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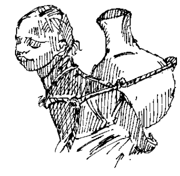
INTEGRATED DEVELOPMENT FOR WATER SUPPLY AND SANITATION



An evaluation of septic tank performance

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IN BANGLADESH, SANITATION technologies are largely limited to on site options and do not involve the conventional sewerage technology, primarily because of its high initial costs. Dhaka, the capital city, is only partly sewered and all the households within the served areas are not connected to the system. The only sewage treatment plant in Dhaka serves about 18 percent of the metropolitan population of about 6.5 million. The most common type of individual sewage disposal system consists of a septic tank and a soakage pit. In the absence of sewers, this is considered to be the most convenient method of waste disposal and is being installed in large numbers in cities and urban centres of the country. Of the total sanitation coverage of about 73 per cent in Dhaka, about 40 per cent are served by individual septic tanks. About 31 percent of nearly 2 million people in Chittagong, the second largest city in Bangladesh, and about 22 per cent of about 8.5 million people in the district towns are also served by septic tanks (Rashid et al., 1994).

The primary purpose of septic tank is to receive household wastewater, to separate solids from the liquid, to store solids which undergo anaerobic decomposition or digestion and to discharge partially clarified liquid effluent for disposal by other means (e.g., through a soakage pit). In Bangladesh, standardised design practice is not followed for septic tanks and organisations like the Public Works Department (PWD), Local Government Engineering Division (LGED) and the Military Engineering Services (MES) have their own design specifications primarily based on quantity 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. In the current design practice, the quality of influent wastewater and the effluent, which may significantly affect the ultimate disposal system (e.g., the soakage pit), are also not given any consideration. In Bangladesh, the usual practice is to connect only the toilet wastewater line to the septic tank. However, in some cases kitchen and bathroom wastewater 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 effluent quality of a septic tank significantly influences the ultimate disposal of the effluent. Although a large number of septic tanks are being used in urban areas of the country, most of them do not have proper effluent disposal facilities. In many cases, septic tank effluents are directly discharged into open water bodies, drains and ditches. Septic tanks which are connected to soakage pits often overflow. Soakage pits receiving septic tank effluents are either under-designed or the pits face the problem of early clogging apparently due to poor effluent quality.

The overall objective of this study is to evaluate the performance of septic tanks receiving different types of wastewater and to assess the influence of effluent quality on the performance of soakage pits. The specific objectives are: (i) to determine the effluent quality and overall performance of septic tanks receiving wastewater from different sources or combination of sources; (ii) to assess the soil absorption capacity of septic tank effluents generated under the different test conditions; and (iii) to suggest changes in septic tank design considering effluent quality and the corresponding soil absorption capacity.

Methodologies

In this study, effluent quality and performance of three septic tanks were evaluated under three different arrangements of domestic wastewater connection to the tanks, viz., septic tank receiving (a) toilet wastewater only (Arrangement 1), (b) toilet and kitchen wastewater (Arrangement 2), and (iii) toilet, kitchen, and bathroom (all purpose) wastewater (Arrangement 3). For this study, three test sites located in the Dhaka Cantonment Residential area were selected. These sites represent typical residential colonies in Dhaka comprising multi-storeyed buildings and wastewater disposal system based on individual septic tanks (one for each building) and soakage pits. It should be noted that most of the septic tanks and soakage pits in the selected areas overflow, requiring frequent cleaning. The selected test sites are (i) Kafrul Officers Quarter (Site 1), (ii) Golf Club Officers Quarter (Site 2), and (iii) Kachukhet Staff Quarter (Site 3). Information on wastewater generation rates at the three sites are provided in Table 1. All the three selected septic tanks are single-compartment tanks where inlet and outlet pipes are "T" shaped and are of 100 mm diameter. The beds of the tanks are sloped at 1:20 inward toward the centre of the tank to facilitate deposition of sludge and cleaning. The tanks are made of brick wall with concrete floor and RCC top. It should be noted that soil absorption capacity was not considered in the design of the soakage pits and the size of the soakage pits at the three sites are identical. The sides of the soakage wells are brick walled up to 2400 mm depth. The top of the pit is covered with concrete slab without any opening and the well is back filled with brick bats.

At all the test sites, only toilet wastewater lines were connected to the septic tank (i.e., Arrangement 1). In order to evaluate performance of the septic tanks under Arrangements 2, kitchen wastewater lines and under Arrangement 3, kitchen and bathroom wastewater lines were connected to the tanks. Before the start of the test program, all the septic tanks were cleaned and test (under Arrangement 1) started three weeks after cleaning. For testing under Arrangement 2, kitchen wastewater line was connected to the septic tanks using PVC pipes and were allowed to remain in this condition for three weeks for attainment of equilibrium condition before testing began. The same procedure was followed for testing under Arrangement 3. It is worth noting that in this study existing septic tank systems were utilised 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 example, flow rates were significantly higher under Arrangements 2 and 3 compared to Arrangement 1 and as a result, detention time under Arrangements 2 and 3 were much shorter. This obviously had a 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 wastewater samples and effluent samples were tested for a range of parameters including Suspended Solids (SS), Temperature, Total Organic Carbon (TOC), Biochemical Oxygen Demand (BOD), chemical Oxygen Demand (COD), Nitrate (NO_3), Phosphate (PO_4), pH, and Faecal Coliform (FC). Nitrate and Phosphate concentrations were determined using a Spectrophotometer (Hach DR EL/4), TOC was determined using a Yanco TOC Analyzer (Model TOC-8L). Other parameters were determined following standard procedures (AWWA, 1985). Soil absorption capacity 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 are conducted during the wet period of the year.

Results and discussion

Table 2 shows characteristics of untreated wastewater from toilet and kitchen. Table 2 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. No clear trend is apparent for PO_4 and NO_3 concentrations, which probably depend on the type of activities (e.g., washing with soap) carried out at the toilets and kitchens at the individual households of the residential buildings. These results suggest that kitchen wastewater should not be discharged untreated into open drains or surface water bodies as it contains high BOD, COD, TOC and SS.

Tables 3, 4 and 5 show removal efficiencies of the septic tanks under three different Test Arrangements. Detention time under each arrangement is also shown 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 site 3. As shown in Table 3, removal efficiencies of different constituents are similar at sites 1 and 2; while they are better at site 3.

A comparison of raw sewage characteristics presented in Tables 3 and 4 shows that combination of toilet and kitchen wastewater significantly reduces the BOD_5 and COD loading of the raw sewage, TOC and SS concentrations are also reduced to some extent, while PO_4 and NO_3 concentrations actually increased. A comparison of removal efficiencies presented in Tables 3 and 4 also show that despite a significant reduction in detention time under Arrangement 2, BOD_5, COD, TOC and SS removal efficiencies of the septic tank have actually improved compared to Arrangement 1. On the other hand, PO_4, NO_3, and FC removal efficiencies have diminished, probably due to a lower detention period and higher initial values. Table 5 shows that combination of kitchen, toilet and bathroom wastewater reduces the BOD_5 and COD loading even further due to dilution with bathroom wastewater. The corresponding changes in the 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 Arrangements 1 and 2. A comparison of Tables 3, 4 and 5 reveals that septic tank effluent quality with Arrangement 2 and 3 is significantly better than that under 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 with a higher detention time. It should be noted however that flow rate of wastewater increases significantly under Arrangements 2 and 3, which would require a much larger tank volume (compared to Arrangement 1) in order to maintain a constant detention time.

Results of percolation tests conducted at the test sites 1 and 3 with effluents from all three test Arrangements are shown in Table 6. Table 6 shows that percolation rate 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 decrease under Arrangements 2 and 3, the chances of soil clogging of soakage pits would be less under these arrangements compared to Arrangement 1. Required seepage area values presented in Table 6 clearly show that the existing soakage pits at sites 1 and 3 with a seepage area of 17 m^2 are insufficient to handle the effluent, which resulted in their functional failure. In addition, infiltration surface at these pits were probably clogged due to continuous inundation of the pits with effluents from septic tanks treating toilet wastewater only, as was observed by Laak (1970).

Conclusions

From the present study it appears that the septic tank effluent quality varies significantly with the composition of domestic wastewater. For septic tanks treating wastewater from toilets only, effluent quality was relatively poor. With the addition of kitchen wastewater (sullage), the effluent quality wit respect to BOD, COD, TOC and SS improved significantly. For all purpose septic tanks receiving toilet, kitchen and bathroom wastewater, 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 and also due to the high initial values of the parameters. Effluent quality with respect to these parameters is likely to improve with an increase in detention time. It should be noted however that addition of kitchen or kitchen and bathroom wastewater significantly increases wastewater volume (flow rate) to septic tanks which would require larger volume tanks resulting in higher initial costs. However, it should be kept in mind that results from this study suggest that kitchen wastewater should not be discharged untreated into open drains or surface water bodies as it contains high BOD_5, COD, TOC and SS; on the other hand bathroom wastewater contain insignificant amount of these quantities, although it is usually high in NO_3 and PO_4.

From soil percolation tests it appears that better quality of septic tank effluent enhances soil infiltration rate. 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. However, long term effect of effluent quality on soil absorption rate could not be determined within the scope of the present study.

Based on the results from this study and from an analysis of removal efficiency of different wastewater constituents in septic tanks with detention time and loading, the following three options have been proposed for the design of septic tanks for domestic wastewater. The options are (i) Option 1: toilet and kitchen wastewater with 3 (three) day detention time; (ii) Option 2: all purpose septic tank with 1 (one) day detention time; (iii) Option 3: toilet only septic tank with 5 (five) day detention time. However, more field testing is needed for assessing relative merits and demerits of these options.

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Table 1. Basic information on test sites

Site	# Sorey (# Flats)	Resident (total)	Total Wastewater Flow (lpd)*	Flow from Toilet (lpd)*
1	4 (8)	48	5760	1724
2	5 (10)	50	6000	1800
3	4 (8+8)**	96	9600	3450

* estimated from household survey
** two buildings

Table 2. Characteristics of untreated (raw) sewage

Site	Sample	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)
1	Toilet	160	290	102
	Kitchen	130	240	110
2	Toilet	190	340	106
	Kitchen	140	290	130
3	Toilet	200	340	160
	Kitchen	160	380	212

Table 2. (contd.)

Site	Sample	SS (mg/L)	PO_4 (mg/L)	NO_3 (mg/L)
1	Toilet	58	25	30
	Kitchen	105	15	15
2	Toilet	65	20	13
	Kitchen	129	40	20
3	Toilet	40	15	13
	Kitchen	84	50	24

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

Site	Sample	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)
1 *(67)	Raw Sewage	230	370	180	86
	Effluent	110	170	91	59
	Removal (%)	52	54	50	31
2 *(64)	Raw	250	380	171	94
	Effluent	120	180	92	66
	Removal (%)	52	53	46	30
3 *(114)	Raw	100	200	56	93
	Effluent	42	80	38	56
	Removal (%)	58	60	32	40

* Detention Time in Hours

Table 3. (contd.)

Site	Sample	PO_4 (mg/L)	NO_3 (mg/L)	FC ($x10^6$/100 ml))
1 *(67)	Raw Sewage	4	12	15
	Effluent	2	5	5
	Removal (%)	50	58	66
2 *(64)	Raw	7	13	20
	Effluent	4	7	10
	Removal (%)	57	46	50
3 *(114)	Raw	20	13	6
	Effluent	7	6	3
	Removal (%)	65	46	50

* Detention Time in Hours

Table 4. Performance of septic tank receiving toilet and kitchen wastewater (arrangement 2)

Site	Sample	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)
1 *(46)	Raw Sewage	140	250	87	70
	Effluent	60	100	38	45
	Removal (%)	58	60	56	36
2 *(44)	Raw	160	300	96	71
	Effluent	70	120	49	46
	Removal (%)	56	60	49	35
3 *(83)	Raw	180	300	82	80
	Effluent	60	110	33	40
	Removal (%)	66	63	60	50

* Detention Time in Hours

Table 4. (contd.)

Site	Sample	PO_4 (mg/L)	NO_3 (mg/L)	FC ($x10^6$/100 ml))
1 *(46)	Raw Sewage	45	50	250
	Effluent	30	40	150
	Removal (%)	33	20	40
2 *(44)	Raw	35	50	15
	Effluent	21	30	10
	Removal (%)	40	40	33
3 *(83)	Raw	45	35	9
	Effluent	25	18	5
	Removal (%)	45	48	45

* Detention Time in Hours

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

Site	Sample	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)
1 *(20)	Raw Sewage	110	200	121	80
	Effluent	40	60	55	38
	Removal (%)	63	70	46	50
2 *(19)	Raw	110	190	85	78
	Effluent	45	50	47	40
	Removal (%)	60	64	45	40
3 *(73)	Raw	110	210	102	86
	Effluent	35	60	60	35
	Removal (%)	68	72	58	70

* Detention Time in Hours

Table 5. (contd.)

Site	Sample	PO_4 (mg/L)	NO_3 (mg/L)	FC ($x10^6$/100 ml))
1 *(20)	Raw Sewage	6	40	13
	Effluent	4	38	9
	Removal (%)	30	16	30
2 *(19)	Raw	25	55	12
	Effluent	20	10	9
	Removal (%)	20	10	25
3 *(73)	Raw	45	30	8
	Effluent	30	19	5
	Removal (%)	33	35	40

* Detention Time in Hours

Table 6. Soil absorption capacities of septic tank effluents

Test Site	Effluent Type	Absorption rate ($L/m^2/d$)	Seepage area required (m^2)
Site 1	T	51	25
	T + K	53	24
	T + K + B	56	23
Site 3	T	78	19
	T + K	79	19
	T + K + B	83	18

T = Toilet; K = Kitchen; B = Bathroom