PERFORMANCE EVALUATION OF WASTEWATER STABILIZATION PONDS IN ARAK-IRAN

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ABSTRACT
Arak waste stabilization pond facilities consist of two stabilization pond systems, module 1 and module 2. The existing facilities have had several problems in their operation. The objectives of this research were to evaluate the performance of stabilization ponds in wastewater treatment of the city of Arak, because of several problems in their operation, and to prepare a scheme of its upgrading, if necessary. Within the period of May to September 2007, analyses were carried out for both raw and treated wastewaters. Results of these investigations showed that the average effluent concentrations of BOD_5, COD and SS taken from primary and secondary facultative ponds of module 1 were 91.5, 169, 114; and 70, 160, 123 mg/L, respectively. These results indicated that the effluent of the primary facultative ponds of module 1 were complied with the Iranian treated wastewater standards for agricultural reuse in terms of BOD_5 and COD concentrations; hence the secondary facultative ponds could be changed to other primary facultative ponds in order to increase the capacity of wastewater treatment plant. For module 2, BOD_5, COD, and SS average concentrations of treated wastewater for the secondary and tertiary facultative ponds were obtained as 69, 101, 77; and 76, 127, 78 mg/L, respectively. Thus the effluent of the secondary facultative pond was complied with the considered standards in terms of all studied parameters. Consequently, the tertiary facultative pond could be changed to other secondary facultative pond to upgrade both the quality and the quantity of treated wastewater.

Keywords: Biological wastewater treatment, stabilization pond, upgrading

INTRODUCTION
Wastewater Stabilization Pond (WSP) is considered as the most appropriate system to treat the increasing flows of urban wastewater in tropical and subtropical regions of the world (Jeroen *et al*., 2007). WSPs are commonly used as efficient means of wastewater treatment relying on little technology and minimal, albeit regular maintenance. Their low capital and hydraulic loads have been valued for years in rural regions and in many countries wherever suitable land is available at reasonable cost (Nameche *et al*., 1998; Agunwamba J.C., 2001; Nelson *et al*., 2004; Handy *et al*., 2006; Kaya *et al*., 2007). They generally consist of a series of ponds where the wastewater has around twenty days retention time and usually a depth from one to three meters depending on the type of pond (Toumi *et al*., 2000).

The city of Arak is located in the central part of Iran, with a population of around 490,000 inhabitants and many small and large industries. Municipal and industrial wastewaters of this city are conducted to a wastewater treatment plant through sewer. The basic wastewater treatment process in Arak is stabilization pond. However, due to inappropriate design and consideration of both biological process and physical aspects of the ponds, the existing facilities suffer serious malfunctioning problems. Hence, a program was developed within the period of May to September 2007 with case study on the existing facilities. The main objectives of the program were to train the of personnel to monitor, to and evaluate the pond performance and effluent quality of the

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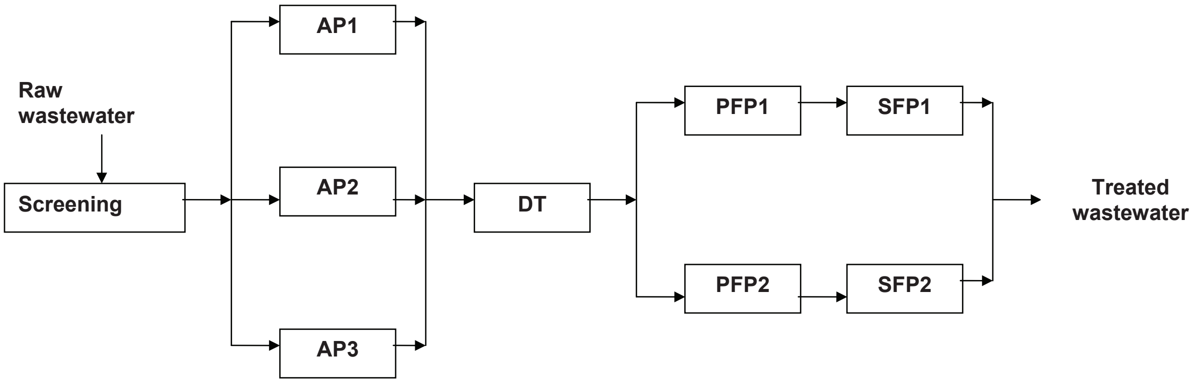
stabilization ponds and, depending on the results obtained, to propose a scheme for upgrading and expanding WSPs, if necessary. Similar programs have been developed in many parts of the world (Escalante *et al*., 2000; Oakey *et al*., 2000; Yaghubi *et al*., 2000; Nelson *et al*., 2004).

MATERIAL AND METHODS

Site specifications

The wastewater treatment plant of Arak is located in the north of the city, close to the main road of Arak airport. The latitudinal location of the Arak WSPs is about 34.08^o N, the longitude is around 49.7^0 E and the pond's altitude is 1710 m above sea level. Arak treatment plant consists of two waste stabilization pond systems as AWSP module 1 (M1) and AWSP module 2 (M2). The M1 and M2 facilities are in parallel to eachother and have started their operation in 1993 and 2006, for the equivalent population 25000 and 80000, respectively.

As can be seen in Fig.1, the studied WSP systems are the same as classical pond configurations with anaerobic and facultative ponds. The studied wastewater treatment plants in Arak have a pretreatment unit that includes screens followed by the WSP systems. Tables 1 and 2 present the physical and operational characteristics of the AWSP systems. The M1 AWSP comprises three anaerobic ponds (APs) in parallel followed by a distribution tank that distribute the APs effluent into two parallel primary facultative ponds (PFPs), followed by two secondary facultative ponds (SFPs) in parallel (Fig. 1).



AP=Anaerobic Pond
PFP=Primary Facultative Pond
SFP=Secondary Facultative Pond
DT=Distribution Tank

Fig.1: Schematic flow diagram for M1 AWSP

Table 1: Physical and operational characteristics of the M1 AWSP system

Component	Area (m^2)	Depth (m)	Volume (m^3)	Hydraulic retention time (day)
Anaerobic pond 1 (AP1)	1768	9.25	5200	2.9
Anaerobic pond 2 (AP2)	1768	4.25	5200	2.9
Anaerobic pond 3 (AP3)	1768	4.25	5200	2.9
Total Anaerobic	5304	-	15600	2.9
Primary facultative pond1 (PFP1)	20800	3.5	33280	11.3
Primary facultative pond2 (PFP2)	20800	3.5	33280	11.3
Secondary facultative pond1 (SFP1)	20800	3.5	33280	11.3
Secondary facultative pond2 (SFP2)	20800	3.5	33280	11.3
Total facultative	83200	-	133120	22.6
Total	88504	-	148720	25.5

Daily treated flow: 5500 m^3

Table 2: Physical and operational characteristics of the M2 AWSP system

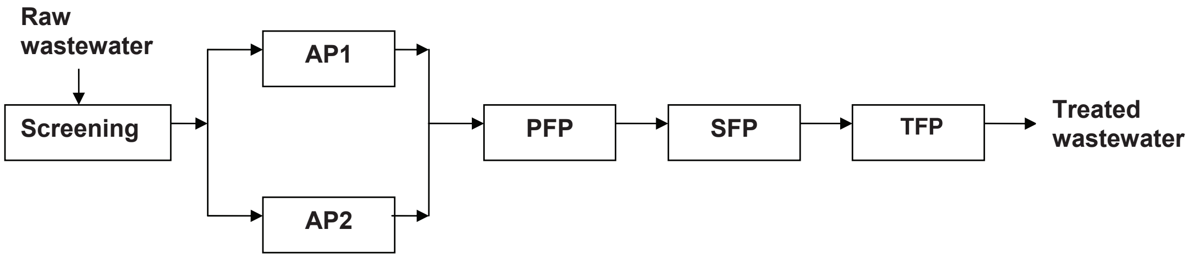
Component	Area (m^2)	Depth (m)	Volume (m^3)	Hydraulic retention time (day)
Anaerobic pond 1 (AP1)	10000	4.1	32000	2.73
Anaerobic pond 2 (AP2)	10000	4.1	32000	2.73
Total Anaerobic	20000	-	64000	2.73
Primary facultative pond (PFP)	147000	2.3	215000	12.2
Secondary facultative pond (SFP)	77600	2.3	113000	6.42
Tertiary facultative pond (TFP)	7800	2.3	113500	6.5
Total facultative	302600	-	441500	25.12
Total	322600	-	505500	27.85

Daily treated flow: 17600 m^3

The M2 AWSP comprises also two APs in parallel followed by one PFP, SFP and TFP (Fig. 2). The treated wastewater of both M1 and M2 facilities are used for agricultural reuse. As pointed out by Mara et al (1992), the current reuse of wastewater for agriculture purposes is attractive to many local authorities, especially to those in water-scarce regions. It is known that agriculture is responsible for more than 80% of total world water consumption (Valencia E., 1998).

Sampling

Wastewater samples were taken weekly at the inlet and outlet of each pond. The collected samples were composite samples taken over a period of 48 hours. The samples were taken directly by means of 2 L beaker glass. Each sample of 2 L taken at a wastewater depth of 1 m was directly transferred to a 30 L sample container and fixed for physicochemical analysis (Yaghoubi *et al*., 2000). Sampling was conducted from May to September 2007.



AP=Anaerobic Pond
PFP=Primary Facultative Pond
SFP=Secondary Facultative Pond
TFP=Tertiary Facultative Pond

Fig. 2: Schematic flow diagram for M2 AWSP

Climate

Arak city has a relatively cold and dry climate. The maximum temperature may rise up to +35 ^{0}C in summer and may fall to -25 ^{0}C in winter. The average temperature in the coldest month is -10.48^{0}C. The average precipitation is around 300 mm and the annual relative humidity is 50 %.

Analyzed parameters

Total BOD_5, COD and SS were determined for both influent and effluent of the modules. The measurement of flow was carried out by means of a Partial flume located at the inlet channel. Analytical approaches were based on the Standard Methods (APHA, 2005).

RESULTS

Total system performance evaluation

The results obtained for each stage and for the total systems of M_1 AWSP and M_2 AWSP, are presented in Tables 3 and 4, respectively.

Table 3: Average and removal percentage of the parameters in the M1 AWSP system (n= 18)

Pond Type		BOD_5 (mg/L)	COD (mg/L)	SS (mg/L)
AP1	Influent	242.2	524.9	127.8
	Effluent	145.7	279.5	140.4
	% Removal	40	47	-10
AP2	Influent	242.2	524.9	127.8
	Effluent	158	249	142
	% Removal	32	43	-11
AP3	Influent	242.2	524.9	127.8
	Effluent	171.2	318.3	144.2
	% Removal	29	39	-13
PFP1	Influent	158	299	142
	Effluent	90.6	166.3	111
	% Removal	43	44	22
PFP2	Influent	158	299	142
	Effluent	92.5	172.4	116.7
	% Removal	42	42	18
SFP1	Influent	90.6	166.3	111
	Effluent	73.3	148.2	117.7
	% Removal	19	11	-6
SFP2	Influent	92.5	172.4	116.7
	Effluent	65.7	153.4	128.2
	% Removal	29	11	-10
Total	% Removal	71	71	4

Table 4: Average and removal percentage of the parameters in the system of M2 APs (n= 18)

Pond Type		BOD_5 (mg/L)	COD (mg/L)	SS (mg/L)
AP1	Influent	242	525	128
	Effluent	133	287	188
	% Removal	45	45	-46
AP2	Influent	242	525	128
	Effluent	126	294	168
	% Removal	48	44	-32
PFP	Influent	130	290	178
	Effluent	107	151	84
	% Removal	18	48	53
SFP	Influent	107	151	84
	Effluent	69	101	77
	% Removal	36	33	8
Total (without TFP)	% Removal	71	80	40
TFP	Influent	69	101	77
	Effluent	76	127	78
	% Removal	-10	-25	-2
Total (with the TFP)	% Removal	69	76	39

The averages of raw wastewater flow rates entering the systems were 5500 and 17600 m^3/d for the AWSP system of M1 and M2, respectively, which were equivalent to the expected design. The measured average of BOD_5 and COD concentrations of raw wastewater, as around 242 and 525 mg/L, were also near the expected design concentrations of 250 and 550 mg/L, respectively, for BOD_5 and COD. However, the average SS concentration for raw wastewater, around 128 mg/L was well below the expected design concentration of 220 mg/L. Thus, the raw wastewater in Arak could be classified as medium to strong, in terms of BOD_5 and COD, and weak to medium for SS (Metcalf and Eddy, 2003).

Analysis of pond performance parameters

AWSP system M1

As Table 3 indicates, the removal efficiencies of BOD_5, COD, and SS for the APs with HRT=2.9 days and the PFPs with HRT=11.3 days, were 42%, 13% and 20%, respectively. The SFPs with the HRT=11.3 days, had the removal efficiencies of 24%, 11%, and – 8% for BOD_5, COD, and SS, respectively.

AWSP system M2

As shown in Table 4, for the ASPs with the HRT=2.7 days, the calculated removal efficiencies of BOD_5, COD, and SS were 46%, 44%, and -39% , respectively.

With respect to the HRT=12.2, 6.4, and 6.5 days, respectively for the PFP, SFP and TFP, the percentage removal of BOD_5, COD, and SS were 18, 48, 53; 36, 33, 8; and -10, -26, and -10, respectively.

DISCUSSION

M1 AWSP system

With respect to the effluent quality of the PFPs and SFPs and in comparison with the Iranian treated wastewater standards for agricultural irrigation that has indicated BOD_5, COD, and SS concentrations should be less than 100, 200, and 100 mg/L, respectively, the results indicated that the average effluent concentrations of BOD_5, COD, and SS were 91.5, 169, 114 mg/L, respectively, for PFPs, and 70, 160, 123 mg/L, respectively, for SFP. The effluent of the studied PFPs complied with the considered standards in terms of BOD_5 and COD concentrations.

As shown in Figs. 3-5, although the average effluent concentrations of BOD_5 and COD of the SFPs were lower, the average concentration of effluent SS was higher than the concentration of the effluent SS of the PFPs. The main constraint in the WSPs is the high SS in the effluents, which is primarily due to high concentrations of algal cells in the effluent (Esen *et al*., 1991). Thus in practice, the SFPs would not be required and could be replaced with other PFPs, in parallel with the existing PFPs, to enhance the quantity of treated wastewater in future years and to optimize the treated wastewater quality.

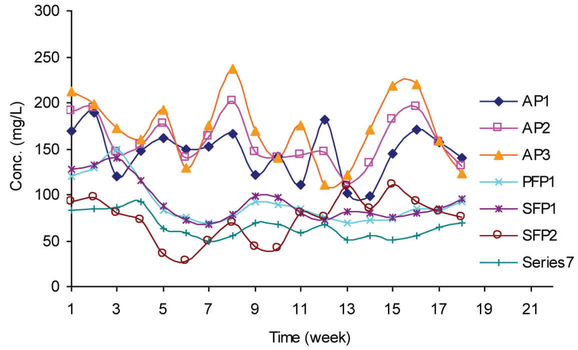


Fig. 3: COD variations for M1 AWSP

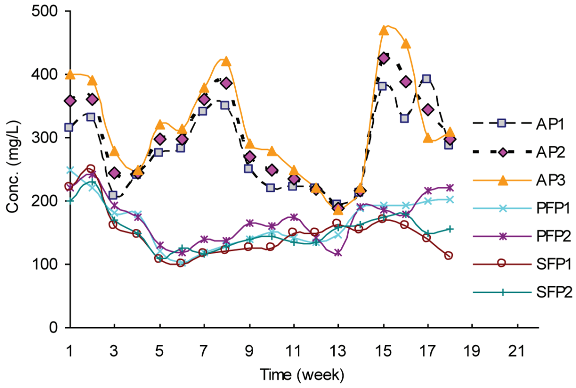


Fig. 4: BOD5 variations for M1 AWSP

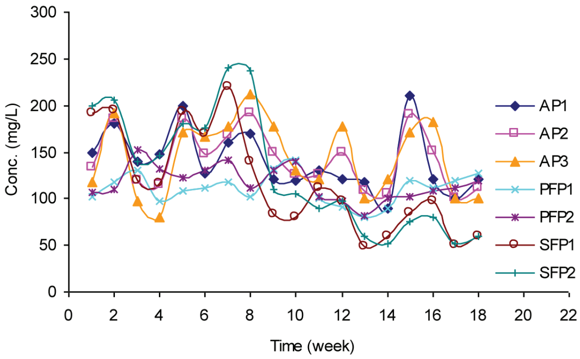


Fig. 5: TSS variations for M1 AWSP

M2 AWSP system

According to Figs. 6-8, the average effluent concentrations of BOD_5, COD, and SS of the SFP and the TFP were obtained as 69, 101, 77; 76, 127, 78 mg/L, respectively. These results indicated that not only the average effluent concentrations of studied parameters of SFP were complied the considered standards, but also the average effluent concentrations of studied parameters for the TFP were higher than those for the SFP. Consequently, the TFP would not be required and could be used to receive the raw wastewater, in parallel with the SFP, to increase the treatment capacity of the M2 AWSP.

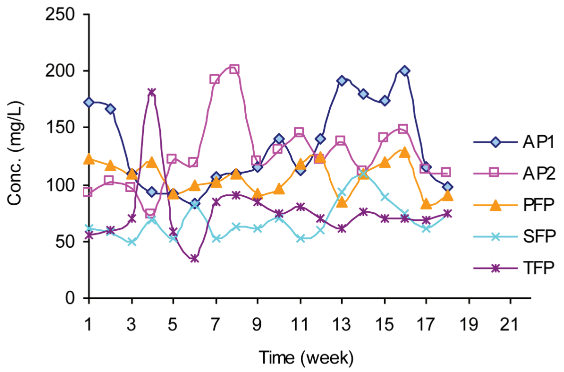


Fig. 6: COD variations for M2 AWSP

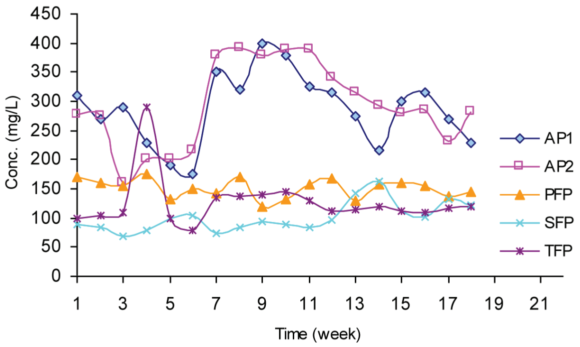


Fig. 7: BOD5 variations for M2 AWSP

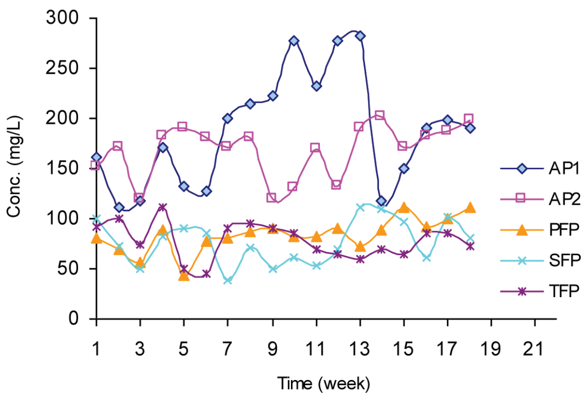


Fig. 8: TSS variations for M2 AWSP

The range of BOD_5 concentrations of SPFs for M1 and M2 were less than the results obtained in a study conducted for stabilization ponds in Egypt (Hamdy *et al.*, 2006). The removal efficiency of Arak facility for BOD_5 was higher than the removal efficiency of another study that was conducted in Spain, as 54% (Travieso *et al.*, 2006). However, the removal efficiency of COD of that study was about the same as in Arak (about 70%). In a study that was carried out in Tanzania, the rate of COD removal was 66% for PFP, 68% for SFP1, 71% for maturation pond (MP), and the overall COD removal rate was about 94%, (Kayombo *et al.*, 2002), much higher than in Arak which were 71% for M1 and 76% for M2.

For conclusion, the TFP of M2 can be used as a serial SFP in order to increase Arak wastewater plant capacity and effluent quality enhancing by population growth. In another way for enhancing effluent quality of Arak facility, it could be practical to put some baffles in SPFs of both M1 and M2 to optimize HRT and plug flow condition of wastewater, and consequently, enhancing removal efficiencies of BOD_5, COD and SS.

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