An Evaluation of Septic Tank Performance in Bayelsa State, Nigeria

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ABSTRACT

Standard procedures were applied in the comparative evaluation of the performance of septic tanks receiving three types of domestic waste water in Bayelsa State: namely, (a) toilet waste waters only (arrangement 1), (b) toilet and kitchen wastewater (Arrangement 2) (c) toilet, kitchen and bathroom wastewater (arrangement 3),with a view to improving the design of septic tanks in the State. Influent wastewater quality was tested by collecting samples at the inlet point of the septic tanks and effluent samples collected at the inlet point of the soakage pits. These samples were analysed for a range of parameters including suspended solids, (SS), total organic carbon (TOC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate (NO_3) phosphate (PO_4) and faecal coliforms (FC). Results show that septic tank effluent quality varies significantly with the composition of domestic sewage. Effluent quality from septic tanks treating toilet wastewater only was found to be poor. With the addition of kitchen and bathroom wastewaters, the effluent quality with respect to BOD, COD, TOC and SS improved significantly. Removal efficiencies of FC, NO_3 and PO_4 however decreased with the addition of kitchen and bathroom wastewaters primarily due to reduction in detention time. Results also reveals that kitchen wastewater must be treated before disposal into open drains or water bodies as it contains high $BOD_{5,}$ COD, TOC and SS concentrations. Therefore, the following recommendations are made for the design of septic tanks for domestic wastewater; (i) toilet and kitchen wastewater with 3 day detention time (ii) all purpose septic tanks with one day detention time (iii) toilet only septic tank with five day detention time be use in this area.

Keywords: Septic tanks, design, performance, effluent quality, detention time.

1. INTRODUCTION

In Bayelsa State, sanitation technologies are largely limited to onsite options and do not involve the conventional sewage technology, primarily because of its high initial costs. The most widely accepted and common types of individual sewage disposal system consist of a septic tank and an absorption field (Bound, 1994; Jowett, 1997; Waller, 1994). In the absence of sewers, feacal inputs into the river system and septic systems are considered to be the most convenient methods of waste disposal in the state. The septic systems are installed in large numbers in Yenagoa, the capital city and local government headquarters throughout the state (Burubai, 2004).

The main purpose of septic tank is to receive household wastewater, segregate settleable and floatable solids (sludge and scum), accumulate, consolidate and store solids, digest organic matter and discharge partially treated effluent for disposal by other means (Venhuizen, 1998; Piluk, 1994; AS/NZS, 2000; NCDENR, 1999). In Bayelsa State, standardized design practice is not followed for septic tanks and individuals and the government have their own design specifications primarily based on quantity and cost considerations. The design volume of a septic tank is usually based on the liquid retention period and the desludging interval, which usually varies from three to five years (Seablom, 2003; Oldrieve, 2000; Tyler, 1994). In the current design practice, the quality of influent wastewater and effluent which may significantly affect the ultimate disposal system are also not given any consideration. In Bayelsa State, the usual practice is to connect only the toilet waste water line to the septic tank. However, in some cases kitchen and bathroom waste water lines are also connected to septic tanks along with the toilet lines. The effluent quality of a septic tank is expected to vary significantly with various combinations of influent sources.

The ultimate disposal of effluent from septic tanks is being influenced by the effluent quality. In most cases, septic tank effluents are directly discharged into open water bodies, drains and ditches. Septic tanks which are connected to soakage pits often over flow. Soakage pits receiving septic tank effluent are either under-designed or the pits face the problem of early clogging apparently due to poor effluent quality.

It is therefore the objective of this study to evaluate the effluent quality of septic tanks receiving domestic waste water under three different arrangements such as (a)toilet waste water only,(b)toilet and kitchen waste water, and (c)toilet,kitchen and bathroom waste waters.

2. MATERIALS AND METHODS

In this study, effluent quality and performance of three septic tanks were evaluated under three different arrangements of domestic wastewater connection to the tank, Viz; septic tank receiving (a) toilet wastewater only (arrangement 1), (b) toilet and kitchen wastewater (Arrangement 2), (c) toilet, kitchen and bathroom (Arrangement 3). Three test sites located in the Yenagoa metropolis were selected. These sites represents typical residential areas with individual septic tanks (one for each building) and soakage pits. These systems overflow and requires frequent cleaning. The selected test sites are (i) Opolo Housing Estate (site 1), (ii) Azikoro Housing Estate (site 2), and (iii) Civil Servants Quarters (site 3). Information on wastewater generation rates at the three sites are provided in table 1. All the three selected septic tanks are single compartments where inlet and outlet pipes are "T" shaped and of 100mm diameter. The tanks are made of sandcrete walls with concrete floor and reinforced concrete top. The sides of the soakage wells are sandcrete walled up to 240mm depth. The top of the pit is covered with concrete slab without any opening.

At all the test sites, only toilet wastewater lines were connected to the septic tank (i.e Arrangement 1). Before starting the experiment all the septic tanks were cleaned and test (under Arrangement 1) started three weeks after cleaning. For test under arrangement 2, kitchen wastewater lines were connected to the septic tanks using PVC pipes and were allowed to remain in this condition for three weeks for attainment of equilibrium conditions before testing began. The same procedure was followed for testing under Arrangement 3. It is worth nothing that in this study existing septic tank systems were utilized and as a result inflow and outflow rates and hence detention time of wastewater in the septic tank could not be kept the same for different combinations of wastewater. For instance, flow rates were significantly higher under Arrangement 2 and 3 compared to arrangement 1 and as a result, detention time under Arrangement 2 and 3 were much shorter. This obviously had marked influence on the efficiency of the septic tanks.

Effluent samples were collected at the inlet point of the soakage pits. Influent wastewater quality was tested by collecting samples at the inlet point of the septic tanks. Influent and effluent samples were tested for a range of parameters including suspended solids (SS), total organic carbon (TOC), Biochemical oxygen demand (BOD), chemical oxygen demand (COD), Nitrate(NO_3), Phosphate (PO_4), and facial coliforms (FC). Nitrate and phosphate concentrations were determined using a spectro photometer (Hach DR EL/4), TOC was determined using a Yanco TOC Analyser (model TOC-81). Other parameters were determined following standard procedures (APHA, 1985). Soil absorption capacities of effluents generated under the three different arrangements were measured by standard percolation test at test sites 1 and 3. It should be mentioned that the soil absorption capacities were measured during the dry season and results are expected to be different if the tests ate conducted during the wet period of the year.

3. RESULTS AND DISCUSSION

Table 2 shows characteristics of untreated wastewater from toilet and kitchen. It shows that for all three sites, BOD_5 and COD of toilet wastewater are significantly higher than the kitchen wastewater (sullage); while TOC and SS concentrations are lower than those for sullage. The PO_4 and NO_3 concentrations which depends on the types of activity was low.

These results indicate that kitchen wastewater should not be discharged untreated into open drains or surface water bodies as it contains high BOD, COD, TOC and SS.

Table 1. Basic Information on test sites

Site	Flats	Resident (total)	Total Waster water flow (LPD)	Flow from toilet (LPD)
1	2	6	720	216
2	2	18	2160	648
3	4	25	3000	900

Table 2. Characteristics of untreated (raw) sewage

Site	**Toilet Sample**			**Kitchen Sample**		
	Parameter	N	Mean ± SD(Range)	Parameter	N	Mean ± SD(Range)
1	BOD_5 (mgl^{-1})	3	339.3 ±13.7 (355.2-331.4)	BOD_5 (mgl^{-1})	3	301.3± 2.3(304-300)
	COD (mgl^{-1})	3	396.1 ± 12.5(410.40-3877)	COD	3	358.9 ± 11.5(368.2-346)
	TOC (mgl^{-1})	3	147 ± 42.5(196-120)	TOC	3	114.0± 4.0(118.0 -110.0)
	SS (mgl^{-1})	3	93.7 ±4.1(98.4-90.6)	SS	3	180.8 ± 1.38(182.4-179.8)
	PO_4 (mgl^{-1})	3	25.3± 0.57(26.0-25.0)	PO_4	3	15.3± 0.58(16.0-15.0)
	NO_4 (mgl^{-1})	3	32.0 ± 2.0(34.0-30.0)	NO_4	3	15.0 ± 1.00(16.0-14.0)
2	BOD_5	3	362 ± 2.25(364.7-360.20	BOD_5	3	308.1± 2.1(310.1-3060)
	COD	3	443.1± 3.36(446.8-440.20)	COD	3	412.2 ± 3.1(415.8-410.0)
	TOC	3	135.0± 3.0(138-132)	TOC	3	152.0± 3.5(156-150)
	SS	3	74.4 ±3.8(78.4 -70.8)	SS	3	198.4 ± 1.8(200-196.4)
	PO_4	3	41.3 ± 4.1(46.0-38.0)	PO_4	3	40.0 ± 1.0(410-390)
	NO_4	3	13.0 ± 1.0 (14.0 – 12.0)	NO_4	3	20.0± 4.0(24.0-16.0)
3	BOD_5	3	372.2 ± 3.9(376.8-369.6)	BOD_5	3	324.2 ± 3.7(326.8-320)
	COD	3	437.0 ± 6.1(440.8-430.0)	COD	3	415.3 ± 3.5(419-412)
	TOC	3	172.0 ± 2.0(174-170)	TOC	3	218.2 ± 7.7(226.8-212)
	SS	3	41.6 ± 1.5(43.0-40.0)	SS	3	84.8 ± 3.6(88.6-81.4)
	PO_4	3	15.0 ± 2.0(17.0-13.0)	PO_4	3	50.5 ± 3.2(53.9-47.6)
	NO_4	3	13.0 ± 1.0(14.0-12.0)	NO_4	3	24.0 ± 4.0(28.0-20.0)

Table 3. Performance of septic tank receiving toilet waste water (arrangement 1)

Site	**Sample**	**N**	**Detention Time**	**Raw Sewage**	**Effluent**	**Removal Efficiency, %**
1	BOD_5 (mgl^{-1})	3	24hrs	633.2 ± 31.7(665-603)	290.2± 6.4(296.4-283.7)	54.2
	COD (mgl^{-1})	3		750.9 ± 15.9(765-734)	321.6 ± 23.3(347-301)	57.2
	TOC (mgl^{-1})	3		330.3 ± 1.5(332-329)	165.3 ± 2.5(168-163)	50.0
	SS (mgl^{-1})	3		270.5 ± 1.8(272-269)	169.6± 5.0(175-165)	37.3
	PO_4 (mgl^{-1})	3		40.3± 2.5(43-38)	20.3 ± 1.5(22-19)	49.6
	NO_4 (mgl^{-1})	3		43.4± 6.0(48-36)	18.8± 0.2(19-18.5)	56.7
	FC(10^6/100^6m)	3		15.0 ± 2.0(17-13)	5.2 ± 0.5(5.7-4.8)	65.3

2	BOD_5 (mgl^{-1})	3	48Hrs	635. ± 6.0(642-630)	307.7± 2.7(310-304)	51.6
	COD (mgl^{-1})	3		849.4 ± 5.7(854.7-843.4)	398.7 ± 2.7(400-395)	53.1
	TOC (mgl^{-1})	3		285.3± 1.6(287-283)	155.1± 3.9(159-152)	45.6
	SS (mgl^{-1})	3		272.6± 2.5(275-270)	190.5± 3.7(194-186)	30.1
	PO_4 (mgl^{-1})	3		61.1 ± 3.4(64.9-58.5)	25.2 ± 1.3(26.0-23.7)	58.8
	NO_4 (mgl^{-1})	3		32.3 ± 3.1(35-29)	17.7 ± 1.3(19-16.5)	45.2
	FC(10^6/100^6ml)	3		20.3 ± 3.5(24-17)	10.7 ± 3.3(14-7.4)	47.3
3	BOD_5 (mgl^{-1})	3	72hrs	596.4 ± 9.1(602-586)	254.0 5.3(260-250)	57.4
	COD (mgl^{-1})	3		790.4 ± 9.7(800-780)	337.3 21.3(361-320)	57.3
	TOC (mgl^{-1})	3		382.0 ± 2.0(384-380)	263.0 6.2(270-258)	31.2
	SS (mgl^{-1})	3		124.3 ± 3.9(128-120)	73.9 3.4(76.9-70.3)	40.6
	PO_4 (mgl^{-1})	3		64.9± 4.9(69.8-60)	22.1 1.9(23.5-19.9)	66.0
	NO_4 (mgl^{-1})	3		37.1± 2.4(39.6-34.8)	20.3 2.5(23-18)	45.3
	FC(10^6/100^6ml)	3		6.7 ± 1.1(7.8-5.7)	3.6 0.7(4.3-2.9)	46.3

Table 4. Performance of septic tank receiving toile tank kitchen waste water (Arrangement 2)

Site	Sample	N	Detention Time	Raw Sewage	Effluent	Removal Efficiency, %
1	BOD_5 (mgl^{-1})	3	24hrs	231.3 ± 6.1(238-226)	110.0 ± 10.0(120-100)	52.4
	COD (mgl^{-1})	3		370.6 ± 6.0(377-365)	169.3 ± 4.0(173-165)	54.3
	TOC (mgl^{-1})	3		181.0 ± 5.6(187-176)	91.0± 3.0(94-88)	49.7
	SS (mgl^{-1})	3		90.0 ± 3.6(94-87)	65.3 ± 4.0(69-61)	27.4
	PO_4 (mgl^{-1})	3		10.7 ± 4.0(15-7)	5.0 ± 2.0(7-3)	53.3
	NO_4 (mgl^{-1})	3		51.0 ±4.6(56-47)	40.0± 3.0(43-37)	21.6
	FC(10^6/100^6m)	3		251 ±5.6(257-246)	150 ±3.0(153-147)	40.2
2	BOD_5 (mgl^{-1})	3	48hrs	262.7 ± 5.9(267-256)	116.9± 2.3(119.3-114.7)	55.5
	COD (mgl^{-1})	3		302.3 ± 6.8(310-297)	120.7 ± 2.8(123.8-188.4)	60.1
	TOC (mgl^{-1})	3		96.1±1.9(98.1-94.3)	49.1± 3.3(52.1-45.5)	48.9
	SS (mgl^{-1})	3		71.1± 2.6(73.7-68.6)	46.0 ± 1.0(47-45)	35.3
	PO_4 (mgl^{-1})	3		35.5 ±2.2(37.9-33.6)	21.5 ± 2.0(23.7-19.9)	39.4
	NO_4 (mgl^{-1})	3		50.6 ± 2.3(53.1-48.6)	30.3± 2.7(33.2-27.8)	40.1
	FC(10^6/100^6m)	3		15.0 ± 0.4(15.4-14.70)	10.3 ± 0.6(10.9-9.9)	31.3
3	BOD_5 (mgl^{-1})	3	72hrs	180.8 ± 2.6(183.7-178.7)	60.3 ±2.5(62.9-57.9)	66.7
	COD (mgl^{-1})	3		302.7 ± 6.8(310.5-297.7)	108.3 ± 7.6(115-100)	64.2
	TOC (mgl^{-1})	3		82.9± 2.3(85.3-80.7)	32.7 ± 2.5(35-30)	60.6
	SS (mgl^{-1})	3		80.3 ±1.6(82.1-78.9)	40.6 ± 2.3(43.2-38.7)	49.4
	PO_4 (mgl^{-1})	3		45.0± 2.0(47-43)	25.3± 2.2(27.6-23.3)	43.8
	NO_4 (mgl^{-1})	3		35.9 ±1.5(37.6-34.7)	18 ± 1.0(19-17)	49.9
	FC(10^6/100^6m)	3		9.3 ± 0.7(10.20-8.7)	5.6± 0.5(6-5)	39.8

Table 5. Performance of septic tank receiving toilet, kitchen and bathroom wastewater (arrangement 3)

Site	Sample	N	Detention Time	Raw Sewage	Effluent	Removal Efficiency, %
	BOD_5 (mgl^{-1})	3		110.7 ± 4.0(115-107)	40.9 ± 1.9(43.1-39.7)	63.1
	COD (mgl^{-1})	3		175.2 ± 49(207-48.7)	59.5 ± 2.1(61.3-57.3)	66.1
	TOC (mgl^{-1})	3		121.5 ± 2.0 (123.7-119.7)	54.9 ± 1.9(56.9-53)	54.8

1	SS (mgl^{-1})	3	24hrs	80. ± 1.4(81.4-78.6)	36.1 ± 2.1(38-33.9)	54.9
	PO_4 (mgl^{-1})	3		6.2 ±0.4(6.7-5.9)	4 ± 1(5-3)	35.5
	NO_4 (mgl^{-1})	3		41.0 ± 3.6(45-38)	37.7± 2.5(40-35)	8.1
	FC($10^6/100^6$ml)	3		13.2 ± 0.6(13.9-12.7)	9.4 ±0.6(9.9-8.7)	28.9
2	BOD_5 (mgl^{-1})	3	48hrs	111.3 ± 6.1(118-106)	45.1 ± 1.7(46.3-43.1)	59.5
	COD (mgl^{-1})	3		190.3 ± 3.1(193.3-187.2)	50.7± 2.2(53.1-48.7)	73.4
	TOC (mgl^{-1})	3		85.1± 3.0 (87.9-81.9)	45 ± 2.0(47-43)	47.1
	SS (mgl^{-1})	3		77.9 ± 1.8(79.5-76)	40.6 ± 2.3(43.1-38.7)	47.9
	PO_4 (mgl^{-1})	3		65 ± 2.0(67-63)	21.4± 2.1(23.7-19.8)	67.1
	NO_4 (mgl^{-1})	3		55.2± 1.5(56.8-53.9)	10.1 ± 0.4(10.5-9.8)	81.7
	FC($10^6/100^6$ml)	3		11.7 ± 1.5(13-10)	9.1± 0.5(9.7-8.7)	22.2
3	BOD_5 (mgl^{-1})	3	72hrs	110.3 ± 4.5(115-106)	35.3 ±1.5(37-34)	68.0
	COD (mgl^{-1})	3		209.7 ± 4.5(214-205)	61.1± 2.9(64.3-58.9)	70.9
	TOC (mgl^{-1})	3		102.3 ± 2.59(105-100)	60.6± 2.3(60.6-587)	40.8
	SS (mgl^{-1})	3		85.4 ± 1.4(86.5-83.8)	34.7 ± 2.5(37-32)	59.4
	PO_4 (mgl^{-1})	3		45.0 ± 2.1(47.1-43.0)	30.1± 0.5(30.7-29.7)	33.1
	NO_4 (mgl^{-1})	3		30.3± 2.5(33-28)	19.3 ±1.5(21-18)	36.3
	FC($10^6/100^6$ml)	3		8.0 ± 2.0(10-6)	5.4 ±0.5(5.7-5.0)	32.5

Table 6. Soil absorption capacities of septic tank effluents

Test site	Effluent type	Absorption rate (L/m^2d)	Seepage area required (m^2)
Site 1	T	61	25
	T + K	63	24
	T + K + B	66	23
Site3	T	78	19
	T + K	79	19
	T + K + B	83	18

T = Toilet, K = Kitchen, B = Bathroom

Tables 3,4 and 5 shows removal efficiencies of the septic tanks under three different test arrangements. Detention time under each arrangement is also indicated in the tables. Table 3 shows that under the arrangement 1 (septic tank receiving toilet wastewater only), composition of raw sewage are similar for septic tanks at sites 1 and 2,while concentrations of tested parameters are significantly lower for septic tank at sites 3. As shown in table 3,removal efficiencies of different constituents are better at site 3. A comparison of raw sewage characteristics presented in table 3 and 4 shows that combination of toilet and kitchen wastewater significantly reduces the BOD_5 and COD loadings of the raw sewage. TOC and SS concentrations are also reduced while NO3 concentration increased. A comparison of removal efficiencies presented in tables 3 and 4 also shows that reduction in detention time in arrangement 2, actually improved the removal efficiencies of BOD_5, COD, TOC and SS as compared to arrangement 1. On the other hand PO_5, NO_3 and FC removal efficiencies have diminished, probably due to reduction in detention period. Table 5 shows that combination of kitchen, toilet and bathroom wastewater reduces the BODS, and COD loading even further due to dilution with bathroom wastewater. The corresponding changes in influent. TOC and

SS concentrations are relatively smaller. A comparison of tables 3,4 and 5 shows that despite a significant reduction in detention time, BOD_5, COD and SS removal efficiencies have actually improved under arrangement 3 compared to arrangement 1 and 2. A comparison of these tables revealed that septic tank effluent quality with arrangement 2 and 3 is better than that of arrangement 1 with respect to BOD_5, COD, TOC and SS. Better quality with respect to FC could probably be achieved under arrangement 2 and 3. It should be noted that flow rates of wastewater increased significantly under arrangements 2 and 3 which would require a much larger tank volume as to maintain a constant detention time. Table 6 shows the results of percolation tests conducted at the test sites 1 and 3 with effluents from all three test arrangements. Table 6 shows that percolation rates slightly increases with toilet and kitchen wastewater for the same type of soil and the rate is highest when all types of wastewater are discharged to septic tanks. The percolation test results confirm the previous studies by Siegrist (1987), that increasing the pre-treatment of domestic wastewater prior to soil application increases the soil absorption capacity. As TOC contents, of effluents decreases under arrangements 2 and 3, the chances of soil clogging of soakage-pits would be less under these arrangements compared to arrangement 1.

Also, clogging at the infiltration surfaces were probably due to continuous inundation of the pits with effluents from septic tanks treating toilet wastewater only, as was observed by Laak (1970).

4. CONCLUSION AND RECOMMENDATIONS

Based on this study, it can be deduced that septic tank effluent quality varies significantly with the composition of domestic wastewater. For septic tanks treating wastewater from toilets only, effluent quality is poor. With the addition of kitchen wastewater, the effluent quality with respect to BOD, COD, TOC and SS improved significantly. For all-purpose septic tanks receiving wastewater from toilet, kitchen and bathroom, the effluent quality with respect to these parameters improved even further. Removal efficiencies of FC, NO_3 and PO_4 however decreased with the addition of kitchen and bathroom wastewater primarily due to reduction in detention time. It should be noted that addition of kitchen and bathroom wastewater significantly increases wastewater volume to septic tanks resulting in higher initial costs. However, results from the study reveals that kitchen wastewater should not be discharged into open drains or surface water bodies as it contains high BOD,COD, TOC and TSS values in all three arrangements. They all decreased as detention hours increased from 24hours to 72hours . Also bathroom wastewater contains high amount of NO_3 and PO4, although insignificant amount of other parameters. Results from percolation test reveals that, better quality of septic tank effluent enhances soil infiltration rates. This means that soakage-pits would require less area and would perform well for septic tanks treating kitchen and bathroom wastewater, in addition to toilet wastewater. Therefore, based on results obtained ,it is recommended that for effective and efficient design of septic tanks in the study area;one day detention time be used for tanks receiving toilet wastewater only ,and three days detention time be applied for the all purpose septic tank (arrengement3) and septic tank receiving both toilet and kitchen wastewater(arrangement 2).

5. ACKNOWLEDGEMENT

Appreciation is extended to the Ministry of environment Bayelsa State for their assistance in sponsoring this project.

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