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A SURVEY OF THE PERFORMANCE AND EFFICACY OF THE WASTEWATER TREATMENT PLANT IN KHORRAMABAD, IRAN

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ABSTRACT
Aerated lagoons are a type of aerobic suspended growth system used in the treatment of wastewater. Since they are quite flexible in design, they are widely used in the treatment of urban wastewater both in the developing and in the developed countries. Aerated lagoons are one of the most important treatment methods which are able to filter urban wastewater at the desired levels. Additionally, in comparison with modern wastewater treatment methods, the costs of construction, operation, and maintenance of these systems is relatively low. In the present research, the performance of the wastewater treatment system in Khorramabad has been studied for the duration of one year from March to February. In the present research, quality indexes including pH, TSS, BOD5, DO, and COD were measured on a weekly basis, and indexes such as TN, N-NH3, N-NO3, N-NO2, P-PO4, T.c, and F.c were measured and tested twice a month. The samples were regularly collected from the influent and effluent canals of the treatment plant. The tests were conducted at the plant laboratory according to the standard methods of testing water and wastewater. The contaminant removal yield is TSS=85.59%, BOD5=82.21%, COD=82.02%, N-NH3=37.90%, P-PO4=46.36%, T.c=99.94%, F.c=99.29%. In case the effluent is used to water lawns, agricultural fields, or it is emptied into surface waters, it is necessary that the microbial contamination be as low as those set by the standards of the Iranian Environmental Protection Agency.

KEY WORDS: Aerated lagoons, filtration of urban wastewater, effluent reuse.

INTRODUCTION

All communities produce liquid and solid wastes. The liquid part, which is called wastewater, is basically the tap water, which has been contaminated due to daily uses. In fact, it is not correct to consider only human waste as wastewater, because all water which has been somehow put to use turns into wastewater. If wastewater is not filtered, the incomplete breakdown of its organic matter may lead to the production of large amounts of foul-smelling gas. Additionally, untreated wastewater contain many pathogenic microorganisms, which had lived in human digestive tract (Metcalf & Eddie, 1995). Moreover, wastewaters are rich in nutrients, which stimulates the growth of water-borne plants and results in the early eutrophication of surface waters. Therefore, prompt transfer of the wastewater from the production source, and then its proper treatment and disposal is not only desirable, but also absolutely necessary in the contemporary communities, and can ensure the health of the environment, people and other living creatures (EPA, 1992).

To treat wastewater in Khorramabad, the anaerobic subsequent aerated lagoons has been selected for the wastewater treatment system. The objective of the present research is to study the efficiency of this system. Aerated lagoons are a type of aerobic suspended growth system in which artificial aeration in a pool allows microorganisms to grow and multiply and, as a result, change the waste materials. There are two types of aerated lagoons:

1. Aerated lagoons in which the dissolved oxygen and the suspended particles are distributed evenly (CMAL).
2. Aerobic-anerobic or optionally aerobic lagoons in which oxygen is supplied at the upper layer of the pool fluid, but only part of the solid particles are suspended and the rest have settled (PMAL).

This process is somewhere between simple units such as optional pools and efficient and more work-intensive units like activated sludge, in terms of land use, equipment and machinery, implementation and operation. Given its flexibility in design, this system has been found useful in both the developing and the developed countries. Based on studies that WHO experts had conducted between 1950 and 1970 on a number of working lagoons in different countries, it was concluded that lagoon-based treatment is the most appropriate and cheapest wastewater treatment method, especially for the third-world countries. Lagoons as a wastewater treatment method can remove up to 99.9 percent of the pathogens and between 90 to 95 percent of the contaminants (Bauer *et al.*, 1979). The performance of the wastewater treatment system using aerated and aerobic lagoons was studied in the Edinkirk plant in Belgium's Flanders in 1999. The obtained results showed that the contaminant removal yield was 94.9% for BOD5, 89.8% for COD, 94.6% for TSS, 34.4% for total nitrogen, 86.5% for total phosphorus. The concentration of the contaminants in the effluent was at a satisfactory level in comparison with the standards of wastewater effluents. Another study that can be mentioned is that of the Dakhala treatment system in Egypt, which was conducted by the department of the environmental health of the Alexandria University in 1995. The studied system is a combination of aerated lagoons and pools. In this study, the removal yield was determined to be 95, 93, and 92 percent for COD, TSS, BOD5, respectively (Alexandria University, 1995).

Another study by Cauchie et al was carried out in 2000. The removal yields for BOD5 and COD were 69-81 percent and 40-70 percent respectively, while phosphorus removal yield was less than 40 percent. Microbial removal yield was reported to be higher than 93 percent in urban wastewater (Cauchie *et al.*, 2000). Khorramabad wastewater treatment plant is located at a distance of 10 Km from Khorramabad on the Khorramabad-Kouhdasht road. The studies related to the design of the wastewater treatment plant in Khorramabad were endorsed based on the prospective population of the city. The design included the first two phases of subsequent anaerobic aerated lagoons nd the third and fourth phases of upgraded activated sludge, each phase designed for 150000 people. At the present, the first and second phases are in operation. The treatment process includes an anaerobic pool, an aerated lagoon and a sedimentation pond.

METHODS AND MATERIALS

This study was conducted on the wastewater influent and effluent streams of the wastewater treatment plant in Khorramabad for the duration of one year. To assess the performance of this treatment plant, after having conducted the necessary investigations in situ, the amounts of pH, TSS, BOD5, DO, COD, and temperature were measured on a weekly basis, and TN, N-NH3, N-NO3, N-NO2, P-PO4, Tc, and Fc were measured twice a month. Factors including pH, TSS, SVI, and DO were measure in the operational units on a weekly basis. The sampling techniques used were instantaneous and composite sampling. To measure parameters such as temperature, pH, and DO, instantaneous sampling was used and to measure parameters such as COD, BOD5, TSS, nitrogen compounds, phosphorus compounds, and microbial tests composite sampling was used. Since an automatic sampling machine was not available, for composite sampling, 8 times in each 24 hours instantaneous samples were taken (at 8:00, 10:00, 12:00, 14:00, 16:00, 18:00, 20:00, 22:00) and formula (1-2) was used to calculate the mixing coefficient of each sample in terms of the sampling instantaneous discharge and the final sample was produced.

n = the number of samples
V_i = volume coefficient of each sample for the creation of the composite sample
V_t = the needed composite sample volume
Qave = average discharge of the stream

The sampling containers were of the polyethylene type. The containers were washed with detergent and 5% nitric acid and were rinsed with distilled water to remove all contaminants. The experiments conducted on the samples and the experimental methods used in this project are based on the *Standard Methods for Water and Wastewater Examinations* (1998) (AWWA, 1991), and the instructions of the manufacturers of the laboratory equipment, such as spectrophotometer DR 7000 as follows:

Biochemical Oxygen Demand (BOD_5):

Using the 5210B method, the sample was cultured in dilution water with a digestion period of 5 days at a temperature of 20 degrees centigrade. Based on the difference in the dissolved oxygen concentrations at the beginning and the end of the experiment, the amount of oxygen consumed can be determined as BOD_5 (mg/L).

Chemical Oxygen Demand (COD):

In experiments on wastewater samples performed to determine the chemical oxygen demand, the catalogs of the DR 7000 photometer filtration machine were used.

Total Suspended Solids (TSS) and Mixed Liquid Suspended Solids (MLSS):

To measure total suspended solids in the wastewater, the 2540D method from the Standard Methods textbook was used, and in which the wastewater was filtered using a fiberglass filter and is dried at a temperature of 103-105 degrees centigrade, after which the weight of the dried solids is reported in mg/L.

The sedimentation capacity of the sludge: To determine and measure this property, the 2710C method from the Standard Methods textbook was used.

(pH): To measure and determine this property, the 4500-HB (the electrode method) was adopted and used from the Standard Methods textbook.

(DO): To measure this property, the 4500OG (membrane electrode) method from the Standard Methods textbook was used.

Nitrogen and phosphorus compounds:

To carry out the above-mentioned experiments, the catalogs of the DR 7000 photometer filtration machine were used.

Total coliforms and fecal coliforms: the 9223 method from the Standard Methods textbook was used.

After measuring and determining the target parameters, the contaminant removal yield was calculated, and then the figures obtained by this research was compared with the standards set by the Iranian Environmental Protection Agency (Iranian Environmental Protection Agency, 1999). SPSS was used to statistically analyze the data.

RESULTS

The results obtained from the experiments conducted on the wastewater influent and effluent streams are summarized in Table 1 and 2. The results presented in Table 3 show that the contaminant removal yield is 85.59% for TSS, 82.21% for BOD_5, 82.02% for COD, 37.90% for $N\text{-}NH_3$, 46.36% for $P\text{-}PO_4$, 99.94% for Tc, and 99.29 for Fc.

Given the obtained results and the comparison of the amount of measured contaminants with the standards set by the Iranian Environmental Protection Agency as presented in Table 4, there can be observed a significant difference between the measured BOD_5 and COD ($P>0.05$) and also between the mean fecal coliforms and total coliforms with the amounts proposed by the Iranian Environmental Protection Agency for the effluent being emptied into surface waters and agricultural waters ($P>0.001$),

Figure1. The general plan of the treatment plant modules.

Table 1. The average of the statistical variation of the measured parameters in the influent stream in the sampling period.

Sampling Time / Parameter	21 Mar – 20 Apr	21 Apr – 21 May	22 May – 21 Jun	22 Jun – 22 Jul	23 Jul – 22 Aug	23 Aug – 22 Sep	23 Sep – 22 Oct	23 Oct – 21 Nov	22 Nov – 21 Dec	22 Dec – 20 Jan	21 Jan – 19 Feb	20 Feb – 20 Mar	Mean	Maximum	Minimum	Standard Deviation
pH	7.6	7.6	7.3	7.6	7.4	7.5	7.4	7.5	7.5	7.5	7.7	7.5	7.5	7.7	7.3	0.10
Temperature (°C)	18	23	27	29	30	28	24	18.5	15	14	12	14	21	30	12	6.62
TSS (mg/L)	155	139	147	144	167	158	106	192	195	200	182	185	168.5	200	139	21.41
BOD_5 (mg/L)	220	248	290	320	315	265	250	235	240	213	290	275	263.4	320	213	42.7
COD (mg/L)	358	390	550	480	516	435	422	360	413	400	460	452	438.5	550	358	58.8
TN (mg/L)	15.6	17.5	18.5	18	17.5	16	14.5	15.6	19	15	13.7	14.5	16	19	13.7	1.75
$N\text{-}NH_3$ (mg/L)	12	14	12	13.5	12.5	10.7	12	13	14.5	11.5	10.5	10	12	14.5	10	1.41
$P\text{-}PO_4$ (mg/L)	7	9	9	9.5	9	8	8	9	8	9	8.5	7.5	8.4	9.5	7	0.79
Tc (No/100 mL)	$7*10^7$	$9.5*10^7$	$12.5*10^7$	$8*10^7$	$7.5*10^7$	$9*10^7$	$7*10^7$	$8.5*10^7$	$7.5*10^7$	$7.5*10^7$	$8*10^7$	$7*10^7$	$8*10^7$	$12.5*10^7$	$7*10^7$	-
Fc (No/100 mL)	$4.5*10^7$	$5*10^7$	$4*10^7$	$6*10^7$	$4.5*10^7$	$5*10^7$	$5.5*10^7$	$4.5*10^7$	$30*10^6$	$25.5*10^6$	$4*10^7$	$27*10^6$	$4*10^7$	$6*10^7$	$25.5*10^6$	-

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Table 2. The average of the statistical variation of the measured parameters in the effluent stream in the sampling period.

Sampling Time / Parameter	21 Mar – 20 Apr	21 Apr – 21 May	22 May – 21 Jun	22 Jun – 22 Jul	23 Jul – 22 Aug	23 Aug – 22 Sep	23 Sep – 22 Oct	23 Oct – 21 Nov	22 Nov – 21 Dec	22 Dec – 20 Jan	21 Jan – 19 Feb	20 Feb – 20 Mar	Mean	Maxi-mum	Mini-mum	Standard Deviation
pH	7.8	7.9	7.6	7.9	7.8	7.8	7.6	7.8	7.8	7.6	7.9	7.7	7.7	7.9	7.6	0.11
Temperature (˚C)	15	20	24	28	27.5	28.5	22	16	12	9.5	8.5	12.5	18.6	28.5	8.5	7.34
TSS (mg/L)	22	19	20	21	23	18	19	28	30	34	31	29	24.5	34	18	5.55
BOD5 (mg/L)	40	44	46	38	46	48	47	45	46	52	50	50	46	52	38	4.02
COD (mg/L)	67	75	83	70	75	78	82	75	78	80	80	78	77.5	83	67	4.69
DO (mg/L)	0.9	1.2	1.3	1.7	1.5	1.4	1	1.8	1.6	1.4	1.5	1.7	1.4	1.8	0.9	0.2
N-NH3 (mg/L)	7.5	9	9	9.5	8	6.5	9	7	6.5	5.5	7	6	7.5	9.5	5.5	1.33
N-NO3 (mg/L)	8	9	10	8	9	8.5	7	5	7	4	4.5	4	7	10	4	2.03
N-NO2 (mg/L)	0.7	0.5	0.9	1.3	1	0.8	0.5	0.8	0.6	0.7	0.6	0.5	0.74	1.3	0.5	0.23
P-PO4 (mg/L)	5	5	4	5.5	5	4.5	5	3.5	4	3.5	5	4	4.5	5.5	3.5	0.62
Tc (No/100 mL)	$43.5*10^3$	$5.5*10^4$	$5*10^4$	$6*10^4$	$7.5*10^4$	$4*10^4$	$6.5*10^4$	$4.5*10^4$	$27.5*10^3$	$31*10^3$	$36.5*10^3$	$41*10^3$	$47*10^3$	$7.5*10^4$	$27.5*10^3$	-
Fc (No/100 mL)	$3*10^4$	$26.5*10^3$	$29*10^3$	$2.5*10^4$	$3.5*10^4$	$2.5*10^4$	$3*10^4$	$19.5*10^3$	$15.5*10^3$	$17*10^3$	$22*10^3$	$21.5*10^3$	$24*10^3$	$3.5*10^4$	$15.5*10^3$	-

Table 3. The contaminant removal yield for the measured contaminants in the wastewater treatment plan of Khorramabad, Iran (%)

Sampling Time / Parameter	21 Mar – 20 Apr	21 Apr – 21 May	22 May – 21 Jun	22 Jun – 22 Jul	23 Jul – 22 Aug	23 Aug – 22 Sep	23 Sep – 22 Oct	23 Oct – 21 Nov	22 Nov – 21 Dec	22 Dec – 20 Jan	21 Jan – 19 Feb	20 Feb – 20 Mar	Mean	Maximum	Minimum	Standard Deviation
TSS (mg/L)	85.80	86.33	86.30	85.41	86.22	88.60	88.12	85.41	84.61	83	82.96	84.32	85.59	88.60	82.96	1.73
BOD5 (mg/L)	81.81	82.25	84.13	88.12	85.39	81.88	81.20	80.85	80.83	75.58	82.75	81.81	82.21	88.12	75.58	1.84
COD (mg/L)	81.28	80.76	84.90	85.41	85.46	82.06	80.56	77.22	81.11	80	82.60	82.74	82.02	85.46	77.22	3.16
N-NH3 (mg/L)	37.50	35.71	25	29.62	36	39.25	25	46.15	55.17	52.17	33.33	40	37.90	55.17	25	9.56
P-PO4 (mg/L)	28.57	44.44	55.55	42.10	44.44	43.75	37.50	61.11	50	61.11	41.17	46.66	46.36	61.11	28.57	9.47
Tc (No/100 mL)	99.93	99.94	99.96	99.92	99.90	99.94	99.90	99.94	99.96	99.95	99.95	99.94	99.94	99.96	99.90	0.26
Fc (No/100 mL)	99.93	99.94	99.92	99.95	92.22	99.95	99.94	99.95	99.94	99.93	99.94	99.92	99.29	99.95	92.22	2.23

Table 4. The standards set by the Iranian Environmental Protection Agency for the disposal of wastewater and reuse of effluents (Iranian Environmental Protection Agency, 1999).

Contaminant	Emptied into surface waters	Emptied into absorbing wells	Used for agriculture and irrigation
BOD5 (mg/L)	30	30	100
COD (mg/L)	60	60	200
TSS (mg/L)	40	-	100
DO	2	-	2
pH	6.5-8.5	5-9	6-8.5
Ammonium based on NH4	2.5	1	-
Nitrite based on NO2	10	10	-
Nitrate based on NO3	50	10	-
Phosphate	6	6	-
Total coliform	1000	1000	1000
Fecal coliform	400	400	400

DISCUSSION AND CONCLUSION

Comparing the obtained figures with the standards set by the Iranian Environmental Protection Agency for the effluent emptied into surface waters and the effluents used for agriculture, we can say that the wastewater effluent can be used for agriculture and irrigation purposes, and the measured items are lower than the standards, no significant difference being observed between the standards set by the Iranian Environmental Protection Agency for the disposal of the effluent for irrigation purposes and the results of this study ($P<0.05$). The effluent from this wastewater treatment plant may not be emptied into surface waters, because based on the statistical tests, in case of BOD_5, COD, and $N\text{-}NH_3$, there are significant differences between the measured amounts and the standards related to the effluents emptied into surface waters ($P>0.05$). Additionally, a comparison of the total coliforms and fecal coliforms present in the effluent with the standards set by the Iranian Environmental Protection Agency for waters emptied into surface waters and used for agricultural and irrigation purposes shows that there is a significant difference between the measure amounts and the standards ($P>0.001$). Therefore, the effluent may not be emptied into surface waters and used for agricultural and irrigation purpose in terms of microbial standards.

Variations in the Influent

The mean discharge of the influent stream in the first phase of the treatment plant is 30193 m^3 each day. Considering the initial design criterion (at most 24100 m^3 each day), the additional hydraulic is quite apparent. Moreover, due to the entrance of surface waters and floods as a result of heavy rainfall into the wastewater collection system, the variation coefficient of the influent stream is rather great. In other words, the stream distribution is uneven and shows great variation. A comparison between the mean measured amounts during different months with the initial design criterion shows a significant difference (sig > 0.01). It is also important to note that because no parshall flume was installed on the second phase of the treatment plant, during the sampling period, the measurement of the influent to this phase was not possible. But the discharge of the wastewater influent stream into the second phase of the treatment plant was estimated to be similar to that of phase one.

Variations in the Concentration of TSS, BOD_5, and COD in the Influent Stream

Based on the results of the statistical analysis, it can be observed that the treatment plant has an everyday and average influent stream. Comparing the mean BOD_5 of the influent stream with the initial design criteria, we can find no significant difference between the measured amounts and the initial BOD_5 (sig < 0.01). This issues indicates that the concentration of this contaminant has not changed or increased considerably over time.

Variations in pH and Temperature in the Influent and Effluent Streams

Based on the results, little difference can be observed between the pH in the influent and effluent streams.

But generally speaking, pH in the effluent is slightly higher than the pH in the influent. Additionally, increases in the influent temperatures correspond with increases in the effluent temperatures. But the increase in the effluent temperature has not been as dramatic. Variations in the temperature of the influent was between 12 to 30 degrees, while the temperature of the effluent was between 8.5 and 28.5 degrees centigrade. Generally, effluent temperature is lower than influent temperature. This issue can be explained by the higher temperatures of the untreated wastewater, due to its freshness.

Variations in pH in Different Parts of the Treatment Plant

The average pH in different research stations was recorded as between 7.6 to 7.8. Low pH indicates the production of acids and consequently the generation of odors in the pools. Therefore, pH must be maintained at levels higher than 7.5. No significant difference was found between the measured values in the similar units of the first and second phases of the treatment plant ($sig < 0.01$).

Variations in Dissolved Oxygen in Different Parts of the Treatment Plant

The mean dissolved oxygen was measured as 0.4 to 0.5 mg/L in the sedimentation pools, and 4.1 to 5.6 mg/L in the aerated lagoons. This issue indicates the abnormally high levels of dissolve oxygen in the aerated lagoons. The range of variations of the dissolved oxygen was quite different from the optimum amounts of 1 to 2 mg/L during the sampling period. No significant difference was found between the measured values in the similar units of the first and second phases of the treatment plant ($sig < 0.01$).

Variations in TSS in Different Parts of the Treatment Plant

The removal levels of the suspended solids materials in the anaerobic pond, aerated lagoon, and the sedimentation pond was at the optimum level, and the mean suspended solids in the effluent was lower than the standard levels. In the initial treatment, some part of the organic matter and the suspended solids is separated from the wastewater. This separation is usually performed using physical operations like coarse degree screening and initial sedimentation in the anaerobic ponds. In secondary treatment, the main objective is to remove the biodegradable organic matter and the suspended solids which are separated in the sedimentation ponds. A significant difference can be observed between the similar units of the first and second phases ($sig > 0.01$).

Variations in the SVI Index in Different Parts of the Treatment Plant

Variations in this index indicate the proper sedimentation of the sludge and lack of bulking problems in the treatment plant. Since the wastewater effluent is a result of household activities, and does not contain compounds aggravating bulking, this phenomenon was not observed in the treatment plant. The mean value of this index during the sampling period in the sedimentation pond was 39.7 to 74.5, which is at an acceptable level. Comparing the measured values shows a significant difference between the similar units of the first and second phases of the treatment plant ($sig > 0.01$).

Variations in the Concentration of TSS, BOD_5, and COD in the Effluent

The concentrations of BOD_5 and COD in the effluent show some fluctuations, but the concentrations of these same contaminants in solution form show little variations. This can be explained by the fact that the cause of these fluctuations is related to the part of the contaminants that are suspended. Since it was attempted to take samples during times when the streams were at a maximum volume, these fluctuations could have been generated when the treatment plant was facing abnormally high loads. A significant difference was observed between the measured values during different months ($sig > 0.01$).

The Efficiency of the Treatment Plant in the Removal of TSS, BOD_5, and COD

Considering the results, it can be observed that the average removal efficiency for these contaminants is about 85.59, 82.21, 82.02 percent. The optimum removal yield for BOD_5 using the aerated lagoon method was between 75 and 90%, and the initial design criterion of the system in the removal of the BOD_5 was assumed to be 88.82% for BOD_5 and 76.26% for TSS. A significant difference was observed in comparing the mean removal rates of these contaminants with the initial design criteria (sig > 0.01).

Variations in the Concentration of Nitrogen and Phosphorus Compounds in the Effluent

The wastewater treatment plant in Khorramabad was designed to remove the essential contaminants, and the removal of nitrogenous and phosphorus-containing nutrients is not one of its objectives. Therefore, these parameters were studied. Given the obtained results, it is clear that the amounts of nitrates and nitrites in the effluent were at the standard level and the amount of ammonia was higher than the acceptable level. The low concentration of the phosphates in the effluent can be explained by the use of good and standard detergents and low level of phosphates in them. No significant difference was found between the measured values across different months (sig < 0.01).

Variations in the Number of Counted Bacteria in the Effluent

Based on the results of the experiments, it can be observed that the mean number of total coliforms and fecal coliforms in the effluent is much higher than the initial design criterion (sig > 0.01). The reason for this issue is that the effluent does not undergo disinfection. This issue is the most serious problem in the treatment plant, which reduces the removal yield for the contaminants and the violates the standards related to the effluents.

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Data sent by the Aqufin company (organization: in the Flemish region that designs. Finances, constracts and operates, the supra - communal in restructure for the treatment of urban wastewater)

