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Fluctuation of organic substances, solids, protozoan cysts, and parasite egg at different units of a wastewater integrated stabilization pond (full scale treatment plant): a case study, Iran

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ABSTRACT

Appropriate treatment of wastewater and achieving desired standards are among the important objectives in wastewater treatment. The amount of organic compounds (BOD & COD), suspended solids, protozoa cysts, and parasites are different in each of these units, due to different conditions of treatment and design parameters on the stabilization pond units. The aim of this study was to determine changes of the mentioned parameters in a series of stabilization pond units in a real scale. This descriptive–analytical study was conducted on 64 samples collected in both warm and cold periods. Measurement of the parameters and parasitic analysis were done based on water and wastewater standard and Bailenger methods, respectively. Results showed no significant difference in the mean of total efficiency removal of any parameters between every two ponds with each other. Further, there was significant difference in the efficiency removal of all parameters in three ponds (anaerobic, primary, and secondary facultative), except soluble COD removal of warm season between anaerobic and primary facultative ponds, TDS of warm season between primary and secondary facultative ponds, and TDS of cold season between anaerobic and primary facultative ponds) $p < 0.05$). Also, changes of the trend for all the measured parameters of the system were decreasing, and efficiency removal of protozoan cysts and parasites was 100%. According to the results, it can be said that the anaerobic pond had a greater role than the facultative ponds in terms of reducing organic and parasitic parameters; but, to reach the effluent standards, a facultative pond was needed after the anaerobic pond.

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Keywords: Integrated stabilization ponds; Organic materials; Solids; Parasite eggs; Protozoan cysts

1. Introduction

Appropriate wastewater treatment and achieving the desired standard with operation and easy maintenance are among the most important aims of wastewater treatment. For this aim, various methods have been used globally such as activated sludge, tricking filter, and stabilization ponds. Stabilization ponds are one of the natural, simplest, and least costly treatment wastewater methods, especially in developing countries, including Iran (due to weather conditions) [1].

Typically, this system includes the anaerobic, facultative, and two or some maturation ponds (aerobic). In anaerobic ponds, more solids are deposited and biologically degraded under anaerobic conditions. Facultative ponds have three layers, and there is a symbiotic relationship between bacteria and algae in the surface layer. Because of the anaerobic conditions in the deep layer, accumulated solids are decomposed by anaerobic bacteria. In the intermediate layer, organic matters are decomposed by facultative bacteria. After anaerobic and facultative ponds, maturation ponds are posited that are used for polishing the effluent of facultative ponds and further reduction of pathogenic microorganisms [1,2].

Considering different treatment conditions (anaerobic, facultative, and aerobic) and the difference between the basic design parameters in stabilization pond units (especially, in terms of depth and hydraulic retention time), reducing the level of physical, chemical, and biological parameters is different in each of these units [3]. Because of the lack of some stabilization pond units (mainly, aerobic pond) in some small communities (villages and towns), accordingly, it is needed to reveal the efficiency of each unit in terms of removing pollutants to meet reuse standards when the effluent of pond units are separately used for fish farming, agricultural irrigation, etc. [4,5].

Organic compounds (BOD & COD), suspended solids, protozoa cysts, and eggs of parasites are the most important pollutants in wastewater compared to the standards of reuse of agricultural irrigation and fish farming [6,7]. There is limited information about the level changes of various wastewater pollutants in stabilization ponds in the actual scale (information mostly obtained from the pilot scale). Therefore, the aim of this study was to investigate the fluctuation of organic substances, solids, protozoa cysts, and parasite egg in the pond series of Gilan-e-Gharb city in the actual scale.

2. Material and methods

2.1. Studied site

Gilan-e-Gharb city is located in the west of Kermanshah province between northern latitudes 33˚–49´ and 34˚–28´ and eastern latitudes 45˚–51´ and 46˚–37´ to Greenwich meridian. This city is situated at the altitude of 800 m above sea level, has a predominantly semiarid desert climate where the average temperature in summer and winter is 32.5 and 11˚ C, respectively, average annual rainfall of city is 385 mm, and snow is rarely seen. Wastewater treatment plant (WTP) in Gilan-e-Gharb was originally constructed with 3,500 m^3 capacity in 2005 and consisted of six stabilization ponds in two modules operated in parallel (two anaerobic ponds and two primary and secondary facultative ponds). In addition, it included screening system (manual and mechanical), flow measurement unit (Parshall flume), and basin chlorinator (with 30-min hydraulic retention time), respectively (see Fig. 1 and Table 1).

2.2. Sampling

This descriptive–analytic study was performed within 6 months during both warm and cold periods. June, July, and August months were selected as warm season, and December, January, and February were the cold season. The samples were collected weekly from the effluent of raw wastewater, anaerobic ponds, and primary and secondary facultative ponds. In the first and third weeks of each month, the samples were

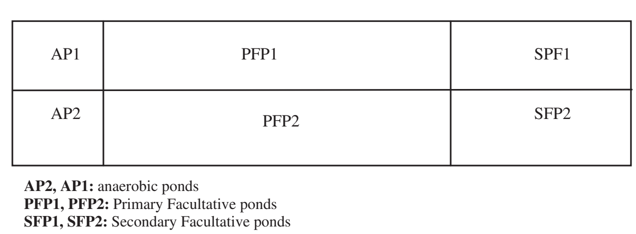

Fig. 1. A simple schematic of the wastewater stabilization pond system of Gilan-e-Gharb.

Table 1
Characteristics of primary and secondary facultative ponds in two parallel series of similar

Type of pond	Width (m)	Length (m)	Deep (m)	Surface loading (kg BOD/ha.d)/ volume loading (g/m^3.d)	Upper level (m^2)	Volume (m^3)	Hydraulic retention time (d)
Anaerobic	30	49	4	100 (Volume loading)	1,472	12,768	1.7
Primary facultative	45	167	1.54	150 (Surface loading)	7,525	53,688	1.7
Secondary facultative	45	167	1.5	87 (Surface loading)	33,271	22,219	1.7

taken from the first series of ponds (AP1, PFP1, and SFP1), and in the second and fourth weeks of each month, the samples were taken from the second series of ponds (AP2, PFP2, and SFP2). Thus, 16 samples in each month and in total 64 samples were taken with 12-h composite samples. Measurement of total COD, dissolved BOD, dissolved COD,TS, TSS, and TDS parameters was conducted based on water and wastewater standard methods [8]. Parasitological analysis was performed based on modified Bailenger method with McMaster counting slides (with the volume held under the grid equal to 0.3 ml) [9]. All the chemicals used in this study were obtained from Merck Co., Germany.

2.3. Statistical analysis

To compare total mean measured parameters in two series of ponds, independent t test was used. Also, to compare the mean efficiency of three ponds in terms of removing pollutants, one-way ANOVA was applied. All the statistical tests were carried out using SPSS, ver. 16, with the significance level of 0.05.

3. Results and discussion

Results showed no significant difference in the mean of total efficiency removal of any parameters between two ponds) $p < 0.05$). Moreover, there was significant difference in terms of efficiency removal of all the parameters in three ponds (anaerobic, primary, and secondary facultative), except soluble COD removal in warm season between anaerobic and primary facultative ponds, TDS removal in warm season between primary and secondary facultative ponds, and TDS removal in cold season between anaerobic and primary facultative ponds ($p < 0.05$). Mean levels of various parameters in raw wastewater and effluent from wastewater stabilization ponds of Gilan-e-Gharb in the warm and cold seasons are shown in Tables 2 and 3, respectively. Results indicated that pH level of the anaerobic pond was less than that of raw wastewater, primary, and secondary facultative ponds, which might be because of the activities of acidogen (*streptococcus*, *clostridium*, and *staphylococcus*), methanogen (*methanobacterium* and *methanospirillum*), and sulfate-reducing (*desulfovibrio*) bacteria to get food and breakdown of organic compounds [2]. Thus, first, the acidogen bacteria transformed organic matters into volatile fatty acids (acetate, propionate, and butyrate); then, methanogen bacteria transformed volatile fatty acids into methane and carbon dioxide. Also, sulfate-reducing bacteria oxidized the organic compounds and transformed sulfate into sulfide that included H_2S gas. Therefore, the acidic compounds and carbon dioxide caused decrease of pH in this pond [4].

Also, pH level in the secondary facultative pond was higher than the primary facultative pond, which can be due to photosynthetic of algae (especially, chlorella) that absorbed CO_2 during the day [10].

On the other hand, because of the low entrance of organic matter into the facultative pond, the activity of the aerobic bacteria was reduced; hence, CO_2 production was decreased and the resulting pH was increased. Also, the anaerobic part of the facultative pond had lower activity, resulting in the release of compounds that might decrease of pH; that is, because the activity of the anaerobic bacteria in the facultative pond was the depositing factor of suspended organic matters and this activity in the secondary facultative pond was less than the primary facultative and anaerobic ponds [11,12]. Similarly, Tyagi et al. [13] showed that, irrespective of carbonate and bicarbonate ions produced by algae that release hydroxyl ions (pH rising), because of solar ray, photosynthetic activity increased and consequently, CO_2 level was reduced (pH rising).

Results indicated that dissolved oxygen (DO) trends from the anaerobic to secondary facultative ponds were increasing, because there was no DO in the anaerobic pond due to its deeper and higher

Table 2
Mean amount of different parameters in raw wastewater and effluent from wastewater stabilization ponds of Gilan-e-gharb in cold season

Parameters	Type of wastewater (effluent)			
	Raw wastewater	Effluent of anaerobic pond	Effluent of primary pond	Effluent of secondary pond
Temperature (°C)	18.8 ± 1.44	16.1 ± 1.04	15.5 ± 1.32	15.5 ± 1.32
pH	7.45 ± 0.07	7.22 ± 0.03	7.75 ± 0.21	8.06 ± 0.20
DO (mg/l)	0.2 ± 0.0	0.11 ± 0.03	2.4 ± 0.66	3.05 ± 1.23
Total BOD (mg/l)	201.6 ± 20.2	11.6 ± 7.6	85 ± 6.6	65 ± 6.7
Dissolved BOD (mg/l)	176.4 ± 17.7	87.1 ± 7.4	68.4 ± 5.1	33.3 ± 3.8
Suspended BOD (mg/l)	52.2 ± 6.7	24.5 ± 5.5	16.6 ± 3.5	31.7 ± 4.8
Total COD (mg/l)	470.16 ± 28.44	268.83 ± 13.51	214.3 ± 8.31	204.5 ± 16.04
Dissolved COD (mg/l)	356 ± 25.2	226 ± 14.5	128 ± 12.5	114 ± 12.1
Suspended COD (mg/l)	113.8 ± 9.2	42.5 ± 5.5	85.6 ± 8.5	90.5 ± 11.2
TS (mg/l)	648.33 ± 18.58	613.33 ± 21.55	587.66 ± 16.62	573.66 ± 12.06
TDS (mg/l)	553 ± 17.35	19.76 ± 527.33	510.33 ± 17.50	501.66 ± 7.77
TSS (mg/l)	95.66 ± 4.16	85.66 ± 3.06	77.66 ± 3.06	73 ± 6.24
Total parasite eggs (number in liter)	55.5 ± 22	0	0	0
Nematode eggs (number in liter)	43.4 ± 12	0	0	0
Protozoan cysts (number in liter)	15.9 ± 7	0	0	0

Table 3
Mean amount of different parameters in raw wastewater and effluent from wastewater stabilization ponds of Gilan-e-gharb in warm season

Parameters	Type of wastewater (effluent)			
	Raw wastewater	Effluent of anaerobic pond	Effluent of primary pond	Effluent of secondary pond
Temperature (°C)	20.16 ± 1.53	20.16 ± 1.50	19.66 ± 2.52	18.5 ± 3.12
pH	7.54 ± 0.08	7.40 ± 0.15	7.77 ± 0.30	8.01 ± 0.33
DO (mg/l)	0.36 ± 0.18	0.25 ± 0.15	2.01 ± 1.07	4.05 ± 0.61
Total BOD (mg/l)	198.3 ± 20.2	128.3 ± 10.4	96.7 ± 12.6	80 ± 18.9
Dissolved BOD (mg/l)	173.5 ± 17.7	96.2 ± 7.8	74.4 ± 9.7	36.7 ± 6.3
Suspended BOD (mg/l)	24.8 ± 3.7	32.1 ± 4	22.3 ± 5.5	43.3 ± 9.3
Total COD (mg/l)	447.66 ± 43.7	284.66 ± 19.75	214.33 ± 20.81	199.66 ± 35.8
Dissolved COD (mg/l)	339 ± 30	239 ± 18.5	147.17 ± 20.2	123 ± 14
Suspended COD (mg/l)	108.67 ± 10.5	67.45 ± 12	72 ± 8.5	76.67 ± 9.2
TS (mg/l)	694 ± 40.51	639.66 ± 23.67	615.33 ± 32.32	602.66 ± 23.25
TDS (mg/l)	569.33 ± 40.07	548 ± 19.52	532.66 ± 23.16	520.33 ± 13.65
TSS (mg/l)	126.33 ± 10.97	91.66 ± 12.74	82.66 ± 15.57	83.33 ± 9.45
Total parasite eggs (number in liter)	61.8 ± 22	0	0	0
Nematode eggs (number in liter)	54.7 ± 12	0	0	0
Protozoan cysts (number in liter)	19.81 ± 7	0	0	0

organic load; but, due to algae photosynthesis in facultative pond, DO could be produced, particularly in upper layers (depth of 20 cm) that had the greatest aggregation of algal so that this subject was more evident in the secondary facultative ponds [10,11]. DaSilva et al. [12] showed that further algal activity, hydraulic retention time, and temperature changes affected pH and DO levels in the ponds.

Results also demonstrated that in the secondary facultative pond, due to high activity of algae in warm seasons, DO level was higher than in the cold season (1 mg/L) [13]. Similarly, Belmont et al. [14] reported that algal activity and climate change were two important sources of oxygen supply in facultative ponds so that, from April to August, DO level was maximum and, in December and January, it was minimum.

Moreover, the removal percentage of total COD in warm season was 61%,which was 6% higher than its removal in cold seasons; but, this value was 4% for soluble COD, which could be attributed to more activity of microorganisms and algae in the warm season and also increased oxidation rate of organic matters due to more production of DO in warm season [2].

High efficiency of COD removal was observed in the anaerobic pond and, except suspended COD, the efficiency removal trends of all COD forms from the anaerobic to secondary facultative ponds were decreasing. Similarly, Mahassen et al. [11] revealed that total efficiency of WSP for total COD removal was 48.8% and removal rate of the anaerobic pond was more than that of the facultative pond. According to the results, efficiency removal of the suspended COD of raw sewage by the anaerobic ponds in warm and cold seasons was 38 and 62.6%, respectively. Also, suspended COD level increased from the anaerobic to primary and secondary facultative ponds, which can be attributed to increased water viscosity (decreased temperature) and microbial activity that caused reduction of gas productive (gas caused the increase of deposited suspended solids). So efficiency removal of suspended COD in the facultative ponds was less than that of the anaerobic pond; also, suspended COD in the facultative ponds can be increased due to algae growth as green effluent [15]. In another research by Pivelli et al. [16], efficiency removal of COD in summer was more than other seasons, which was attributed to the increase of microbial activity in the warm season.

Results showed that soluble BOD removal was more than the total BOD in both warm and cold seasons, which may be due to the point that total BOD included suspended BOD, the biodegradation of which needed the hydrolysis of organic particles that was long [17]. Moreover, production of “algal BOD” in the primary and secondary facultative ponds caused the decrease of suspended BOD removal in those ponds notwithstanding the increase of hydraulic retention time [1, 2, and 18].

Further, the efficiency removal of total BOD was 8% more than cold season, which may be due to increased microbial activity in the warm season [2]. Similarly, Goyal et al. [2] stated that, because of changing of microbial activity by seasons, in summer, the amount of BOD removal was more than winter. The changes of total BOD removal in stabilization pond series had a decreasing trend, and efficiency removal of total BOD was as follows: secondary facultative < primary facultative < anaerobic, which could be due to the reproduction of biomass in primary and secondary facultative ponds (especially, biomass production in secondary facultative). However, BOD was reduced in the facultative ponds by decomposition and sedimentation; but, because of the biomass reproduction, BOD removal was less than the anaerobic pond [19]. Based on the results, the increased part of suspended BOD in the output of secondary facultative was related to algal biomass; that inverse of soluble BOD cannot be a danger for the environment. It should be emphasized that this effluent may be advantageous to be reused in agriculturing, because algae essentially acts as slow-release fertilizers and promotes plant growth via increasing the soil humus content and improving its water-holding capacity [13].

Results showed that efficiency removal of soluble BOD in ponds was as follows: primary facultative < secondary facultative < anaerobic. Due to high level of microorganism and high rate algal density (more oxygen production), efficiency of the secondary facultative pond in soluble BOD removal was higher than the primary facultative pond (inverse of total BOD) [2]. Also, the efficiency removal of total and soluble BOD in the warm season was higher than the cold seasons, which could be due to high activity of microorganisms and algae growth in the warm season [11].

Results indicated that, except TDS, the efficiency removal of TS and TSS in the cold seasons was more than the warm season, which may be due to more settling of suspended solids in the cold season because of high viscosity of water, decrease of water turbulence, microorganism activity, and algae growth (that produce suspended algal biomass) [2]. Similarly, Goyal and Mohan [20] reported that TSS removal occurred in stabilization ponds due to settling; then, the deposited matters were degraded by microbial activity; this process mostly occurred in anaerobic ponds.

Results showed that the system can remove 100% of protozoan cysts and parasite eggs so that, in this case, the anaerobic pond played a main role. Moreover, because of the dominance of long retention time (increase of settling) and the main mechanism of parasite and protozoan cyst removal, the stabilization pond (especially, anaerobic pond) can achieve the highest removal efficiency provided that it was designed and operated appropriately [3,21,22]. The findings can be confirmed by the results of similar works. Efficiencies as high as 100% for nematode egg removal in stabilization ponds have been reported by Amahmid et al. and Zahedi and Arbai [20,22]. In a study conducted by Grimason et al. [23], removal efficiencies were less than 100% for Giardia cysts in stabilization ponds because of poor design and inadequate retention time. Similarly, Ellis et al. [24] showed that stabilization pond could not completely eliminate parasite eggs. Ben Ayed et al. [25] conducted a study in Tunisia and indicated that, among wastewater stabilization pond systems, three plants had 100% efficiency in parasite ova removal, while two other plants did not have such efficiency due to insufficient retention time.

A study based upon 5 stabilization ponds in Tunisia revealed that 3 plants effectively removed 100% of parasites, while 2 plants did not have such a situation due to insufficient retention time. None of the five plants, however, completely removed protozoan cysts [25].

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