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Evaluation Of Waste Stabilization Ponds Performance In Egypt

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ABSTRACT

This study aims to describe, evaluate, and provide procedures to upgrade the performance of waste stabilization ponds (WSP) at a waste water treatment plant in rural area at Nile Delta, Egypt. Wastewater treatment system in the studied plant was designed to serve 3500 persons. Wastewater flow at year 2012 is about 280 m3/day mainly of domestic origin. This system consists of 500 primary septic tanks, a pumping station and wastewater stabilization ponds which have two series in parallel. Each series of pond consists of an anaerobic pond, a facultative pond, and a maturation pond. Effluents of 500 septic tanks are collected and discharged to pump station which in turn is discharged to WSP. The final effluents of WSP are discharged into an agricultural drain. The effluents of WSP which are discharged in the drain had the BOD reduced to 65.1 mg/l (79.5% removal), while the COD was reduced to 133.5 mg/l (79.2% removal) and the total suspended solids (TSS) were reduced to 57.2 mg/l (80.8% removal). The reduction percentages of total coliform (TC), faecal coliform (FC), and salmonellae were 99.99, 99.99, and 99.90% respectively.

Key words: waste stabilization pond- evaluation- performance- efficiency- waste treatment in rural areas.

Introduction

A wide variety of wastewater treatment systems are used worldwide such as activated sludge, trickling filter and waste stabilization pond (WSP) systems. Pond systems are commonly employed for municipal sewage purification, especially in developing countries, due to its cost effectiveness and high potential of removing different pollutants (Arar, 1988; and Christian *et al.*, 2003). WSPs are designed to achieve different forms of treatment up to three stages in series, depending on the organic strength of the input waste and effluent quality objectives. Usually, classical WSPs consist of an anaerobic pond, followed by primary or secondary facultative ponds. If further pathogen reduction is necessary, maturation ponds will be introduced to provide tertiary treatment. WSPs are very widely used for small rural communities but large systems exist in Mediterranean basin, France and also in Spain and Portugal. However, in warmer climates (the Middle East, Africa, Asia and Latin America) ponds are commonly used for large populations (Hamzeh and Pronce, 2002). In developing countries and especially in the tropical and equatorial regions like Egypt, a shortage of wastewater treatment systems is observed in rural communities. There is a great need to wastewater treatment systems to avoid the health risk problems in these communities. Wastewater treatment by WSPs has been considered an ideal way of using natural processes to improve wastewater effluents. In natural treatment systems such as WSP, the pathogens are progressively removed along the pond series with the highest removal efficiency taking place in the maturation ponds (Mara and Pearson, 1998). The aim of this study was to evaluate the performance of WSP in rural area in Egypt and to determine its role in the contamination of the drain.

Materials and Methods

Wastewater treatment system in the studied plant was designed to serve 3500 persons. Wastewater flow at year 2012 is about 280 m3/day mainly of domestic origin. This system consists of 500 primary septic tanks; each septic tank is approximately 1.8 m^3 in volume with area 1.12 m^2 and a depth of 1.6 m which used as primary treatment, a pumping station and wastewater stabilization pond which has two lines in parallel. Each line of pond consists of an anaerobic pond with volume 1400 m^3 (depth 3 m and area 475 m^2), a facultative pond with volume 1500 m^3 (depth 1.5 m and area 1050 m^2) and a maturation pond with volume 850 m^3 (depth 1.4 m and area 635 m^2). Effluents of 500 septic tanks are collected and discharged to pump station which in turn is discharged to WSP. There was a trial to evaluate this system attempted by Ghazy *et al.*, 2008. The final effluents of WSP are discharged into an agricultural drain. Figure (1) shows the flow chart of the studied WSP system. Wastewater and water samples were collected monthly during a whole year at five sites from each stage of WSP. Samples represent raw sewage (influent to all septic tanks), influent (effluent of all septic tanks),

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anaerobic effluents, facultative effluents and maturation effluents. All samples were collected and transported within ice box and analyzed within 6 hours of collection for chemical and biological examinations. Some physicochemical parameters such as total suspended solids (TSS), chemical oxygen demand (COD), and biological oxygen demand (BOD) were determined according to (APHA, 1998).

Total bacterial count was determined using poured plate method while classical bacterial indicator (total coliform TC and faecal coliform FC) were determined using MPN method. All parameters were carried out according to (APHA, 1998).

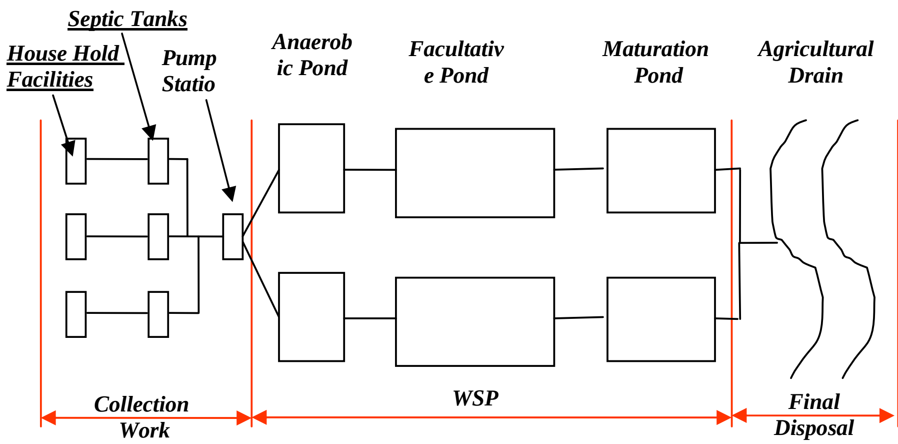

Fig. 1: Flow Diagram of the Studied WSP System.

Results and Discussion

In this study, septic tanks were used as a pretreatment of household's wastewater. The overall flow of wastewater to WSP which is the effluent of the septic tanks was 280 m^3/day. The water temperature records were between 20 and 29 ^oC, the average water temperature in anaerobic and facultative ponds was 26 ^oC while in maturation pond was 20 ^oC. The pretreatment of wastewater in the septic tanks achieved removal efficiencies of 16.4 %, 20.8 %, and 14.9 % for COD, BOD, and TSS, respectively. The average removal efficiencies of organic load in WSP measured as COD were 27.6, 39.9 and 52.2% after anaerobic, facultative and maturation ponds respectively. The anaerobic effluent indicated a COD average value of 464.5 mg/l, the facultative effluents 279.0 mg/l and maturation effluents 133.5 mg/l. On the other hand, the anaerobic effluent indicated a BOD average value of 244.1 mg/l, the facultative effluents 142.2 mg/l and maturation effluents 65.1 mg/l. The removal efficiencies of this parameter were 23.1, 41.7 and 54.2% in anaerobic, facultative and maturation effluents respectively. The mean values of TSS in this system were 349, 298, 243.5, 131.5, and 57.2 mg/l in raw sewage, influent, anaerobic, facultative, and maturation effluents. The reduction of TSS was 18.3, 46.0 and 56.5% in anaerobic, facultative and maturation ponds, respectively, as indicated in Table (1).

Table 1: Some physico-chemical characteristics of wastewater samples.

		Parameter (mg/l)		
		COD	BOD	TSS
Raw Sewage	Min.	701	353	310
	Max.	834	446	382
	Avg.	768.5	401	349
Influent (After Septic Tanks)	Min.	611	304	281
	Max.	672	331	311
	Avg.	641.5	317.5	298
Anaerobic Effluent	Min.	403	213	224
	Max.	524	273	262
	Avg.	464.5	244.1	243.5
Facultative Effluent	Min.	234	121	116
	Max.	326	162	146
	Avg.	279	142.2	131.5
Maturation Effluent	Min.	94	43	35
	Max.	171	84	78
	Avg.	133.5	65.1	57.2

The mean and removal percentages of microbial indicators and bacterial pathogens for each stage of WSP effluent are presented in Table (2). The results showed that the load of total bacterial count (TC) of WSP samples were 5.4×10^7, 1.8×10^6, 3.4×10^4, and 3.4×10^2 Cfu/ml in influent, anaerobic, facultative, and maturation effluents. The removal efficiencies of TC were 96.67, 98.11 and 99.0% in anaerobic, facultative and maturation effluents, respectively. Also, the mean values of faecal coliform (FC) in this system were 1.4×10^7, 2.4×10^5, 2.9×10^3, and 2.1×10^2 Cfu/ml in influent, anaerobic, facultative, and maturation effluents, respectively. The reduction of FC was 98.23, 98.79 and 92.76% in anaerobic, facultative and maturation ponds, respectively. The final measured parameter was salmonellae. The load of salmonellae in WSPs were 9.2×10^4, 2.4×10^4, 1.1×10^3, and 90 Cfu/ml in influent, anaerobic, facultative, and maturation effluents, respectively. The removal efficiencies of salmonellae were 73.9, 95.4 and 91.8% in anaerobic, facultative and maturation effluents, respectively.

Table 2: Microbiological characteristics of wastewater stabilization pond.

		Parameter (Cfu/ml)		
		TC	FC	Salmonellae
Raw Sewage	Min.	1.1×10^8	2.4×10^7	4.8×10^4
	Max.	2.4×10^9	1.8×10^8	2.1×10^5
	Avg.	1.3×10^9	1.0×10^8	1.3×10^5
Influent (After Septic Tanks)	Min.	2.6×10^7	1.8×10^6	3.7×10^3
	Max.	1.6×10^8	2.7×10^7	1.8×10^5
	Avg.	5.4×10^7	1.4×10^7	9.2×10^4
Anaerobic Effluent	Min.	1.2×10^5	1.4×10^4	1.1×10^3
	Max.	3.4×10^6	4.6×10^5	4.7×10^4
	Avg.	1.8×10^6	2.4×10^5	2.4×10^4
Facultative Effluent	Min.	4.3×10^3	1.1×10^3	1.0×10^2
	Max.	6.4×10^4	4.6×10^3	2.1×10^3
	Avg.	3.4×10^4	2.9×10^3	1.1×10^3
Maturation Effluent	Min.	2.8×10^2	1.4×10^2	70
	Max.	4.1×10^2	2.6×10^2	1.0×10^2
	Avg.	3.4×10^2	2.1×10^2	90

Waste stabilization pond systems are a widely used technique for the treatment of wastewater for rural areas (Racault and Boutin, 2005). In this study, settling of solid particulates of wastewater in the septic tanks is one of the main processes to remove organic material from liquid phase (Kamel and Hegazy, 2006). The effluents of the septic tanks are used as influent in WSP. Our results showed that the overall reductions were 80.8% (TSS), 79.2% (COD), and 79.5% (BOD). The performance of WSP attained a lower efficiency than expected. The lowest efficiency was recorded with anaerobic than facultative and maturation ponds for TSS, COD and BOD reduction. Also, the results showed that the overall reductions were 99.999% (TC), 99.998% (FC), and 90.187% (salmonellae). The removal efficiencies of the treatment system are shown in Figure (2).

From the obtained results, it can be observed that the facultative pond was more efficient in the reduction of classical bacterial indicators such as TC and FC. Additionally, the reduction of salmonellae were higher at maturation ponds. The final effluent complied with WHO guidelines for restricted irrigation (WHO, 2005). Generally Barjenbrach and Erler (2005) reported that, there are several causes for deterioration of the purification performance; such as unsuitable design of the pond; incomplete mixing of aerated pond; type of preliminary treatment; insufficient maintenance and increased organic influent loads.

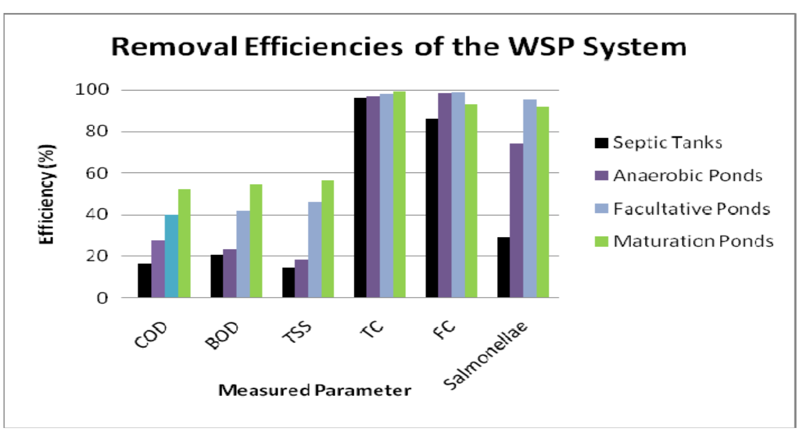

Fig. 2: Removal Efficiencies of the Studied WSP System.

In our study, although, the retention time is sufficient in the anaerobic ponds, bad removal of BOD, COD and pathogens was observed. Although anaerobic ponds are suitably and safely designed, they are not functioning efficiently. The results showed that BOD removal ratio in the anaerobic ponds is 23.1 % and the COD removal is 27.6%, while it was designed to remove 50 to 80 % of both BOD and COD (Metcalf and Eddy, 2002). This may be attributed to the existence of 500 primary septic tanks which used as primary treatment by precipitation to remove 16.4 %, 20.8 %, and 14.9 % of COD, BOD, and TSS, respectively, before the anaerobic ponds. The design of these tanks prevents the scum from passing with the sewage to the anaerobic ponds. This means that the anaerobic conditions are not well prevailed in the anaerobic ponds. Also, the primary septic tanks precipitate significant amount of the total suspended solids which contain some of the active bacteria and prevent it from passing to the anaerobic ponds. This means that the total count of active bacteria in the anaerobic ponds might be not enough to sustain the efficiency of treatment. Moreover, the increase in the detention time more than recommended may lead to the death of some bacteria and then decrease of the efficiency of the ponds. For increasing efficiency, special microorganisms, such as pediococcus spp and bacillus spp, should be added to the anaerobic ponds.

The low efficiency of the anaerobic ponds increased the organic load on the facultative ponds, which lead to the severe need to construct another two facultative ponds, one for each series, with area 1450 m^2. The existing facultative ponds area could be sufficient in design, for now, if the required efficiency of the anaerobic ponds is restored. The poor removal in maturation pond may, also, be due to some defects in the design of the ponds. Some of these defects are that the entrance of wastewater to different ponds was from one point. It means bad distribution of the wastewater and bad mixing with the microorganisms in the pond. Modifications of the design of the pond by adding some additional points for entrance of wastewater to the ponds to make complete mix in the different ponds are needed. The efficiency of the facultative ponds might be raised by increasing the points of entrance and exits of each pond to achieve well mixed flow conditions and avoid dead zones. On the other hand, it was noticed that the entrances and exits lack the maintenance and need purging to get rid of the deposits that block them.

However, due to the poor efficiency of maturation ponds, the system needs to increase 4 more maturation ponds to each series with area 635 m^2, for each, and depth 1.4 m. These additional maturation ponds are required in order to achieve FC effluent of 20 Cfu/ml, which comply with the requirements of disposal to agricultural drains.

The efficiency of the whole treatment system could be raised by converting the existing anaerobic ponds into facultative ponds and increasing the points of entrance and exits of each pond to avoid dead zones and to ensure well mixed flow conditions.

We should, also, notice that the treatment occurring in WSP results from the complex symbiosis of bacteria and algal species which results in an ecological pattern different from that of these organisms grown in pure culture. Changes of pH, temperature and light intensity control the abundance and activity of specific groups of microorganisms in the multi-species microbial communities' characteristic of facultative ponds (Kurihara, 1992; and Wilderer *et al.*, 1991).

Conclusions:

1. Although anaerobic ponds are safely designed, they are not functioning efficiently.
2. The poor efficiency of anaerobic ponds may be attributed to the existence of septic tanks which precipitate some of the TSS and prevents the scum from passing with the sewage to the anaerobic ponds and, as a result, decrease the total count of active bacteria and prevent the prevailing of anaerobic conditions.
3. The low efficiency of the anaerobic ponds increased the organic load on the facultative ponds, which lead to the severe need to construct another two facultative ponds, one for each series, with area 1450 m^2.
4. The existing facultative ponds area could be sufficient in design, for now, if the required efficiency of the anaerobic ponds is restored.
5. Modifications of the design of the facultative pond by adding some additional points for entrance of wastewater to the ponds to make complete mix in the different ponds are needed.
6. For increasing efficiency of anaerobic ponds, special microorganisms, such as pediococcus spp and bacillus spp, should be added along with increasing contact time.
7. The system needs to increase 4 more maturation ponds to each series with area 635 m^2, for each, and depth 1.4 m in order to comply with the requirements of disposal to agricultural drains.
8. The efficiency of the whole treatment system might be raised by converting the existing anaerobic ponds into facultative ponds and increasing the points of entrance and exits of each pond to achieve well mixed flow conditions and avoid dead zones. Additional step is to purge entrances and exits to get rid of the accumulated deposits that block them and have periodical maintenance.

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