Journal of Engineering and Applied Sciences 14 (12): 3997-4003, 2019
ISSN: 1816-949X
© Medwell Journals, 2019

Evaluation of the Performance Efficiency of Al-Najaf City Sewage Treatment Plant

Tagreed Hameed Khlif and Fatima Mohsen Kizar
Faculty of Engineering, University of Kufa, Najaf, Iraq

Abstract: Trickling filters are one of the biological treatment methods used to treat the wastewater before being discharged to the receiving water (rivers and drains) in order to keep water quality within specifications and hence can be used for other purposes. This study considers the performance evaluation of the sewage treatment plant in Al-Najaf city. Laboratory tests were carried out on the influent and effluent wastewater of the plant in 2014 and continued for 12 months (from Nov. 2014-2015). The determinants of environmental pollution of effluent wastewater that have been considered and evaluated comprise Biological Oxygen Domain (BOD), Chemical Oxygen Domain (COD), Total Suspended Solid (TSS), Phosphate ion $(PO_4)^{-3}$, Sulphate ion $(SO_4)^{-2}$, Nitrate $(NO_3)^{-3}$, Nitrite ion $(No_2)^{-3}$, Hydrogen ion (pH), Chloride ion $(CL)^{-1}$, ammonia (NH_3), H_2S, grease and oils. Removal percentages have been employed as the quantitative measure for evaluating the performance efficiency of the sewage treatment plant. Based on the analysis results it was found that the removal percentages of (BOD), (COD) and (TSS) are 72.26, 63.26 and 43.7%, respectively. Similarly, the values of PO_4, SO_4, CL and NH_3 are 19.1, 9.64, 13.72 and 35.73%, respectively whereas the percentages regarding H_2S and grease and oils are 71.06, 28.05%. The results showed removal percentages with negative values for nitrate, nitrite and hydrogen ions that is the external concentrations were higher than internal ones due to the absence of advanced treatment in the plant. According to the results, the plant performance efficiency is generally acceptable, however, most of the concentrations of the pollutants of effluent wastewater exceeded the corresponding Iraqi standard specification due to the extra load resulted from internal and international visitors to Al-Najaf city in religious occasions.

Key words: Wastewater, treatment, BOD, Najaf, Total Suspended Solid (TSS), Biological Oxygen Domain (BOD)

INTRODUCTION

Wastewater typically includes domestic waste, industrial waste and agricultural run-off. All these types of wastewater can individually or collectively contaminate the environment. Therefore, wastewater must be carefully treated before being released to the environment to prevent pollution. Characteristics of wastewater are mainly governed by population density and geographical location of the area under study. The selection of suitable treatment method for wastewater depends on many criteria including capital and maintenance costs, location and availability of land, flexibility in operation and effluent's required standards. These criteria are affected by several factors such as population, organic loads, type of sewerage system, temperature, area of treatment plant and location topography (Al-Khalaf, 2011).

In the treatment plant of Al-Najaf city, untreated water is pumped by pumping station to the project which contains preliminary, primary and secondary treatments in addition to chlorination and sludge treatment. The first treatment includes removing the large solid objects and suspended minerals as they can cause malfunctions in equipment and rollers. The wastewater then pumped to the first sediment tank and then distribution tank which distributed to four biological filtered by the trickling filters where secondary treatment is started. Water treatment is pumped into the secondary sedimentation tanks and then into the primary fermentation tanks (Palmer, 2004).

Break sludge by an aerobic bacteria results methane gas. The fermentation reduces about 30-50% of biological blocks for sludge and also minimizes the level of disease associated with non-fermented sludge. Fermentation processes should be at a regular rate of around 18-20 days in order to be completed. Fermented sludge is pumped into drying tanks where dry sludge is removed after (10-14) days, however, in Winter due to humidity and low temperature the period is usually increased to 4 weeks. Figure 1 shows the mechanism of operation treatment plant. Note that chlorination unit was stopped for safety purposes. The objective of this study is to increase the treatment efficiency of the influent sewage, so that, the effluent sewage characteristics are within the acceptable standard limits and hence, improving the current conditions of aquatic environment.

The area study: Al-Najaf Province is known to be one of the hottest and driest places in Iraq. It is situated between

Corresponding Author: Tagreed Hameed Khlif, Faculty of Engineering, University of Kufa, Najaf, Iraq

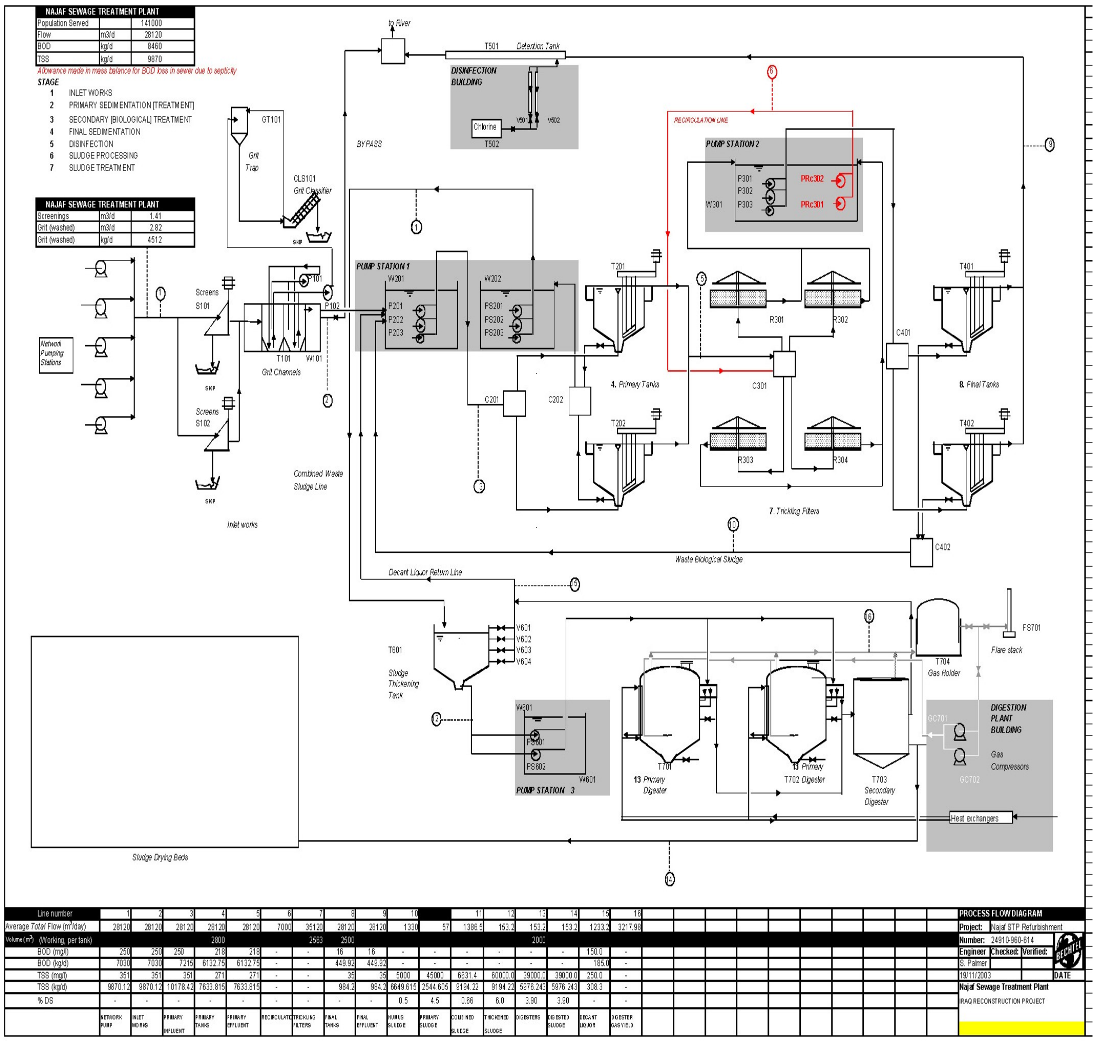

Fig. 1: The process flow diagram of Najaf sewage treatment plant

Fig. 2: The aerial photo of study area (Khassaf, 2017)

(42°50′-45°44′) longitude and (29°50′-32°21′) latitude about 180 km South of Baghdad and nearly 10 East of the Al-Kufa River. The average ground elevation level in the area is about 55 m above the sea level. Najaf sewage treatment plant is located in Al-Barakia Region which lies about 3 km from the center of Al-Kufa city. Figure 2 shows an aerial photo for the Najaf sewage treatment plant. The plant is designed to receive a load of 140000 citizens and the characteristics of final flow is to be 20 mg/L of BOD and 30 mg/L of S.S. The highest rate of flow is 27000 m^3/day (Khassaf, 2017). The plant was established in 1982 and has recently been rehabilitated. The treatment mechanism in the plant is non-advanced and classical. It lacks of Chlorine, Phosphate, Sulphate and Nitrate processing unit. Najaf is a holy city, thus, it hosts very large numbers of visitors on religious occasions, so, it is very important to evaluate the viability of the plant to accommodate this extra load.

Table 1: Methods of measurement of determinants of pollution

Determinants	BOD	COD	TSS	PO_4	pH	SO_4	CL	NO_3	NH_3	O&G
Methods of measurement	5-Day BOD test	Closed reflex colorimetric	Tss (103-105c)	Vanadomolybdo phosphoric acid colorimetric	pH-Schott	Gravimetric method with drying of residue	Argentometric	Indigo olometric	Tetimetric	Partition-Gravionetric

MATERIALS AND METHODS

Data collection and methods of measurments: The experimental work of this study was performed in Al-Najaf sewage treatment plant to study efficiency of waste water and hence, plant's performance. The experimental work was conducted between Nov. 2014-2015. All tests were conducted at Al-Najaf Water and Sewerage Laboratory. The analysis samples were taken 4 times/month for performing BOD, COD, TSS, PO_4, SO_4, NO_3, CL, NH_3 and O&G tests. Samples were collected from influent waste water in the primary tanks and from final effluent of the treatment plant. The flow shall be measured every hour by flow meter and recording the readings for 48 h. The study also included measuring the changes that occur in the flow rate during the day and effect of seasons and temperature on these rates. Determinants of pollution are measured by recognized measurement methods as shown in Table 1.

RESULTS AND DISCUSSION

The untreated water that entered the plant contains high unacceptable concentrations of pollutants according to the determinant's limits stated in the Iraqi standard specifications as shown in Table 2. This is an expected result of non-processed polluted water disposed to Al-Kufa River. The risk of this water increases when the river water level decreases due to drought and also when people use the river water directly, especially, the villages located on the banks of river. The results of study state that influent concentration values of BOD is within 380-116.5 mg/L, values of COD range is within 410-259.3 mg/L and TSS range is 246.25-157.6 mg/L.

The comparison of these values with the permissible concentrations of pollution determinants highlights the importance of treating contaminated water before the disposal to the river. High values of BOD and COD represent high concentration of organic materials that consume the dissolved oxygen which is essential for aquatic environment. High values of TSS make water invalid to be used for human and can kill the aquatic life that cannot bear the salt medium. Acid function (pH) range 7.6-6.34 mg/L is within the permissible limits according to the Iraqi standards. The range for sulphate concentration is 1224.75-731.5 mg/L. High concentration of sulphate is due to transformation of some types of sulphric bacteria that changed sulphides to sulphates.

The values of Hydrated Sulphide (H_2S) of 40-18 mg/L exceed the Iraqi standard limits. High concentrations of Phosphate (PO_4) due to cleaning powders also exceed the limits. It has been reported that the existence of phosphate in domestic wastewater can contribute significantly to the occurrence of Eutrophication phenomenon. In addition, nitrate concentrations exceed the permissible standard values because of the activity of aerobic bacteria which works on the oxidation of Nitrogenous materials to ammonia and then to nitrite and finally to the nitrate; this is besides the waste water contains nitrogen that changes to nitrate. High concentration of oils and greases were found to be 146 mg/L in May. It can have serious implications on aquatic organism because it consumes dissolved oxygen and obscures the sunlight. Hence, it hinders the process of photosynthesis and clogs the filters.

The treated water at plant showed high concentrations of pollutants compared to Iraqi standards. Table 3 shows the concentrations of pollution determinants of effluent wastewater in Al-Najaf city treatment plant. The results of this study reveal high rates of concentrations of pollution determinants compared with laboratory tests that were carried out at the plant in 2010 as shown in Table 4. This deterioration in plant performance can be seen as a result of several relevant but different factors; increasing in population during the recent years, excessive loads on treatment plant during religious occasions and power failure and problems in deposition tanks.

High concentrations of BOD (especially, during November and December of 2014 and January-March of 2015), concentrations of COD and concentrations of TSS exceeded the allowable limits. Treated water indicates the basal quality more than the influent wastewater for variation of acidic function due to increase of Nitrate. In addition, concentrations of SO_4 and H_2S were with rates higher than specification of Iraqi standard over all study months. Phosphate treatment was not completely effective, concentration was high in some months and low in others due to the lack of phosphate processing unit. Results also proved the plant deficiency in reducing the concentration of chloride below the allowable limits along the months of study.

Table 2: Monthly average of influent sewage of treatment plant

Determinants/Months	BOD	COD	TSS	pH	SO_4	H_2S	PO_4	CL	NO_2	NO_3	NH_3	O&G
November	160	327.8	201.6	7.14	854.8	16.66	4.78	360	0.325	4.5	20.24	97.4
December	217.5	335.75	234.5	7.325	830	19	4.1	372.5	0.2	4.1	28.125	141.6
January	380	282.25	246.25	6.775	903.5	18.25	4.275	343	0.2	Nil	21.84	121
February	180	285	207	7.6	731.5	18.5	3	319	0.1	1.25	21.45	108.5
March	172	267	232	7.5	830	18.1	3.9	349	0.14	1.3	18.6	95.2
April	142	259.3	204.6	7.56	864	18	4.13	335.6	0.2	Nil	23.5	90.33
May	140	410.75	188	7.05	1224.75	26.25	4.275	329	0.15	Nil	26.175	146
June	148	385.2	189.2	7.22	763.8	20.6	6.04	320.25	0.26	Nil	21.8	104
July	160	385.5	193	7.45	752.5	23	3.25	374	1	Nil	21.8	103
August	126	320.4	157.6	6.34	741.6	40	5.2	304.2	0.44	1	17.012	90.8
September	116.6	383	180.66	6.6	823.6	40	5	295.6	0.3	5	16.73	80.66
October	156.66	278.3	170	6.533	823.6	37.33	5.53	290.6	0.466	Nil	17.7	111.6

Table 3: Experimental results of effluent wastewater

	Standard specification											
Determinants	BOD(40)	COD(100)	TSS(60)	pH(9.5-6)	SO_4(400)	H_2S(3)	PO_4(3)	CL(600)	NO_2(0)	NO_3(50)	NH_3(10)	O&G (4)
November	46.25	109.75	126.5	8.075	715.5	3.5	2.3	300	0.97	27.25	11.875	44.1
December	62.75	129.5	134.5	8	701.5	18	3.35	322.5	1.05	15.5	20.975	66
January	100	146.75	148.5	8.5	806.25	9.02	2.7	301.7	0.92	12.75	7.82	92
February	87.5	112.5	133	8.1	706.5	9	2.45	306.5	0.1	10	15.85	96
March	69	110	115	8.3	710	9.3	2.95	311.2	0.15	8.6	12	86.3
April	35	120	94	8.43	713.5	9.85	8.5	314	0.3	9.33	18.46	91.66
May	25	114.75	110.25	8.5	978.5	3.92	3	286.5	NIL	11	20.15	95.75
June	33	103.8	108	8.58	735.2	3.76	4.62	274	0.43	13.6	11.98	68
July	32.5	107.5	106	8.1	795.5	3.4	2.3	281.5	0.95	20	12.6	69
August	30	139.8	79.6	7.5	750	1.84	2.26	257.2	0.15	19.4	8.17	64
September	25	114.3	107.3	7.36	801.3	5.53	2.1	249	0.1	27.6	10.96	70
October	36.6	131.6	91.3	7.93	752	8.5	6.8	240.6	0.1	13.3	13.06	85.33

Table 4: Statistical annual results of influent and effluent water and total removal percentage

	Internal concentrations			External concentrations			
Determinants	Average	Range	SD	Average	Range	SD	Removal percentage
(BOD)	174.89	380-116.6	66.77	48.5	100-25	24.27	72.26
(COD)	326.68	410.75-259.3	51.15	120	146.75-109.75	13.14	63.26
(TSS)	200.36	246.25-157.6	25.5	112.8	148.5-79.6	19.08	43.7
(pH)	7.09	7.6-6.34	0.415	8.11	8.58-7.36	0.37	-
(SO_4)	845.3	1224.75-731.5	125.225	763.8	978.5-701.5	74.37	9.64
(H_2S)	24.64	40-18	8.73	7.13	9.85-1.84	4.26	71.06
(PO_4)	4.45	6.04-3	0.85	3.6	8.5-2.1	1.95	19.1
(CL)	332.72	374-290.6	24.59	287.05	322.5-257.2	25. 85	13.72
(NO_2)	0.315	1-0.1	0.23	0.435	1.05-0	0.395	-
(NO_3)	1.429	5-0	1.86	15.69	27.6-8.6	6.269	-
(NH_3)	21.24	28.125-16.73	3.37	13.65	20.975-7.82	4.135	35.73
(O&G)	107.5	146-80.66	19.2	77.34	96-44.1	15.47	28.05

The treated water was with high concentrations of NO_2 and NO_3 compared with influent sewage water. This can be as a result of activity aerobic bacteria in oxidation of nitrogenous materials to ammonia and then to nitrite and eventually to nitrate. In addition, the waste water is containing Nitrogen that will change later to nitrate. The last reason is the nonexistence of advanced treatment for nitrate at the plant.

The high concentration of NH_3 above the allowable limits during the months of study can be attributed to the lack of treatment units of grease and oils. Evaluating the efficiency of Najaf sewage treatment plant was relied on the removal percentage or efficiency ratio which is calculated as: Removal percentage = [(Annual average of internal determinant concentration-Annual average of external determinant concentration)/Internal determinant concentration]×100. Iraqi standard specification (Jelaway,1998).

The evaluation of the treatment plant efficiency depends on removal percentage. According to the total removal percentages shown in Table 5 and comparing the concentrations of pollutions in effluent wastewater for 12 months with Iraqi specifications as shown in Fig. 3-14, it can be noticed that: The BOD is found with removal percentage of 72.26% which is acceptable percentage in the evaluation of the plant but the values of BOD concentration of effluent treated sewage exceeds the specification for the period from November 2014 until

Table 5: Results of laboratory tests of Najaf sewage treatment plant 2010

	Internal concentrations			External concentrations			
Determinants	Average	Range	SD	Average	Range	SD	Removal percentage
(BOD)	63.92	170–8)	15.237	9.89	(20–2)	3.874	84.52
(COD)	211.4	(953-112)	36.972	44.55	(88-13)	5.765	78.92
(TSS)	101.4	(222–54)	17.57	28.156	(58-16)	4.438	72.232
(PH)	7.68	(8.2- 7)	0.182	7.906	(8.6- 7.3)	0.222	-
(SO_4)	210.75	(1450-1095)	23.373	1031.06	(1369-741)	75.05	14.84
(PO_4)	1.83	(4.8-0.2)	1.246	2.13	(3.6–0.55)	0.211	16.39-
(CL)	406.06	(478–370)	9.877	354.39	(410–40.6)	39.06	12.72
(NO_3)	Nil	Nil	Nil	12.5	(21–0)	4.426	Nil
(NH_3)	21.05	(40.3 -15)	1.436	11.5	(34-7)	3.012	45.36
(O and G)	213.95	(482–95)	93.465	129.9	(261–21)	64.79	39.28

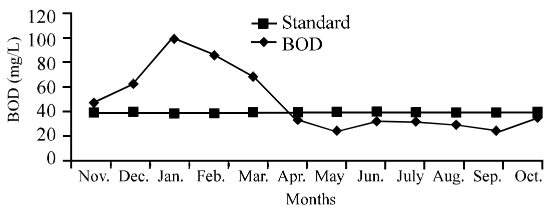

Fig. 3: Concentration of effluent BOD compared with the standard Iraqi specification

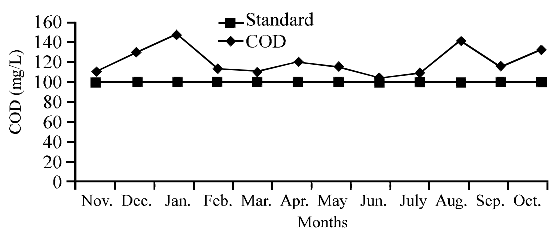

Fig. 4: Concentration of effluent COD compared with the standard Iraqi specification

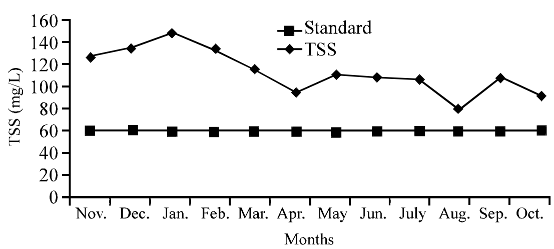

Fig. 5: Concentration of effluent TSS compared with the standard Iraqi specification

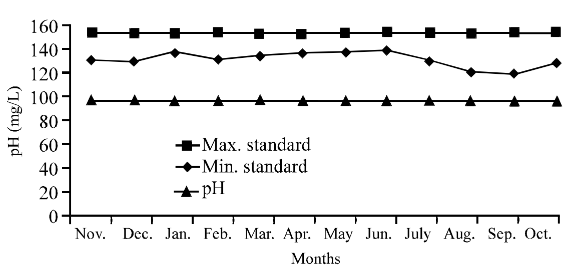

Fig. 6: Concentration of effluent pH compared with the standard Iraqi specification

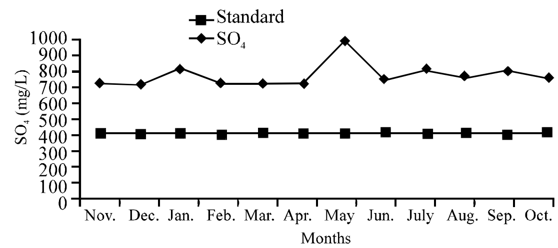

Fig. 7: Concentration of effluent SO_4 compared with the standard Iraqi specification

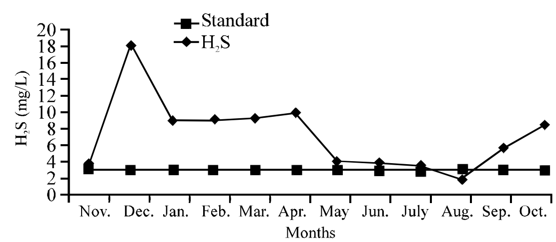

Fig. 8: Concentration of effluent H_2S compared with the standard Iraqi specification

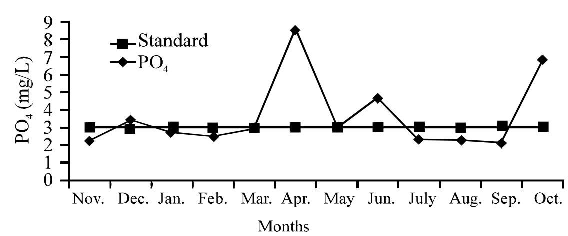

Fig. 9: Concentration of effluent PO_4 compared with the standard Iraqi specification

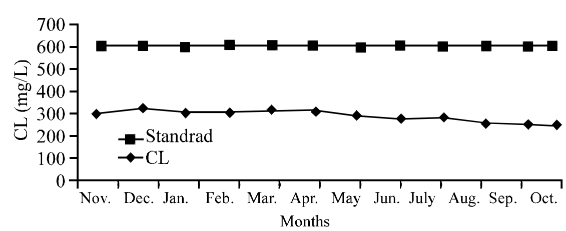

Fig. 10: Concentration of effluent CL compared with the standard Iraqi specification

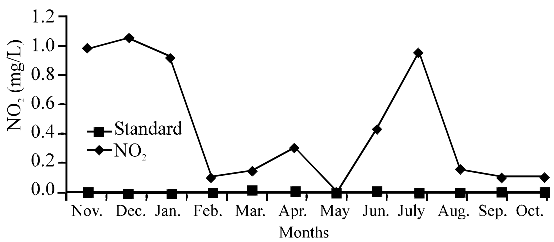

Fig. 11: Concentration of effluent NO_2 compared with the standard Iraqi specification

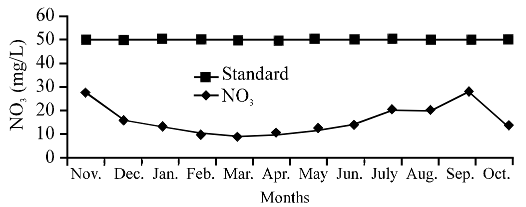

Fig. 12: Concentration of effluent NO_3 compared with the standard Iraqi specification

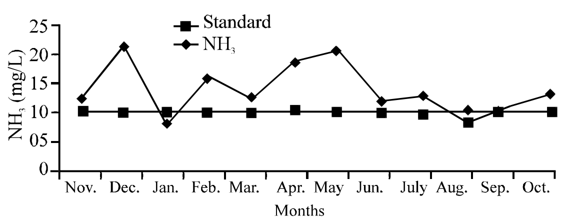

Fig. 13: Concentration of effluent NH_3 compared with the standard Iraqi specification

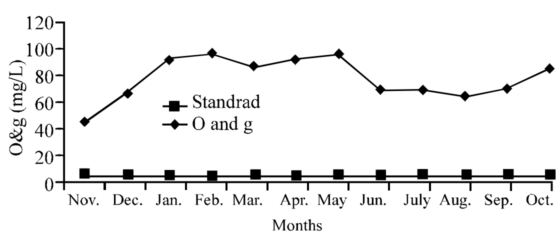

Fig. 14: Concentration of effluent O&G compared with the standard Iraqi specification

April 2015. This is probably because of the increasing number of arrivals to the city for religious tourism and also the maintenance of plant due to malfunction in the pumps (Fig. 3).

Removal percentage of COD is 63.23% which is acceptable percentage but the values of COD concentration in effluent treated sewage exceeded the specification as shown in Fig. 4. Removal percentage of TSS is 43.7%. The TSS concentration in effluent sewage is higher than the permissible limit as shown in Fig. 5. According to Fig. 6, the values of pH concentration of effluent treated sewage are within the permissible limits. The concentration of effluent treated sewage exceeds the influent value due to increase concentration of Nitrate which makes effluent treated sewage more basal than acidic; as a result, the removal percentage is negative.

The values of SO_4 concentration in effluent treated sewage exceed the specification as shown in Fig. 7 and they are quite close to the values of influent sewage water as a result the removal percentage was as low as 9.64%. Removal percentage of H_2S is 71.06% but the values of concentration of effluent sewage are higher than the permissible limit as illustrated in Fig. 8.

According to Fig. 9, PO_4 concentrations of effluent sewage exceed the specification during April, June and October in 2015 and were close to their concentrations in influent sewage water. The removal percentage was only 19.1%. The values of CL concentration of effluent treated sewage are within the specification as shown in Fig. 10 and quite close to values of influent sewage water; the removal percentage was 13.72%.

Removal percentages of NO_2 and NO_3 are negative values because their concentrations in the effluent treated sewage water are higher than in the influent water because of activity bacteria aerobic working on the oxidation of nitrogenous materials to ammonia and then to Nitrite and finally to nitrate. In addition, the waste water containing nitrogen changes to nitrate. Also, there is no advanced treatment plant for Nitrate. The concentrations of NO_3 in effluent treated sewage water are less than the specification as shown in Fig. 12. Figure 11 implies that NO_2 concentrations in effluent water are above the acceptable limit. The NH_3 is found to be with removal percentage of 35.73%; nevertheless its concentration in effluent treated sewage are higher than the permissible limit during all the study period except January and August as shown in Fig. 13.

Removal percentages of fats and grease are 28.05%. Their concentration exceeded the specification as shown in Fig. 14. The statistical annual results of waste water entering and draining from treatment plant and the removal percentages are listed in Table 5 (Steel and McGhee, 1979).

CONCLUSION

The analysis results showed that Al-Najaf treatment plant worked efficiently in removing the concentration of pollution but it failed in reaching the permissible limits of standard specification due to the extra loads on the treatment plant. The increase in the load on the treatment plant in most of the months as a result of the high numbers of tourists for religious tourism has compromised its efficiency significantly during this period. Most concentrations of pollutants were outside the limits of the Iraqi standards for several months and for various reasons related to maintenance, power failure and religious tourism. The removal efficiency for specific pollutants and for specific months was negative due to the lack of advanced treatment in the plant that relied on primary and biological treatment.

RECOMMENDATIONS

Developing of sewage treatment plant in Al-Barakia through expanding and operating of the chlorination unit and by adding an advanced units for treating nitrate, phosphates and sulphates. Coordinating with the Ministry of Electricity to exclude the plant from power turning-off program and to provide AC generators in the cases of power shutdown. Adopting effective monitoring for the industrial and service discharges drained from sewage network to the plant because they can affect the work of the plant and cause a defect in the concentration of chemicals. Designing the fat removal unit at the beginning of the plant as it can enhance plant operation. Cultivate green belt of palm trees or perennial trees around the plant to reduce the unpleasant odors from plant and to repel dust storm. City people are advised to add sterilization tablets for drinking water and to boil water for domestic use during the period of religious visits to the city.

REFERENCES

Al-Khalaf, S.K., 2011. Evaluate the Performance of Almaimirh. Babylon University, Babylon, Iraq,.

Jelaway, S.F., 1998. The performance of waste stabillization ponds in Kerbala City. MSc Thesis, University of Technology Sydney, Ultimo, Australia.

Khassaf, S.I., 2017. Reuse of treated sanitary sewage in Najaf city for agricultural purposes. Al Qadisiyah J. Eng. Sci., 4: 558-578.

Palmer, S.J., 2004. Najaf Wastewater Treatment Plant Operation and Maintenance Manual. Bechtel International Systems, San Francisco, California, USA.,.

Steel, E.W. and J.T. McGhee, 1979. Water Supply and Sewerage. McGraw Hill Book Company, Tokyo, Japan.