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Performance Evaluation of a Septic System for High Water-Table Areas

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Abstract: The performance of a septic system specifically designed for high water-table and inundating areas was evaluated. Three replicates of the system were developed and sited at an area whose soil is characterized by a seasonal high water-table and monitored for a period of 15 months. Samples (effluent) for physicochemical (BOD_5, TSS, pH) and microbiological (FC) analysis were collected monthly and average into an interval of 3months for the period of study. These parameters were determined using standard procedures. Experimental results showed that this innovative septic was able to reduce the concentrations of BOD, TSS, pH and FC to desirable values that fall within limits of both national and international effluent standards before disposal into streams and inland waters. A Kruskal-Wallis H-test (ANOVA by rank) showed no significant difference ($P>0.05$) in the means of all samples investigated in the various locations. This new septic system is more effective efficient, durable and environmentally friendly. It is therefore recommended for adoption in such terrains to control groundwater pollution.

Key words: Septic system · pollution · performance · water-table · soil · filter · cost

INTRODUCTION

A septic system is an enclosed receptacle designed to collect wastewater, segregate settleable and floatable solids, accumulate and digest organic matter and discharge partially treated effluent. The most widely accepted type is the gravity fed (made of sandcrete block) used by over 46% of the people in Nigeria [1]. This consist of a septic tank were approximately 54% of the ultimate sewage treatment is accomplished [2, 3]. According to Burubai, effluent from septic tanks is as dangerous as raw sewage as it contains effluent concentrations higher than both locally and internationally acceptable limits. The dominant bacterial groups measured in septic tanks by Ziebell *et al*. [4], were total and feacal coliforms, streptococci, anaerobes and others. Van and Pur [5] and Bicki [6], assert that there is a direct relationship between feacal pollution and disease and the use of poor water quality supplies. They further claimed that ingestion of these polluted waters on a constant basis enhances the proliferation of water borne diseases. Therefore, the effluent from septic tank is further directed to a soak away pit before disposal. This final treatment and disposal of domestic wastewater is historically done in the soil which serves as a universal filter. Hempton and Jones [7] estimated that 40% of the soils in Africa and the United States have characteristics that limit their use for on-site treatment and disposal of domestic wastewater.

In Nigeria, many soils in the coastal plains are characterized by their hydraulically restrictive layers and seasonally high water-table levels [8]. The seasonal high water-table conditions restrict the use of conventional septic systems. Effluents from septic systems in these areas contaminate ground and surface water because percolation is impossible since the soil is saturated leading to in-filtration and ex-filtration processes in the septic tank [8]. Under this condition, soil depth which would have served as a universal filter becomes a limiting factor in the treatment process. It is therefore the objective of this paper to evaluate the performance of a septic system designed specifically for high water-table and inundating areas.

MATERIALS AND METHODS

Description of septic system: Figures 1a and 1b are the orthographic and sectional views of the septic system respectively. The septic system is a multi-chambered water-tight vault which provides the first and most important pretreatment in the typical small scale onsite wastewater treatment process. It has a sand filter unit

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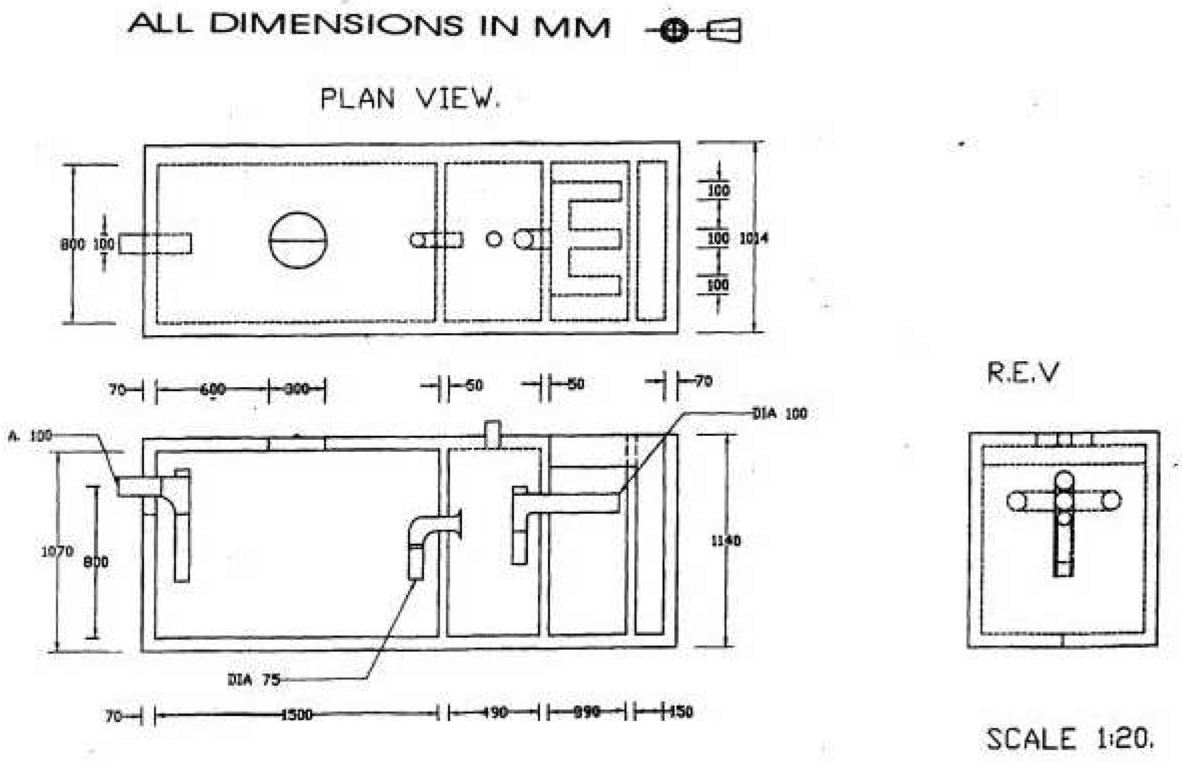

Fig. 1a: Orthographic views of the septic system

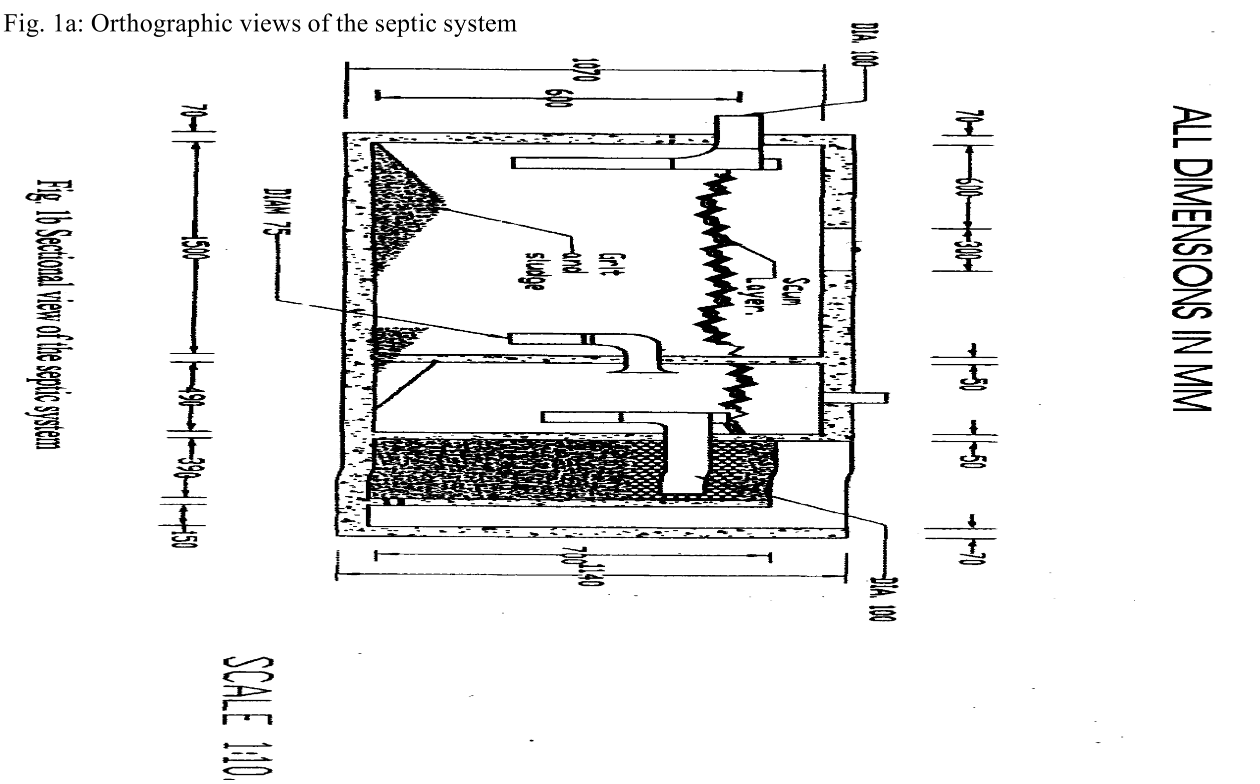

Fig. 1b: Sectional view of the septic system

attached to it which makes it unique from others. The septic tank has dimensions 2040mm X 1000mm X 1020mm representing length, depth and width respectively. The sand filter unit has a volume of $0.6m^3$ at a depth of 0.7m. Three replicates of same design were developed and sited at the Agip area of Port Harcourt, Nigeria. The soils in this area are characterized by a seasonal high water-table that sometimes rises to a level less than 100mm below the surface. As the wastewater from a home of four (4) people enters each of the tanks through the inlet T-shaped PVC pipes, the velocity of flow is reduced providing relatively quiescent conditions, which allows portions of the suspended solids to settle to the bottom, permitting grease and other floatables to rise to the surface and are retained. The partially treated wastewater flow through the overflow elbow pipe into the second compartment where further physical and biological processes occurs. The effluent outlet connects the septic tank to the absorption field which is composed of perforated drain pipes covered with graded sand and gravel as to permit unobstructed passage of water by gravity. The secondary effluent from the absorption field drains by gravity through a horizontal screened outlet close to the bottom of the partition. The filtration process is aerobic at the first layer and anaerobic at the saturated zones of the bottom layers, making it mainly a facultative process. The entire structure is made of 1:1.9:1.9 (cement, sand and gravel) nominal concrete mix. However, to ensure water-tightness of the tank, a hydrostatic test recommended by ASTM-CI224 [9] was adopted by allowing the tank to stand unloaded for 24hours and infiltration was observed.

Physicochemical and microbiological analysis: Samples (effluent from sand filter) for physicochemical and microbiological analysis were collected monthly and averaged into an interval of 3 months for a period of 15 months (January, 2004 -June, 2006). Physicochemical parameters analyzed includes, Biochemical Oxygen Demand (BOD_5) which determines the strength of wastewater, suspended solids (TSS) and pH while Feacal Coliform (FC) was analyzed as microbiological parameters. Samples for microbiological analysis were aseptically collected in 25ml sterile bottles and corked. The samples for BOD were collected in 150ml bottles. A set of these samples were fixed with Winkler I and II reagents at the site and the other wrapped with aluminium foil. The samples were transported in an ice chest to the institute of pollution studies Research Laboratory, University of Science and Technology, Port Harcourt. BOD_5 samples were fixed by the Winklers method after five days incubation at room temperature in the absence of light.

The analytical methods/instruments employed were as described by APHA [10] except TSS which was analysed as described by ASTM [9].

Statistical data analysis: A Kruskal-Wallis test which is a single factor analysis of variance (ANOVA) by ranks was conducted for the BOD, TSS, FC and pH to determine the significant difference of the effluent concentration of these septic systems in the three different locations.
The Kruskal-Wallis test statistics, H, is calculated as:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{ni} - 3(N+1)$$

Where,
n = number of observations in a sample (groupi)
N = ∑ ni (total number of observations in all i =1
R = sum of ranks of ni observations in groupi

RESULTS AND DISCUSSION

The results of the analysis showing levels of physicochemical and microbiological parameters for effluents from the septic systems at locations A, B and C collected monthly and averaged into 3months for a period of 15 months are shown in Table 1, 2, 3 and 4 respectively.

Table 1 shows that the BOD investigated in all three sites fell above the desirable limits (4 $mg1^{-1}$) as prescribed by WHO [11] for the first six (6) months of experimentation. But from the 9th to 12th month result fell within desirable limits; however, a slight rise above the recommended value was obtained from the 15th month indicating a sand filter life span of 12months. This life span compares favourably with that of Seabloom [12]. The results of Kruskal-Wallis test (ANOVA) showed that there was no significant difference (P>0.05) between the means of the various locations.

Table 2 indicates that the TSS ($mg1^{-1}$) values obtained from the third month fell below the desirable limits (30-40 mg l^{-1}) by both national and international (FEPA/WHO) standards for discharge into inland waters, streams and drinking water sources. However results obtained in the first 3months were above the recommended limit. This may not be unconnected with the formation of a biomat. This notwithstanding filter clogging was observed in the 15th month. The mean TSS (mg l^{-1}) values range between 95.6-8.3mg $l^{-1}$for all samples investigated in the three locations. The Kruskal-Wallis

Table 1: Mean BOD (mg L^{-1}) concentrations of filtered affluent from the three locations. Ranks are in parenthesis

Location A	Location B	Location C
63.1$^{(15)}$	59.4$^{(13)}$	60.6$^{(14)}$
32.1$^{(11)}$	35.1$^{(12)}$	30.8$^{(10)}$
40.0$^{(6)}$	3.9$^{(5)}$	3.8$^{(4)}$
2.4$^{(1)}$	2.8$^{(2)}$	3.0$^{(3)}$
7.5$^{(8)}$	7.1$^{(7)}$	8.1$^{(9)}$
$n_1 = 5$	$n_2 = 5$	$n_3 = 5$
$R_1 = 41$	$R_2 = 39$	$R_3 = 40$
N = 5+5+5 = 15		

Table 2: Mean TSS (mg L^{-1}) concentrations of filtered effluents from the three locations. Ranks are in parenthesis

Location A	Location B	Location C
93.5$^{(14)}$	88.2$^{(13)}$	95.6$^{(15)}$
37.2$^{(11)}$	40.6$^{(12)}$	33.8$^{(10)}$
18.9$^{(6)}$	21.4$^{(7)}$	23.5$^{(8)}$
10.9$^{(3)}$	12.3$^{(4)}$	9.8$^{(2)}$
28.9$^{(9)}$	16.51$^{(5)}$	8.3$^{(1)}$
$n_1 = 5$	$n_2 = 5$	$n_3 = 5$
$R_1 = 43$	$R_2 = 41$	$R_3 = 36$
N = 15		

Table 3: Mean FC (cfu ml^{-1}) of filtered effluent from the three locations. Ranks are in parenthesis

Location A	Location B	Location C
210.4$^{(15)}$	150.3$^{(13)}$	180.9$^{(14)}$
101.7$^{(11)}$	122.6$^{(12)}$	99.1$^{(10)}$
43.2$^{(9)}$	31.8$^{(7)}$	40.5$^{(8)}$
13.2$^{(5}$	10.9 $^{(3)}$	18.0$^{(6)}$
10.3$^{(2)}$	9.5$^{(1)}$	11.9$^{(4)}$
$n_1 = 5$	$n_2 = 5$	$n_3 = 5$
$R_1 = 42$	$R_2 = 36$	$R_3 = 42$
N = 15		

Table 4: Mean pH values of filtered effluent from the three locations. Ranks in parenthesis

Location A	Location B	Location C
8.5.4$^{(14)}$	8.7$^{(15)}$	8.0$^{(9)}$
8.2$^{(11)}$	8.3$^{(12)}$	8.4$^{(13)}$
7.6$^{(8)}$	7.2$^{(5)}$	6.9$^{(3)}$
7.8$^{(8)}$	8.1 $^{(10)}$	7.3$^{(6)}$
6.6$^{(2)}$	7.0$^{(4)}$	6.5$^{(1)}$
$n_1 = 5$	$n_2 = 5$	$n_3 = 5$
$R_1 = 42$	$R_2 = 46$	$R_3 = 32$
N = 15		

test (Anova by ranks) showed no statistically significant difference (P>0.05) between the means of the various sample locations.

Results of bacteriological analysis of the effluents in Table 3 showed high concentrations of feacal coliforms. It reveals a maximum value of 210 (cfu ml^{-1}) and a minimum value of 9.5 Cfu mL^{-1}. These values are quite close to that reported by Seabloom [12] for a sand filter designed for water purification. Feacal counts were exceptionally higher than the FEPA standards (<100/100mL) in the first 3months of experimentation, probably due to slow rate of biomat formation. However, appreciable results which were far below the recommended were obtained from the 4-5th months. The ANOVA did not reveal any significant difference (p>0.05) between the means of the various locations sampled.

The pH values of the various samples investigated range between 6.5 to 8.7. Results in the first 12 months were alkaline but slightly changed to the acidic region in the last 3 months. This notwithstanding all results obtained fell within national and international standard, FEPA/WHO (6.0-8.5). Statistical analysis (ANOVA) indicates no significant difference (P>0.05) between means of the various locations sampled.

CONCLUSION AND RECOMMENDATION

The performance evaluation of a septic system designed specifically for high water-table and inundating area was investigated. Three replicates of same design were developed and sited at the Agip area of Port-Harcourt, Nigeria. The soils in this area are characterized by a seasonal high water-table. Samples (effluents) were collected monthly and averaged into 3months interval for a period of 15 months. These samples were analysed for a range of parameters which include: Biochemical Oxygen Demand (BOD_5), Total Suspended Solids (TSS), pH and Feacal Coliforms (FC). These parameters were determined following standard procedures [10].

Results obtained show that effluent quality of this novel Septic System fall within both national and international standards before disposal into stream and inland waters. The construction cost of this septic system is sixty seven thousand naira (N67,000.00) as against the twenty nine thousand naira (N29,000.00) for the construction of the conventional type of same capacity. But the new septic system is more effective, efficient, durable and environmentally friendly. Therefore, the objectives of this research work were obtained.

RECOMMENDATIONS

Based upon the results, it is recommended that:

- This novel septic system adopted by individuals living in high water-table areas as a means of both groundwater and surface waters pollution abatement.
- It should be adopted as a means of recycling the finite water resources when further treated.
- The effluent can be used to irrigate crops and
- Further studies be carried out to optimize the system.

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