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A Septic Tank System: On Site Disposal

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Abstract: A septic tank serves primarily as settling chambers removing solids from house domestic sewage contaminants including microorganisms. In this study 40 of the modified septic tanks were used in five small villages such as El-Raad (6); El-Giara (4); El-Geziera (12); El-Azeba (7) and Dandara (11) in Kena governorate. Microbiological and chemical quality were determined to evaluate the efficiency assessments of these modified systems. Results showed that salmonellae were removed completely in 80 % (32/40) from total samples of the fourth compartment effluents of these systems in different areas. The overall reductions were more than 97% for total bacterial counts and total coliforms and more than 99% for fecal coliform and *Escherichia coli*. In addition to that more than 99% reduction for fecal *Streptococci* was obtained in all different areas except El-Raad the removal rate was decreased to 97.7%. The reductions of BOD5 and SS were more than 65% in all areas except El-Geziera where the removal rate of BOD5 was decreased to 55.4%. Density of *Escherichia coli* was 10^2 - 10^3 MPN/100 mL with the effluent of the fourth compartment which complied with reuse wastewater for unrestricted irrigation according to WHO guideline. Anaerobically treated along the septic tank collected from the fourth compartment is directed to a concrete filtration compartment completely filled with gravels over a soil filtration zone. Samples from the fifth compartment can not be able to collect. In this compartment biological processes such as filtration, adsorption and biological interaction between microorganisms may take place which reduce microbial population by about 1-2 log units.

Key words: Modified septic tank, *Escherichia coli*, house domestic sewage, *Salmonellae*

INTRODUCTION

The discharge of raw wastewater into the environment is seriously causing great damage to many forms of life. Domestic wastewater contains a large number of potentially harmful microorganisms and chemical compounds (Bajsa *et al.*, 2003; Lin *et al.*, 2002).

Specifically, household wastewater contains bacteria, viruses, household chemicals and excess nutrients such as nitrates and phosphates all of which can cause health problems in the recipient system (Rose and Gerba, 1991; Pang *et al.*, 2003). Raw domestic wastewater poses a potential risk for transmission of large numbers of human causing diseases (Nirel and Revaclien, 1999). Therefore, household wastewater must have adequate treatment to prevent most of these problems (Voigtlander and Kulle, 1994). Household or wastewater treatment by the traditional in site safe decomposed in common sense system such as septic tank/soil absorption designs may be not feasible in some places because of soil type, adverse topography and or inadequate availability of suitable land area. On the other hand, it is important means for raising the quality of living and protection of public health. Furthermore, these simple, small systems

are a type for water preservation or in other words a type of water recirculation through treatment via soil filtration. Although wastewater reuse has a positive and negative environmental impacts, it can play an important role in water resources especially in arid areas.

Septic systems have two major functions: a septic tank for decomposition and soil absorption and filtration system may be in one compartment or more. Septic systems are designed to hold, treat and dispose household wastewater on site (Khatwada *et al.*, 2002; Scaif *et al.*, 1977). Septic tank systems as it called in some part of the world can treat swage at its location rather than transporting the sewage to a sewer system or larger treatment systems. Because many septic tank systems throughout the world are not functioning properly, various laws have been passed to prevent the serious environmental and human health they may cause (USEPA, 1991, 2000). Among various types of septic systems most common type in many countries consists of an underground septic tank of different types which then connects to a soil system usually used a land drainage system or drainfield. Septic tanks became important to housing development in unsewered area especially in rural ones with small population numbers and density.

The operational control of these systems is usually complicated because of variations in raw influent composition, strength and flow rate as well as the changes in the complex nature of the treatment subjects (VonBonsdroff *et al.*, 2002; Randall, 2003).

In this study, the modified septic system was used in rural areas with warm climates such as Upper Egypt. The capacity of septic tank is based on the size of house. This modified septic system is simple to be comprehended by villagers who did all the construction work by themselves. This study aimed to evaluate the efficiency of this modified system for removal classical bacterial indicators and pathogens.

MATERIALS AND METHODS

Modified septic tank system: Modified septic tank has five compartments in series, the first one was 1 m length \times 1 m width \times 1.5 m total depth and active water depth was 1.2 m, with a total active volume 1.2 m³. The second was 1 m length \times 0.5 m width \times 1.5 m depth and 1.2 m with a total active volume of 0.6 m³. Each of the third and the fourth compartment was 1 m length \times 0.75 m width \times 1.5 m depth. Each of these compartments is filled with gravels in 1.2 m depth. The fifth compartment was 1 m length \times 1 m width \times 1 m depth which was tightly covered completely from up and filled with gravels resting on the filtration zone benthic the compartment. This modified septic tank system was represent in Fig. 1.

Generally raw wastewater from the bathroom, toilet, kitchen and laundry room flows into the first compartment through a tee tube 3 inches to slow down the coming wastes leading to solid separation from the liquid and reduces disturbances of the settled sludge. On the other hand, lighter materials as grease, fats and small particulates float onto the surface forming a layer of scum. In between these two layers liquid mixture is moving to the second compartment through a small hall in the separating wall in up flow direction. The second compartment wastewater effluent is moving to the third compartment through small hall in down flow direction by gravity. While the effluent of third compartment is moving to the fourth compartment through small hall of separating wall in up flow direction. A tee tube 3 inches is carrying the treated effluent from the fourth compartment to the last section of the treatment system and drain field through gravels (1 m depth) where liquid wastewater or effluent flows out of this unit into the soil. The soil provides the final treatment and disposal of the septic tank effluent.

According to the Egyptian Cod Plumbing (ECP) the average water consumption for a village with population

less than 50,000 capita is 125 L/capita/day. The average wastewater production (q_{ww}) is 80% of water consumption/capita/day (125 \times 0.8). The rate of accumulation of sludge in septic tank is 50 L/capita/year.

The detention time of wastewater in septic tank ranged between 1 and 3 days. The number of persons served by each septic tank system is 10 capita (ECP, 1997).

$$\text{Active volume of septic tank} = P \times q_{\text{av.ww}} \times T$$

P = Population numbers.

q_{av.ww} = Average wastewater production.

T = Detention time

Active water dimensions of the existing septic tank is (1 \times 1 \times 1.2 m), (1 \times 0.5 \times 1.2 m), (1 \times 0.75 \times 1.2 \times 40%) and (1 \times 0.75 \times 1.2 \times 40%) for the first, second, third and fourth compartments, respectively.

T1 = 1.2 days

T2 = 0.6 day

T3 = 0.36 day

T4 = 0.36 day

$$\begin{aligned} \text{Detention time (T) in all compartments of the system} \\ = T1 + T2 + T3 + T4 \\ = 1.2 + 0.6 + 0.36 + 0.36 = 2.52 \text{ days.} \end{aligned}$$

Note: 40% is the volume voids between used gravels size in third and fourth compartments.

Sampling site: From each modified septic tank system four samples were collected from the first, second, third and fourth compartments. Samples collected from modified septic tank units from four villages in Kena governorate as El-Raad (6), El-Giara (4), El-Geziera (12), El-Azeba (7) and Dandara (11). Thus, in this study 160 samples were collected and transported within ice box from 40 modified septic tank units and analyzed within (12 h) of collection for chemical and bacteriological examination.

Chemical and bacteriological analysis: Biological oxygen demand BOD₅ and Total Suspended Solids (TSS) were carried out according to APHA (1998).

Total bacterial counts were determined by using poured plate method, while classical bacterial indicators (Total Coliform (TC), Fecal Coliform (FC), *Escherichia coli* (*E. coli*) and Fecal Streptococci (FS)) were determined by using MPN methods. All parameters were carried out according to APHA (1998).

In addition salmonellae determination by using bismuth sulfite agar media were carried out according to El-Taweel *et al.* (2000).

RESULTS

Results obtained from samples collected from different compartments constituted the used septic tank system are presented in Table 1. Each figure of these data representing the average data obtained from separate analysis of many houses (4-12) representing one of the five chosen villages from Kena governorate. Mostly the number sampled from each village is not the same in the others as well as the number of dwellers in each house. Results of the first compartment of this system showed that the average counts were 10^{10} cfu 1 mL for total viable bacterial counts with all the different areas except El-Gziera and Dandara areas where the counts were 10^{11} cfu 1 mL either at 37°C or at 22°C . With regard to the classical bacterial indicators, the average densities MPN/100 mL were 10^{10} for total coliforms, 10^9 for fecal coliforms and 10^7 for fecal streptococci in all different areas except El-Giara area where the average densities of both total coliforms and fecal streptococci were 10^9 and 10^8 MPN/100 mL, respectively. *Escherichia coli*, average densities MPN/100 mL varied from 10^4 to 10^8 . Salmonellae average counts were 10^4 cfu/100 mL mostly in all different areas except El-Raad and El-Giara areas where the counts reached 10^5 cfu/100 mL. The average values of SS and BOD5 ranged from 385.7 to 555.5 mg/L and 461 to 697.5 mg $\text{O}_2 \text{ L}^{-1}$ respectively. The fourth compartment content which represents the final effluent that can be collected and sampled representing the influent of the closed fifth compartment which moved into gravels on soil absorption bed (Fig. 1). Results obtained from the contents of the fourth compartment effluent showed that the average counts of total viable bacteria varied from 10^7 to 10^8 at 37°C and 10^7 to 10^9 cfu/1 mL at 22°C . Results of classical bacterial indicators varied from 10^6 to 10^8 for TC, 10^5 to 10^7 for FC, 10^2 to 10^4 for *E. coli* and 10^4 to 10^5 for FS as MPN/100 mL (Table 1).

Salmonellae were not detected in 32 samples from 40 samples collected from the fourth compartment at different areas. Generally, the highest average counts of *Salmonellae* were 60 and 35 cfu/100 mL at El-Giara and El-Raad from the fourth compartment effluent. On the other hand, the lowest average counts of salmonellae were 4.0, 7.4 and 17 cfu/100 mL in El-Geziera, Dandara and El-Azaba, respectively. The average values of SS and BOD5 in this effluent (of fourth compartment) were varied from 82 to 170.8 mg L^{-1} and 124.4 to 292.1 mg $\text{O}_2 \text{ L}^{-1}$, respectively.

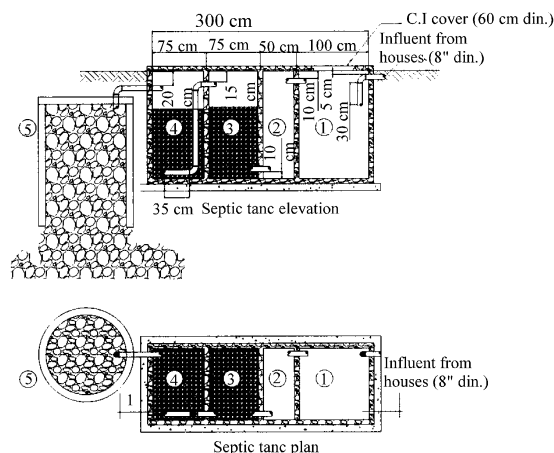


Fig. 1: Schematic diagram of the modified septic tank

The reductions percent ratios along this modified septic tank system were summarized in Table 2. The highest reduction percentage in total bacterial counts at 37°C and at 22°C were 95.1 and 98% at El-Giara in between the first and second compartment, while reaching 94.5 and 96.9 at Dandara in between the second and the third compartments, respectively. In between the third and the fourth compartments, the highest reduction was 94.7 at Dandara and 91.7 at El-Giara for total bacterial counts at 37°C and at 22°C , respectively (Table 2).

Generally the overall reductions in total bacterial counts were more than 98% at 37°C and 97% at 22°C between the first and the fourth compartments. The highest reduction of classical bacterial bioindicators were 91.1% for Tc (El-Azaba), 96.6% for Fc (El-Giara), 99.6% for *E. coli* (El-Geziera), 98.1% for FS (El-Giara) and 99.3 for salmonellae (El-Raad) in between the first and the second compartments. A reduction reaching 98.1% for Tc (El-Giara), 96.7% for Fc (Dandara), 90.7% for *E. coli* (El-raad and Dandara), 94.4% for Fs (El-Giara) and 99.1% for salmonellae (El-Azaba) were observed in between the second and the third compartments. While in between the third and the fourth compartments reduction rate was 95.6% for Tc (El-Giara), 94.6% for Fc (El-Giara), 96.6% for *E. coli* (El-Giara), 97.7% for Fs (El-Geziera) and 92% for salmonellae (El-Giara). Regarding with SS and BOD5 reductions, the higher removal rates were 43.3 and 45.2% (El-Giara) in between the first and the second compartments, 59.5 and 58.5% (El-Giara) in between the second and the third compartments and 59.5% (El-Giara) and 40.1% (Dandara) in between the third and the fourth compartments.

Finally, the sum of removal percentages activity as mean values against each bioindicator for 40 different unites has the same design of the tested septic tank

Table 1: Biological quality in each compartment of the used modified septic tank system

Average values												
			Total bacterial counts /1 mL						MPN density/100 mL		cfu/100 mL	mg L ⁻¹
Area	NH	ANP	At 37°C	At 22°C	Tc	Fc	<i>E. coli</i>	Fs	Salm.	SS	BOD	
El-Rraad	1	6	7	5.1×10 ¹⁰	7.9×10 ¹⁰	1.4×10 ¹⁰	6.4×10 ⁹	1.9×10 ⁷	3.1×10 ⁷	3.1×10 ⁵	553.3	608.3
	2			1.6×10 ¹⁰	4.2×10 ¹⁰	1.9×10 ⁹	7.7×10 ⁸	5.3×10 ⁵	4.5×10 ⁶	2.1×10 ³	320.0	382.5
	3			2.7×10 ⁹	8.3×10 ⁹	7.2×10 ⁸	2.5×10 ⁸	4.9×10 ⁴	1.9×10 ⁶	1.1×10 ²	224.7	207.5
	4			7.2×10 ⁸	2.2×10 ⁹	3.5×10 ⁸	2.2×10 ⁷	5.8×10 ³	6.9×10 ⁵	35	170.8	145.8
El-Giara	1	4	6	5.2×10 ¹⁰	6.1×10 ¹⁰	8.7×10 ⁹	1.9×10 ⁹	1.4×10 ⁶	3.0×10 ⁸	1.5×10 ⁵	555.5	697.5
	2			2.5×10 ⁹	1.2×10 ⁹	1.2×10 ⁹	6.4×10 ⁷	4.4×10 ⁴	5.6×10 ⁶	8.3×10 ³	315.0	382.5
	3			7.9×10 ⁸	7.3×10 ⁸	2.3×10 ⁷	3.0×10 ⁶	4.8×10 ³	3.1×10 ⁵	7.5×10 ²	127.5	157.5
	4			1.3×10 ⁸	6.0×10 ⁷	1.0×10 ⁶	1.6×10 ⁵	1.6×10 ²	3.7×10 ⁴	60	92.5	127.5
El-Geziera	1	12	9	1.1×10 ¹¹	1.7×10 ¹¹	2.0×10 ¹⁰	7.1×10 ⁹	9.4×10 ⁸	5.4×10 ⁷	7.1×10 ⁴	496.7	655.2
	2			1.6×10 ¹⁰	4.4×10 ¹⁰	2.2×10 ⁹	6.7×10 ⁸	3.6×10 ⁶	6.1×10 ⁶	1.1×10 ³	378.3	488.0
	3			1.1×10 ⁹	1.7×10 ¹⁰	7.6×10 ⁸	6.3×10 ⁷	5.3×10 ⁵	6.1×10 ⁵	42	277.5	365.5
	4			9.6×10 ⁷	2.2×10 ⁹	7.6×10 ⁷	1.2×10 ⁷	4.2×10 ⁴	1.4×10 ⁴	4	170.8	292.1
El-Azeba	1	7	7	4×10 ¹⁰	7.9×10 ¹⁰	1.7×10 ¹⁰	3.4×10 ⁹	1.5×10 ⁴	3.5×10 ⁷	9.4×10 ⁴	385.7	564.1
	2			9.6×10 ⁹	3.4×10 ¹⁰	1.5×10 ⁹	6.3×10 ⁸	1.6×10 ⁴	2.5×10 ⁶	6×10 ³	245.4	355.6
	3			3.8×10 ⁹	3.5×10 ⁹	6.9×10 ⁸	3.9×10 ⁷	4.9×10 ³	7.5×10 ⁵	52	133.1	248.6
	4			4.3×10 ⁸	6.7×10 ⁸	2.2×10 ⁸	1.0×10 ⁷	5.7×10 ²	1.1×10 ⁵	17	82.0	192.0
Dandara	1	11	6	1.3×10 ¹¹	1.5×10 ¹¹	2.7×10 ¹⁰	2.5×10 ⁹	6.0×10 ⁵	5.2×10 ⁷	8.4×10 ⁴	488	461.4
	2			9.8×10 ⁹	1.9×10 ¹⁰	1.1×10 ¹⁰	1.1×10 ⁹	1.3×10 ⁵	2.3×10 ⁶	7.9×10 ²	289.4	325
	3			5.3×10 ⁸	5.8×10 ⁸	5.8×10 ⁸	3.6×10 ⁷	1.2×10 ⁴	2.8×10 ⁵	56.5	207.3	208
	4			2.8×10 ⁷	2.2×10 ⁸	2.8×10 ⁷	2.6×10 ⁶	9.9×10 ²	2.9×10 ⁴	7.4	124.4	124.4

NH= Number of Houses. ANP= Average number of population. Salm. = *Salmonellae*

Table 2: Removal percentage for each compartment of the modified septic tank system

Reduction (%)										
			Total bacterial counts		Biological indicators					
Area		At 37°C	At 22°C	Tc	Fc	<i>E. coli</i>	Fs	Salm.	SS	BOD
El-Raad	2	73.7	46.8	86.4	87.9	97.2	85.4	99.3	42.16	37.1
	3	83.1	80.2	62.1	67.5	90.7	57.7	94.7	29.8	45.8
	4	73.3	73.4	51.3	91.2	88.1	63.6	68.1	23.9	29.7
Overall R (%)		98.8	97.2	97.5	99.6	99.9	97.7	99.9	69.1	76.0
El-Giara	2	95.1	98.0	86.2	96.6	96.8	98.1	94.4	43.3	45.2
	3	68.4	39.1	98.1	95.3	89.1	94.4	90.9	59.5	58.8
	4	83.5	91.7	95.6	94.6	96.6	88.1	92.0	59.5	19.0
Overall R%		99.7	99.9	99.9	99.9	99.9	99.9	99.9	83.3	81.7
El-Geziera	2	85.4	74.1	89.0	90.5	99.6	89.6	98.4	23.8	25.5
	3	93.1	61.3	65.4	90.5	85.2	90.0	96.1	26.6	25.1
	4	91.2	86.4	90.0	80.9	92.1	97.7	90.4	38.5	20.1
Overall R (%)		99.9	98.6	99.6	99.8	99.9	99.9	99.9	65.6	55.4
El-Azeba	2	76.0	56.9	91.1	81.4	89.3	93.5	93.6	36.4	36.9
	3	60.4	89.7	54.0	93.8	69.3	70.0	99.1	45.8	30.1
	4	88.6	80.8	68.1	74.3	88.3	85.3	67.3	38.4	22.8
Overall R (%)		98.9	99.2	98.7	99.7	99.6	99.6	99.9	78.7	65.9
Dandara	2	92.4	87.3	59.2	56.0	78.3	95.5	99.05	40.7	29.6
	3	94.5	96.9	94.7	96.7	90.7	87.8	92.8	28.4	36.0
	4	94.7	62.1	95.1	92.7	91.7	89.6	86.9	39.9	40.1
overall R (%)		99.9	99.8	99.8	99.8	99.8	99.9	99.9	74.5	73.0

system distributed in five small villages in Kena governorate, classical bacterial indicators and salmonellae as a bacterial pathogen in addition to SS and BOD₅, all indicated in Table 1 and 2. From Table 1 and 2 it can be easily noted that salmonellae as a pathogen as well as *E. coli* the most accepted bioindicator is the highly affected organisms followed by the other organisms showing a reduction reaching 3±1 log.

DISCUSSION

A septic tank system is the most common type of wastewater on site disposal system for small communities, village houses especially in areas where no communal

sewer is available. Any septic tank system commonly perform well if it has been properly sited, designed, constructed, used, desludged and reported when necessary (Hassinger and Forrell-Poek, 2000).

In Ohio a 1000 gallon tank is required for a home with one or two bedrooms. For a three bedrooms home, a 1500 gallon tank is required. A 2000 gallon tank is required for 4-5 and a 2500 gallon tank is required for 6 or more bedrooms (Mancl, 2005).

According to the Egyptian Cod Plumbing (1997), the average water consumption for a village with population less than 50,000 capita is 125 L/capita/day. Furthermore, the rate of anaerobic digested sludge accumulation in the

septic tank reaching 50 L/capita/year. The average of wastewater production was reaching 100 L/capita/day (average water consumption $\times 0.8$). The detention time in the septic tank must be between one and three days (ECP, 1997).

Generally there are many types of septic systems all over the world. The most common type in many countries consists of an underground septic tank of different types which connected to a soil treatment system, usually a land drainage bed or a drain field system. The present study is carried on one of these types which were recently found in Egypt. It is consisted of a large isolated septic tank ($3 \times 1 \times 1.5$ m), divided to four sections by three perforated walls, having a suitable hole to define effluent direction. Each section or compartment have a concrete cover placed over it.

Fecal contamination from humans and animals is believed to be a major cause for increased microbiological and nutrients loads in water resources as inland waterways, coastal or ground water sources (Abdullah, 1995; Paveen *et al.*, 1999; Lipp *et al.*, 2001).

A septic tank system can removes most suttlable and floatable solids from the wastewater. In addition, the soil absorption system can filters and treats the clarified septic tank effluent (Vun-Cugk *et al.*, 2001, 2004). Results obtained during the present study indicated that rates of biological parameters (indicators and pathogens) inactivation or die-off-removal- are considerably different regarding the considered parameter (Table 1, 2) these differences are shown to be unrelated to suspended solids (378.0 to 82.0 mg L⁻¹), dwellers number (6-9 users) or the initial load of each parameter in the first compartment. Seemingly, it seems to be related to village location and the behavior of the users, in other words the surrounding environment. Generally, very few studies reported in the literatures have presented information on removal efficiency for microorganisms during septic tank system treatment (Pang *et al.*, 2003). The available results presents a good and high reduction rates regarding salmonellae (more than 4 logs) *E. coli* (3 to 4 logs) as well as fecal streptococci. On the other hand, Fecal Coliforms (FC) showed higher persistence for the inactivation conditions reaching a reduction between 2 and 3 logs.

The value of coliforms as an indicator of fecal pollution has recently questioned, mainly because these bacteria can also originate from various sources such as soil, agricultural runoff, decaying vegetation and industrial processes (Geldreich, 1990; Dombek *et al.*, 2000). Instead, it has been suggested that enterococci and *E. coli* are much better indicators of fecal contamination, as these bacteria colonize in the gut of humans and other warm-blooded animals (Leclerc, 1993).

However, it has also to be noted that the sole presence of these bacteria in many source dose not provide definitive information regarding their possible source (Kuhn *et al.*, 1997a, b).

The anaerobically treated, along the septic tank collected from the fourth compartment is directed to a concrete filtration compartment completely filled with gravil over a soil filtration zone. We can not able to collect samples from this compartment since it has no cover to be removed. So, the biological quality of the exactly filtered effluent is unknown. Generally, septic tank effluent seems of resinable quality regarding fecal coliforms density (10^5 - 10^7), *E. coli* density (10^2 - 10^4) MPN/100 mL, these criteria mostly in compliance with quality of wastewater treated effluents used for surface unrestricted irrigation of food crops (WHO, 1989).

It must be mentioned here that the combined effects of soil and sewage biota, can play an important role in removing-die off- or inactivation of the percolated effluents (Davies *et al.*, 2005). Furthermore, Jansons *et al.* (1989) reported that polio viruses (vaccine strains) were undetected beyond 1.5 m in soil. A better understanding of the factors that govern behavior of any bio-indicator or pathogenic organism must be considered to facilitate design as well as comparison between different types of septic tank systems. So, inactivation, die-off and adsorption or generally reduction studies is important for good application of septic tank treatment and on site disposal system.

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