original article

Comparison of conventional activated sludge system and stabilization pond in removal of chemical and biological parameters

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ABSTRACT

Aims: The aims of this study were to determine the efficiency of Kermanshah wastewater treatment plant (conventional activated sludge) and Gilan-e-Gharb wastewater treatment plant (stabilization ponds) in removal of organic matters (BOD_5 and COD), suspended solids, total coliform, protozoan cyst, and parasitic eggs in order to reuse their effluent for agriculture.

Materials and Methods: In this study, the samples were taken every five days from both inlet and outlet of wastewater treatment plants (WWTPs) for five months. Identification and counting of the protozoa cysts and parasitic eggs was carried out using McMaster slide according to Bailenger method. Other parameters were determined according to standard methods. Appropriate statistical techniques (T-test, Kolmogorov Smirnov test, and Mann-Whitney U test, Using SPSS ver. 16) were applied to interpret data.

Results: The efficiencies of Kermanshah wastewater treatment plant in removing BOD_5, COD, TSS, total coliform, parasitic eggs, and protozoan cyst were 82 ± 4%, 83 ± 2%, 78 ± 5%, 66.2 ± 4.2%, 97-99%, and 99-100%, respectively. The respective efficiencies for Gilan-e-Gharb stabilization ponds were determined as % 84 ± 3, %82 ± 8, %84 ± 5.3, %75 ± 6, %100, and %100.

Conclusions: According to the results, the removal efficiencies of all parameters except COD in stabilization ponds are higher than those in the activated sludge. Effluent quality in both plants met agricultural effluent reuse standards in view of all studied parameters except total coliform.

Key words: Activated sludge, Gilan-e-Gharb, Kermanshah, microbial and chemical parameters, stabilization pond

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INTRODUCTION

Reuse of treated domestic and raw municipal wastewaters as a valuable source of water for various purposes including farming and irrigation of recreational area, is one of the most important goals of wastewater treatment and protection of water resources, especially in areas where water sources are rare.[1,2] Reuse of

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wastewater particularly in agriculture fields have numerous benefits including initial interest (income from selling treated wastewater, reducing the dust spreading by spraying the treated wastewater on soil area, recycling of nutrients such as phosphorus and nitrogen from wastewater, and subsequent reduction in the consumption of chemical fertilizers, and reducing the costs and consumption of fresh water), secondary interests (subsequent efficacy of wastewater reuse projects), and public interest (improving the environmental and other aesthetic aspects).[1,3-5] The most important matter in this subject is the quality of used effluent, especially compliance with the microbial and chemical characteristics of effluent with national and international standards.[6-9]

Effluent reuse may have significant adverse effects on people and environmental health if ignored its microbial and chemical quality. These impacts would be more important when the treated wastewater used for irrigation of public parks, recreational area, and food products, including vegetables and some fruits.[10-14] In order to remove pollutants such as organic matters and pathogens the wastewater must be treated. There are several different biological processes for wastewater treatment including activated sludge processes, stabilization ponds, artificial wetland, aerated lagoons, and tricking filters.[1] According to the type of pollutants and treatment systems, the removal mechanisms are different. The most important removal mechanisms for parasite eggs during wastewater treatment processes are deposition and sedimentation, which are due to their high density and heavier weight. Other mechanisms are trapping to the biological sludge flocs and inactivation through unfavorable environmental conditions.[2,13,15] The removal mechanisms of bacteria in an activated sludge system are inactivation, hunting by ciliate protozoa, adsorption to solids and capsulation inside the sludge flocs, while in the stabilization ponds they are removed due to extreme temperature, high retention time, increased pH, extracellular antibacterial compounds of algae, sunlight, algae growth, etc.[8]

The efficiency of tricking filters, aerated lagoons, activated sludge, stabilization ponds (due to high retention time), and artificial wetlands with subsurface flow in the removal of parasite eggs has been demonstrated to be about 99 , 99.9, 99, 100, and 100%, respectively. Furthermore, the respective values for BOD_5, COD, and TSS removal in activated sludge systems are in the range of 71-90.5, 84-86, and 93-98%, comparing to the removal rates of 57-64.7, 43-82.6, and -54-83.8% for stabilization ponds. However, the removal efficiency of treatment processes is largely affected by designing criteria and may have vast fluctuations.[15-21]

This study was conducted to determine the efficiency of Kermanshah (conventional activated sludge system) and Gilan-e-Gharb (stabilization pond system) wastewater treatment plants in organic materials (BOD_5 and COD), suspended solids, total coliforms, protozoa cysts, and parasite eggs removal and consequently to determine the compliance of treated wastewater quality with the established standards for effluent reuse in farm irrigation. Considering that both treatment plants are located in Kermanshah province, so they experience similar situations in terms of weather conditions, mean ambient temperature, and annual precipitation. Qualitative characteristics of the influent wastewater for both systems are largely similar. The aim of this study was to determine the efficiency of Kermanshah and Gilan-e-Gharb wastewater treatment plant.

MATERIALS AND METHODS

Summary of operation of the Gilan-e-Gharb treatment plant

The Gilan-e-Gharb wastewater treatment plant was first operated in 2005 year and has a nominal capacity equal to 3400 cubic meter per day. Generally, this plant consists a variety of units including inlet pool, screening (a manual screening and a mechanical screening), flow measurement unit (Parshalflume), anerobic ponds (2 in parallel, with a retention time 1.7 day), facultative ponds (including 4 numbers, by two same series as parallel with the retention time 20 days), and chlorination (with retention time 30 min).

Summary of operation of the Kermanshah treatment plant

The Kermanshah wastewater treatment plant was first operated in 2006 and has a nominal capacity equal to 60000 cubic meter per day. Generally, this plant consists a variety of units including overflows building, screening (a manual screening and a mechanical screening), flow measurement unit (Parshalflume), grit chamber, primary sedimentation basins (2 units of circular type and similar and retention time per unit 2.5 hours), aeration pools (4 unit and retention time per unit: 7 hours), secondary settling basins (4 units of circular type and similar retention time in per unit 5.1 hours), and chlorination pools (with retention time 20 min).

In this cross-sectional study, samples were taken every five days at the both inlet (i.e., 1 liter from screening unit) and outlet (i.e., 10 liter, after chlorination unit) of the wastewater treatment plants over a period of five months. In total, 120 samples (30 samples from input and output of each wastewater treatment plant) were analyzed. Parasitic analysis were done based on the Bailenger method using McMaster counting slide (hole size 0.3 ml). In summary, samples were left for two hours to allow components to sediment. About 90% of supernatant liquid was discarded and the remaining sediment was transferred to tubes and then centrifuged for 15 minutes in 1000 rpm. Deposited materials were combined and transferred into a tube, and re-centrifuged for another 15 minutes in 1000 rpm. Acetoacetic buffer (equal to the volume of sediments, pH: 4.5) and ethyl acetate (twice the volume of sediments) were added to the tube and mixed using a shaker prior to centrifuge in 1000 rpm for 15 minutes. Three layers were formed in the tube, black layer at the top, turbid layer in the middle, and sediments at the bottom. The black and turbid layers were discarded and zinc sulfate (five folds of sediment volume, 33%, and with specific gravity of 1.18) was added to the tube and mixed using a shaker set. The volume of this solution (deposition + zinc sulfate) was recorded as the final product volume. Small fractions of the solution were put on the three McMaster slides (0.3 ml in volume) using Pasteur pipette. The slides were held in static mode for five minutes prior to counting and identifying of protozoa cysts and parasite eggs. The numbers of parasite eggs and protozoa cysts were obtained using the following equation.

$$N=AX/PV$$

Where:
N: is the number of eggs or cysts per liter of sample,
A: is the average number of counted eggs or cysts in three slides,
X: final product volume (ml)
P: the volume of McMaster slide (0.3 ml)
V: the initial sample size (L)

BOD_5, COD, TSS, and total coliforms were measured in central laboratory of Kermanshah Water and Wastewater Company according to Standard Methods.

Appropriate statistical techniques (T-test, Kolmogorov Smirnov test, and Mann-Whitney U test, Using SPSS ver. 16) were applied to interpret data. Confidence level was set to 95% for all statistical analysis. For non-parametric tests, "Mean ± SD" values were substituted with confidence intervals.

RESULTS

The average values determined for BOD_5, COD, TSS, and total coliform are shown in Table 1. The average number of parasite eggs and protozoa cysts detected in raw wastewater influent and treated wastewater effluent of Kermanshah and Gilan-e-Gharb wastewater treatment systems and their removal efficiency are given in Tables 2 and 3, respectively. The results for statistical analysis related to comparing the efficiency of two systems and their effluent quality are summarized in Tables 4 and 5, respectively.

DISCUSSION

Ascaris Lumbricoides eggs were dominant parasite eggs in raw wastewater in both cities that implies high prevalence of Ascaris worm infection within the studied community [Table 2]. This is consistent with the results reported by some other studies.[21,22,23]

Mahvi and Kia found that the average counts of parasite eggs in raw wastewater of studied cities are higher than those of raw wastewater produced in Tehran city. It may be due to the production of more industrial wastewater (without parasitic contamination) in the city.[23]

Jimenez reviewed studies conducted on parasite contamination of raw wastewater in different countries and reported similar results for these countries.[24]

The comparison of raw wastewater parasitic contamination between cities and different countries revealed that the average

Table 1: Mean value and removal percentage of BOD_5, COD, TSS and total coliforms in activated sludge system and stabilization pond

Wastewater plant name	Parameter	Raw wastewater	Treated wastewater	Removal efficiency	Agricultural irrigation standard
Kermanshah (activated sludge system)	BOD_5 (mg/l)	139 ± 29	23 ± 2	82 ± 7	100
	COD (mg/l)	263 ± 68	42 ± 5	83 ± 6	200
	TSS (mg/l)	161 ± 38	23 ± 5	78 ± 5	100
	Total coliform (MPN/100ml)	1.3E6 ± 3.2E5	4.385E5 ± 4.9E4	66.2 ± 4.2	1000
Gilan-e-Gharb (stabilization pond)	BOD_5 (mg/l)	269 ± 32	41 ± 6	84.3 ± 3	100
	COD (mg/l)	483 ± 38	84 ± 4	82 ± 8	200
	TSS (mg/l)	304 ± 16	47 ± 4	84 ± 5.3	100
	Total coliform (MPN/100ml)	1.2E6 ± 4.0E5	3.0E5 ± 3.5E4	75 ± 6	1000

Table 2: Average total number of parasites in raw wastewater and the effluent of Kermanshah and Gilan-e-Gharb WWTPs

Wastewater plant name	Sampling location	Ascaris lumbricoides	Hymenolepis nana	Trichuris trichiura	Total parasite eggs per liter of sample	Total nematodes eggs per liter of sample	Agricultural irrigation standards (nematode eggs)	Removal efficiency (%)	
								Parasite eggs	Nematode eggs
Kermanshah	Influent	51.8 ± 14.2	4.9 ± 0.7	0.8	57.5 ± 19	52.6 ± 16	-	97-99	96.8-99
	Effluent	099 ± 0.42	0	0	0.99 ± 0.42	0.99 ± 0.42	≥1		
Gilan-e-Gharb	Influent	51.3 ± 12.6	7.14 ± 1.2	3.33	61.86 ± 22	54.72 ± 12	-	100	100
	Effluent	0	0	0	0	0	≥1		

Table 3: Average total number of protozoan cysts and nematode larvae in raw wastewater and effluent of Kermanshah and Gilan-e-Gharb WWTPs

Wastewater plant name	Sampling location	Giardia cyst	Amoeba cyst	Nematode larvae	Total protozoan cysts per liter of sample	Protozoan cyst removal efficiency
Kermanshah	Influent	11.27 ± 3.7	24 ± 5.2	0	36.14 ± 18	99-100
	Effluent	0.40.1	0.5 ± 0.18	2	0.9 ± 0.25	
Gilan-e-Gharb	Influent	10.14 ± 3.3	9.6 ± 4.5	0	19.81 ± 7	100
	Effluent	0	0	0	0	

Table 4: Comparison of two WWTP systems in removal of parameters studied

Nonparametric tests	Application (purpose)	*P* value	95% confidence interval of the difference		df
			Lower	Upper	
Two group T-test	Comparison of BOD_5 removal efficiency	0.013	-3.365	-0.343	58
	Comparison of COD removal efficiency	0.246	-8.976	2.018	48
	Comparison of total coliform removal efficiency	0.01	-8.465	-4.535	54
	Comparison of TSS removal efficiency	0.0001	-17.332	-13.668	58
Mann-Whitney U	Comparison of parasite eggs removal efficiency	0.0001	-		-
	Comparison of protozoa cyst removal efficiency	0.001	-		-

Degree of freedom and interval of the differences are not definable

Table 5: Comparison of mean BOD_5, COD, and TSS of Kermanshah and Gilan-e-Gharb wastewater effluent to agricultural irrigation reuse standard by analytical tests

Parameter	P_{value}	df	95% confidence interval of the difference		P_{value}	df	95% confidence interval of the difference	
	Kermanshah				Gilan-e-Gharb		Upper	Lower
BOD_5	0.0001≤	29	-16.86	-19.26	0.0001≤	29	-15.26	-17.16
COD	≤0.0001	29	-116.09	-127.03	≤0.0001	29	-117.49	-118.68
TSS	0.0001≤	29	-20.62	-24.42	≤0.0001	29	-15.50	-16.54
Total coliform	0.358	29	-337.85	-340.61	0.296	29	-322.49	-324.97
Total nematode eggs	0.02	-		-	≤0.0001	-		-

number of parasite eggs in raw wastewater of the subjected cities is lower than those of developing countries (70-300 egg counts per liter), Brazil (166-202 egg counts per liter), Morocco (214-840 egg counts per liter), Jordan (300 egg counts per liter), Pakistan (144 egg counts per liter), Russia (≤2000 egg counts per liter), and Ukraine (60 egg counts per liter).[24] However, parasitic contamination found in our study is higher than those of reported for developed countries such as the United States of America (1-8 egg counts per liter), France (9-10 egg counts per liter), and Germany (≤40 egg counts per liter).[24] Zamo *et al.* reported that the average total parasite egg counts found in raw wastewater from Kenitra, Morocco, is 31 counts per liter.[25] Research performed by Reinoso *et al.* showed better performance for constructed wetland (i.e., 97%) in Giardia cysts removal than stabilization pond.[26] Molleda *et al.* also showed removal rates of equal to 100% for constructed wetland.[18] Caccio *et al.* conducted an investigation in four wastewater treatment plants in Italy and revealed that the removal efficiency in the number of cysts is significantly higher when the secondary treatment consisted of active oxidation with O_2 and sedimentation instead of activated sludge and sedimentation (94.5% versus 72.1 to 88.0%).[27]

According to single-group- T-Test and One-Sample kolmogorov Smirnov at confidence level of 95%, the mean values obtained for the amount of eggs nematodes, BOD_5, COD, TSS in effluent of both WWTP systems are significantly lower than the standard values recommended for wastewater reuse in agriculture and irrigation activities ($P_{value} < 0.05$). However, we found no similar differences for total coliforms ($P_{value} > 0.05$), which may be due to lack of effluent chlorination system in both WWTPs. Unlike the COD, there were significant differences in removal efficiency of BOD_5, TSS, total coliform, protozoa cysts, and parasite eggs between activated sludge and stabilization pond systems (independent-samples T-Test and Mann-Whitney U test, $P_{value} < 0.05$). There has been no nematode eggs in all samples taken from Gilan-e-Gharb WWTP effluent (stabilization pond system). The removal efficiencies for all parameters studied (except COD) in stabilization pond system were higher than those in activated sludge systems (Kermanshah WWTP).

These differences may presumably relate to long retention time in stabilization pond system that play an important role in pollutants removal, especially suspended solids, coliforms, and parasites.[16,17] This observation is consistent with that of

Amahmid *et al.*, who reported removal efficiency of 100% for nematode eggs in stabilization pond system.[28]

While the average total numbers of parasite eggs and protozoa cysts in conventional activated sludge system of Kermanshah WWTP were 0.99 ± 0.42 and 0.9 ± 0.42, respectively, we observed no cyst and parasite in the effluent of Gilan-e-Gharb WWTP. Furthermore, Miranzadeh and Mahmoudi showed that the removal efficiency of extended aeration activated sludge process for nematodes eggs is 100%.[22] Rowe and Abdel-Magid and Goosen and Shayya also reported that the primary sedimentation unit in conventional activated sludge process removes about 99% of the parasite eggs.[2,17]

The removal efficiency of organic materials (BOD_5 and COD) and suspended solids in both processes can be affected by wastewater specifications and design criteria of WWTP, and that vast fluctuations may be observed in removal efficiency of these compounds in wastewater treatment systems. The removal efficiencies of 90.5, 86.9 and 93.3% for BOD_5, COD, and TSS, respectively, were reported by Mehrdadi *et al.*, for activated sludge system, whereas in other study respective values for these parameters were found to be 71, 84 and 98.%.[19] Similarly, while Arbabi and Zahedi reported the removal efficiency of stabilization pond for BOD_5, COD, and TSS to be 57, 43, and 54%, respectively.[21]

The efficiencies of both WWTPs were desirable in removal of BOD_5, COD, TSS, total coliform, protozoa cyst, and parasite eggs. The effluent quality of both plants for all parameters studied (except total coliform) was in compliance with standard requirements of effluent reuse for agriculture activities.

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