum	Maximm	Average	Average Removal (%)
1st to 2nd Compartment	13	41	27	23
2nd to 3rd Compartment	15	55	35	50
Overall	28	72	50	63

Table 4 indicates that the turbidity removal efficiencies have been improved from the 1st compartment to the 3rd compartment. The 1st compartment acts as a sedimentation tank to reduce the suspended materials in the wastewater and the 2nd as an anaerobic treatment basin to remove the colloidal matters. The average removal efficiency between the 1st and 2nd compartments was 27%. The average removal of 35% between the 2nd and 3rd compartment is an indication of better performance by biosphere aerobic filter. The dynamic variation of turbidity removal efficiencies of septic tank is shown in Figure 6. The comparison of the turbidity results with experiment undertaken by Khalife (2000) in Aboriginal community of Pipalyatjara in South Australia, revealed that a better turbidity removal was achieved by Khalife's experiment. This can be attributed to the nature of wastewater used in this two experiments. In the present study the wastewater was collected from Wollongong sewage treatment plant which is the mixture of domestic and industrial wastewater, since in Khalife's study the pilot tank was fed only by domestic wastewater.

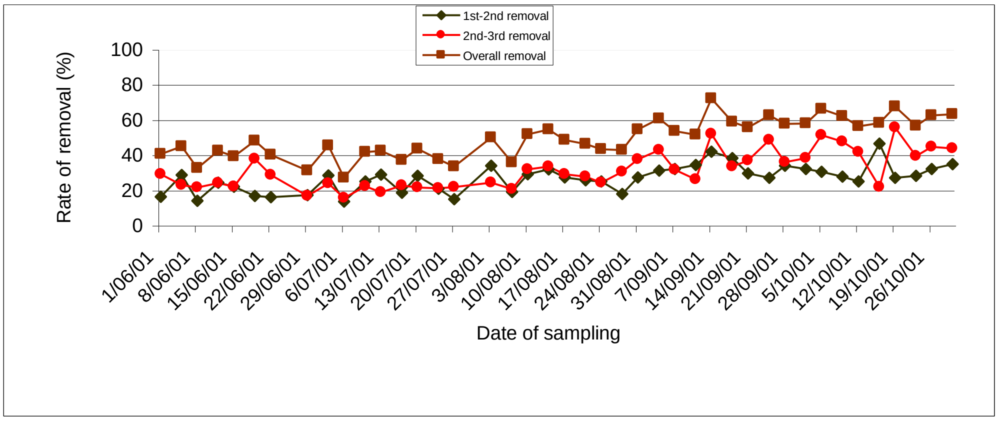

Figure 5: Influent, 2nd compartment and effluent Turbidity variations

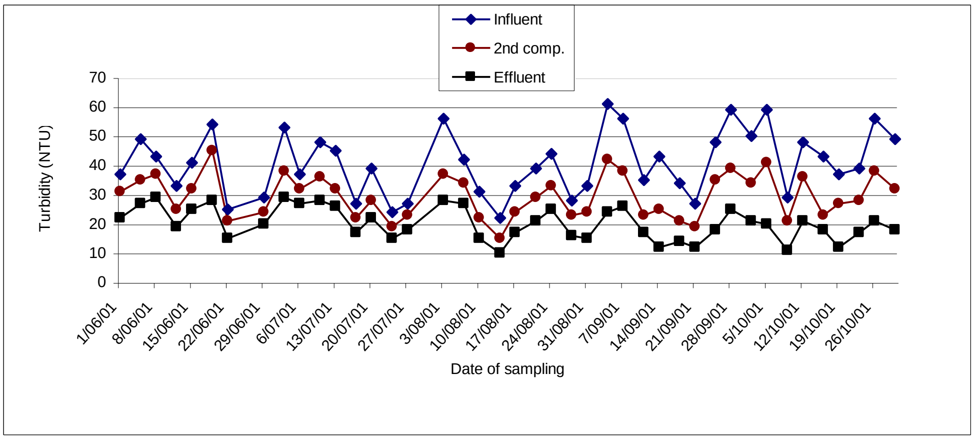

Figure 6: Turbidity removal efficiencies

3.4 Suspended solids

The variations of effluent TSS were recorded between 23 to 75 mg/L with the average of 49 mg/L. The comparison of influent and effluent TSS values indicates the occurrence of a high TSS removal efficiency in the septic tank. This can be attributed to the proper distribution of wastewater over biosphere. The overall TSS removal efficiency improved from 60% to about 85% by replacing the old distributor with the new one. The TSS variation of influent, 2nd compartment and effluent are illustrated in Figure 7. Table 5 demonstrates the minimum, maximum and the average value of TSS removal efficiencies achieved by the septic tank system during the sampling period.

Table 5: Suspended solids removal efficiencies

Compartments	TSS removal efficiency (%)			(Khalife, 2000)
	Minimum	Maximm	Average	Average Removal
1st to 2nd Compartment	28	77	52	-2 %
2nd to 3rd Compartment	11	66	38	40 %
Overall	54	85	69	71 %

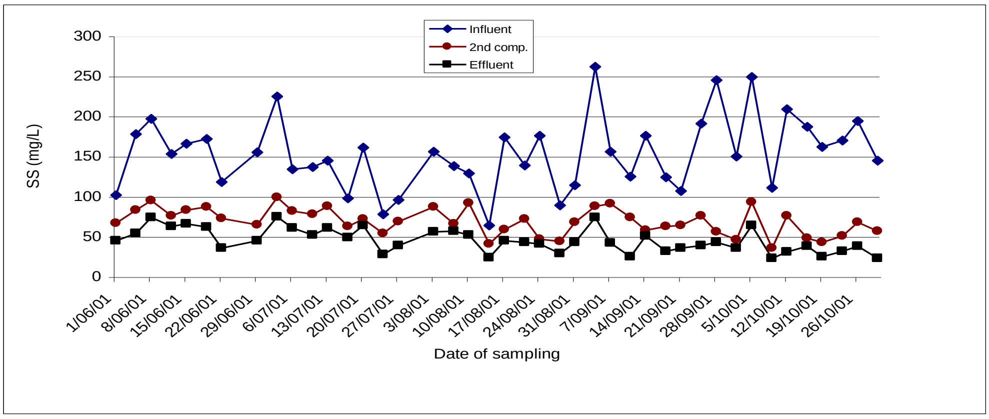

Figure 7: Influent, 2nd compartment and effluent TSS variations

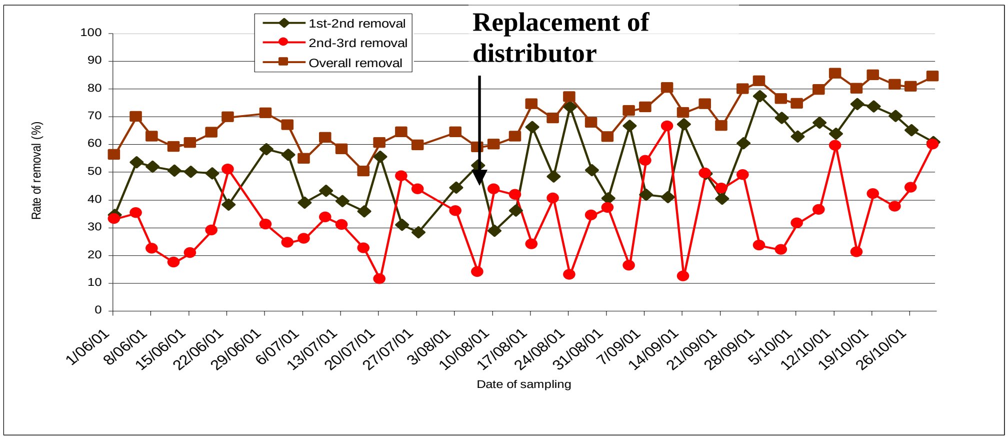

Figure 8: SS Removal Efficiencies

Table 5 indicates that the TSS removal efficiency between the 1st and 2nd compartment of 52% was higher than the removal efficiency between 2nd and 3rd compartment of 38%. This was due to the settling of large amount of solids in the 1st compartment and possible removal of suspended and colloidal matters by anaerobic filter in the 2nd compartment. Figure 8 indicates a removal rate of 60% for the first 2 months, then increasing to 70% in 3rd month and reaching up to 85% in the last 2 months of operation. Comparison of the present study results with Khalife (2000) revealed that the anaerobic filter in Khalife's study did not contribute to TSS removal significantly. The Khalife's result of –2 mg/L was due to solid carryover from anaerobic media caused by sloughing of the biofilm from the deposited slime layers on the media walls while in the present study the TSS removal in the first compartment was significantly higher due to longer detention time. However the results of TSS removal by aerobic filter are very similar for both experiments.

3.5 Biochemical oxygen demand (BOD_5)

The influent BOD_5 varied between 80 and 196 mg/L, with the average concentration of 138 mg/L. The anaerobic filter did not contribute significantly to the reduction of BOD_5, with average BOD_5 in the 2nd compartment of 95 mg/L and the influent average of 138 mg/L. The average effluent BOD_5 concentration of 47mg/L compared to the average influent BOD_5 concentration of 138 mg/L reveals a significant improvement in BOD_5 removal efficiency by using the three-compartment septic tank. The BOD_5 variations of influent, 2nd compartment and effluent are shown in Figure 9 and the performance of the septic tank in term of BOD_5 removal is summarised in Table 6.

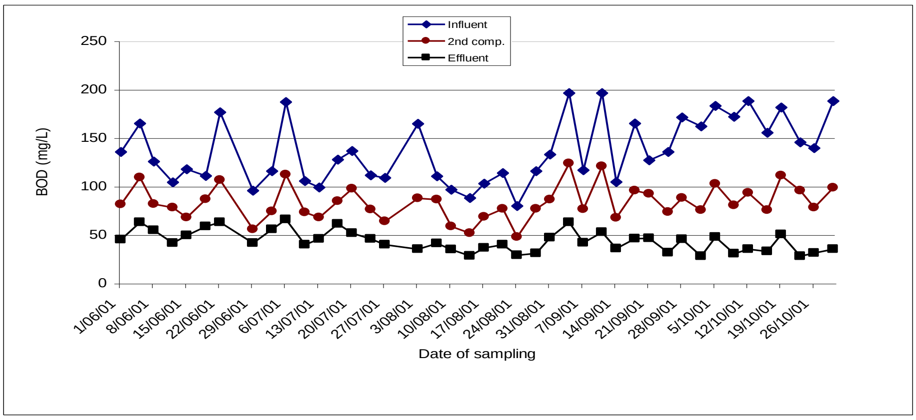

Figure 9: Influent, 2nd compartment and effluent BOD variations

Table 6: Biochemical oxygen demand removal efficiencies

Compartments	BOD_5 removal efficiency (%)			Khalife, 2000
	Minimum	Maximum	Average	Average Removal
1st to 2nd Compartment	21	53	37	8 %
2nd to 3rd Compartment	24	70	47	16 %
Overall	46	82	64	29 %

Table 6 indicates that the average BOD_5 removal of 64% is reasonably high for a septic tank system with 600 mm depth of biosphere. The results may have been better if the poor performance over the first two months was rejected. The minimum BOD_5 removal of 46% occurred in the first month of operation. Figure 10 illustrates the BOD_5 removal efficiency variations in the septic tank system during the five months sampling period. The overall BOD_5 removal of the present study (64%) was considerably higher than that of Khalife's study of 29% (Khalife 2000). This was due to the better distribution of wastewater over the aerobic filter in the 3rd compartment, and better removal rate in the second compartment. The BOD_5 removal of anaerobic filter in Khalife's study was very poor and it could be attributed to improper acclimatisation caused by frequent pump out operations and organic carryover. The performance of the aerobic filter in Khalife's study was also unsatisfactory due to the solid carryover from the second compartment and the clogging of distributor.

Table 7: Design parameters for designing a three-compartment septic tank

Design Parameters	Present Study	Khalife, 2000
For whole tank		
Hydraulic loading rate (m^3/m^3.d)	0.76	1.01
Surface loading rate (m^3/m^2.d)	$2.7x10^{-3}$	$3.6x10^{-3}$
Organic loading rate (kgBOD/m^3.d).	0.103	0.328
For 3rd compartment		
Surface loading rate (m^3/m^2.d)	3.1×10^{-3}	$4.01x10^{-3}$
Organic surface loading rate (kgBOD/m^2.d).	0.229×10^{-3}	$1.34x10^{-3}$
BOD removal per unit surface area (kg/m^2.d)	0.146×10^{-3}	$0.575x10^{-3}$

4 Design Parameters

Table 7 indicates the six important parameters for designing a three-compartment septic tank. The hydraulic loading is expressed as volume of wastewater per unit volume per day (m^3/m^3.d). The surface loading rate is the volume of wastewater per unit area of filter per day

(m^3/m^2.d). The organic loading rate is the weight of BOD per unit volume per day (kg BOD/m^3.d). The organic surface loading rate is referred to as weight of BOD per unit area of filter per day (kgBOD/m^2.d) and the BOD removal per unit surface area is the amount of BOD removed by biosphere in the 3rd compartment.

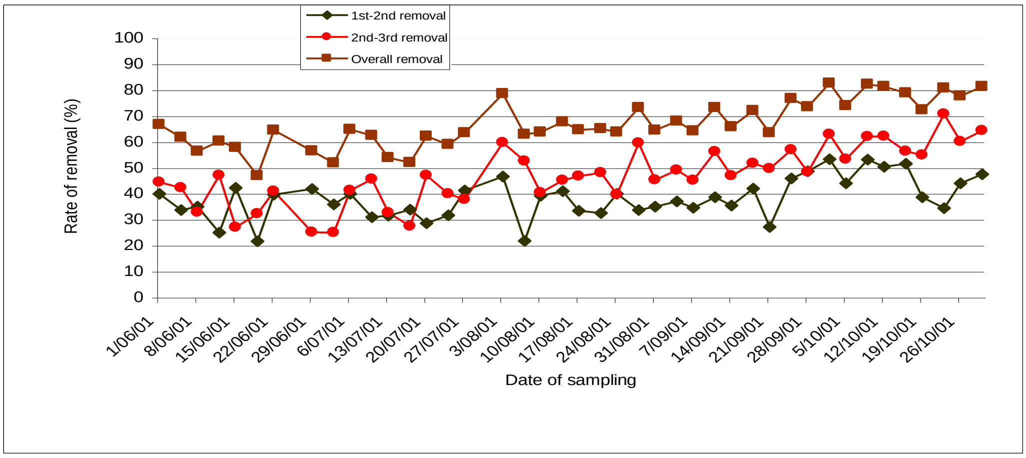

Figure 10: BOD removal efficiencies

5 Conclusion

A detailed experimental investigation has revealed that biomedia can be an excellent choice for on-site wastewater treatment systems because of their high specific surface area, high void space and lightweight and the ability to improve the quality of effluent drastically.

An influent temperature between 15-22°C was unlikely to enhance bacterial growth within the pilot tank system. The pH of effluent was within the typical range of 6-8 and there was no indication of acidity or alkalinity. Significant increase in DO concentrations in the final effluent indicated that aerobic biological activities had taken place, particularly in the third compartment. Consist and accurate experimental results confirm that wastewater distribution rather than the filter depth determines the performance of aerobic biomedia. This investigation proved that improved wetting efficiency of biosphere through an efficient distribution system can be vital to the overall performance of trickling filters.

The anaerobic and aerobic filters used in this experiment perform and can reach removal efficiencies of 80% BOD_5 and 85% TSS. The theoretical and experimental investigations of the performance of 3-compartment septic tank reveal that better design is needed to improve the effluent quality and reduce the potential of disposal area clogging. With some design modifications, septic tanks will remain the most favourable, low cost technology available for the safe treatment and disposal of wastewater in remote areas.

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