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Evaluation of Environmental Performance of Wastewater Treatment Plants in Countries with Crisis: Case Study from Iraq

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ABSTRACT

During last four decades, Iraq had faced multiple political crisis which reduced its ability to encounter emerging environmental problems. As of now, wastewater contamination is one problem that the country is lacking proper infrastructures capable of dealing with. The aim of this study is to evaluate the performance of wastewater treatment plants in the country over time. Barakia wastewater treatment plant is one of the major wastewater treatment plants in Al-Najaf province in Iraq. The plant was taken as a case study to test the trend of the environmental performance. Parameters of BOD_5, COD, TSS, PO_4, NO_3, NH_3, O&G, H_2S, and CL^- were used to test the performance. Ten years data were collected and evaluated. The plant showed downward ability to reduce contaminants efficiently, and recently, the plant turned to be one of the major polluters in the province. Overloading of the plant beyond its design capacity, high frequent power outage, absence of retrofitting advanced treatment such as filtration and nutrients removal, and lack of maintenance and repair parts were the main causes of the plant's poor performance. Iraq, due to its current economic situation may need an international assistance to reverse this trend of degradation.

التدهور في الأداء البيئي لمحطات معالجة مياه الصرف الصحي في البلدان التي تعاني من أزمات: دراسة حالة من العراق

الخلاصة

خلال العقود الأربعة الماضية، واجه العراق أزمات سياسية متعددة قللت من قدرته على مواجهة المشاكل البيئية الناشئة. حاليا مشكلة مياه الصرف الصحي هي واحدة من المشاكل التي يفتقر البلد إلى بنية تحتية قادرة على التعامل معها. محطة معالجة مياه الصرف الصحي في البراكية هي واحدة من محطات المعالجة الرئيسية في محافظة النجف في جنوب العراق. تم أخذ هذه المحطة كدراسة حالة لاختبار اتجاه الأداء البيئي لمحطات معالجة مياه الصرف الصحي في البلاد. على مدى عشر سنوات، أظهرت نتائج هذه الدراسة الانحدار التدريجي لكفاءة المحطة على تقليل الملوثات، ومن ثم تحولت هذه المحطة إلى أحد الملوثين الرئيسيين لنهر الكوفة في المنطقة. الأسباب الرئيسية لأداء المحطة الضعيف هي: زيادة الحمل او الضخ الى المحطة بما يتجاوز قدرتها التصميمية، الانقطاع المتكرر للتيار الكهربائي، عدم القدرة على اضافة مراحل المعالجة المتقدمة مثل وحدة الترشيح او وحدة إزالة النتروجين، ونقص الصيانة وندرة قطع الغيار. العراق، وبالنظر الى تردي وضعه الاقتصادي الحالي، قد يحتاج إلى مساعدة دولية لمعالجة هذا التدهور.

الكلمات المفتاحية

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Introduction

Wastewater Treatment Plants in Iraq

World wastewater treatment sector is facing major problem regarding the spread of pollutants in most of countries water bodies. The population increase as long with the increase in the consumption and economic activities had led to huge generation of pollutants in which mostly associated with wastewater generation and contamination of water resources. The disseminated pollutants in wastewater may spread diseases and outbreaks, threaten the aquatic life, endanger irrigation resources, and harm economic opportunities [1].

The wastewater treatment plants (WWTPs) are designed and operated to reduce pollutants went to rivers and streams. But, due to the influence of political conflicts or economic crisis, many of the pre-developing countries are still straggling to establish the required infrastructure for wastewater treatment. The impacts of pollution dissemination in these countries are severe. In Iraq, and due to continuous wars and crisis, the problem of inappropriate treatment becomes serious. This problem in addition to the absence of effective protection regulations against direct discharge of pollutants, combined with limited environmental awareness in both public and governmental representatives, had led the natural water system in the country to face considerable devastation.

The recent Iraq’s national water management system is incompetent of dealing with the increasing water pollution in the country. Wastewater treatment facilities in Iraq had faced high damage to its infrastructures during last four decades. Wars and sanctions had highly impacted the performance of whole wastewater treatment infrastructure, and epidemics like Cholera in Iraq had become more frequent than other countries [2].

According to the United Nations, six million people in Iraq have no access to clean water, and more than 500,000 Iraqi children access their water from rivers or creeks, and that over 200,000 access their water from open wells [3]. In the first six months of 2010, there were over 360,000 diarrhea cases as a result of polluted drinking water and lack of hygiene awareness among local communities, particularly vulnerable groups such as women and children. The report shows that “Every day at least 250,000 tons of raw sewage is pumped into the Tigris river threatening unprotected water sources and the entire water distribution system” [3].

The wastewater treatment sector in Iraq is administered by government. Currently, the lack of permanent governmental programs for environment protection, lack of expenses and insufficient operating budgets, unavailability of professionals, engineers, and skilled operators, unprofessional design and treatment of most of existing plants, unreliable electricity, lack of public awareness about the danger of direct discharge of wastewater to water courses, and a tendency to look for quick fixes rather than durable solutions to problems had led to serious deficiencies in operations in the country’s wastewater treatment plants [4].

Most of these plants were not designed based on a proper local data, and were constructed by inexperienced companies [5]. In addition to the improper design and implementation, the mechanical and electrical equipment at these plants have suffered from lack of spare parts, power shortage, and no preventative maintenance due to lack of expenses and trained operators. According to UNCEF/Iraqi’s Ministries (2011) report, the main problems facing the sanitation sector in Iraq are trespasses on the sanitation and rainwater networks, lack of awareness and misuse of sanitation networks, and scarcity and instability of electrical power needed for operating treatment and pumping stations [6].

In many cases untreated raw sewage is directly discharged into rivers, endangering the health of residents and downstream populations. United Nations reports in 2003 showed that none of the sewage treatment plants in the country were outfitted, and raw sewage is being discharged into rivers or lakes without proper treatment [7].

Several studies have evaluated the efficiency of WWTPs in Iraq [2, 4, 8, 9, and 10]. Alyaseri (2016) evaluated the wastewater treatment operations of a plant in the City of Alsamawah in south of Iraq. The study showed high exceedance to the standards for most of quality parameters such as BOD_5, COD, TSS, and nutrients. The study concluded that improper design and lack of maintenance are the main reasons for the deficiency in the treatment processes [5]. Alsaqqar et al. evaluated the performance of a WWTP in Al-Diwaniya, another city in the southern part in Iraq. The study indicated many operational problems that render the level of BOD_5, COD, TSS and NO_3 exceeded the disposal limitations [11].

For more understanding to the country’s wastewater treatment system and the degradation in its plant’s performance, more studies are needed, especially for those plants that were not subjected to detailed evaluations. Little studies were conducted to evaluate the performance of current wastewater treatment processes in Al-Najaf Province.

Study Objectives

The objectives of this study are to: 1) evaluate the performance of Barakia WWTP in Al-Najaf, one of the southern cities in Iraq, 2) test the trend of performance in the processes during last ten years, and 3) specify recommendations to improve current performance.

Materials and Methods

Barakia Wastewater Treatment Plant

Al-Najaf province is one of the major provinces in the central region of Iraq. The city population is about 900,000. As of now, the sewer system is serving around 25% of the population. The city is served with three plants of which Barakia WWTP is the largest plant that is located on the southern part of Kufa City. The plant was designed to treat 35,000 m^3/day. The design population equivalent is 140,000. During wet weather, the plant is capable of receiving as double as the flow during dry weather.

The plant is receiving wastewater from six central collection tanks located in various places in the city. The preliminary step of the treatment contains bar rack screens followed by two grit channels for grit removal. From grit channels, the wastewater is taken into the primary clarifiers then moved to trickling filters on which a bed of highly permeable media on whose surface a mixed population of microorganisms to convert most of BOD into settleable solids. These solids are then settled in the bottom of the secondary clarifiers and taken back to the primary clarifiers. Sludge is taken from the bottom of the primary clarifiers then transported to a sludge handling unit. The unit is consisting of one gravity thickener where the supernatant is back to the distribution chamber, and the settled sludge is pumped into two primary anaerobic digesters followed by one secondary anaerobic digester. Biogas is collected in a gas holder, then released and burned in a flare. Prior to discharge to Kufa River, effluent from the secondary clarifiers flows into a chlorine chamber for disinfection (the disinfection unit is not working as of now).

Data Collection

Data used in the evaluation was provided from Barakia WWTP Laboratory, and from the laboratory of the Office of Environment Protection in Al-Najaf. Data for ten years period (from January, 2006 to December, 2016) was collected. Influent and effluent of the wastewater treatment process for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), phosphates (PO_4), Nitrates (NO_3), ammonia (NH_3), oil and grease (O**&**G), hydrogen sulfide (H_2S), and chloride (CL^-) were collected. These parameters were used to compare effluents with standards and evaluate the process's efficiency.

Data for years 2015-2016 was used to evaluate current performance, while older data was used to show the trend of treatment in the plant. The compliance with local and international standards, which represents a major objective in the treatment processes, was used as an evaluation approach.

Results and Discussion

Table 1 shows the characteristics of the influent and effluent of wastewater treatment processes for ten parameters in two years. Statistics of concentrations of BOD_5, COD, TSS, NO_3, PO_4^{-3}, CL^-, NH_3, O&G, and H_2S are shown in the Table.

Table 1. Influent and Effluent Concentrations for Ten Parameters in Barakia WWTP.

Test		Range			Mean (±S.D)		Standards
BOD	in	100	to	380	160	±54	
	out	10	to	100	44	±25	40
COD	in	216	to	667	364	±109	
	out	94	to	206	135	±22	100
TSS	in	126	to	302	203	±41	
	out	48	to	180	111	±27	60
SO_4	in	589	to	2339	861	±209	
	out	542	to	1661	771	±141	250
PO_4	in	0.8	to	12.2	5.7	±2.8	
	out	0.5	to	15.5	3.0	±2.3	3
NH_3	in	11.2	to	30.8	20.3	±3.7	
	out	5.1	to	24.1	13.3	±4.5	10
NO_3	in	1	to	5	2.5	±1.6	
	out	3	to	40	15.6	±7.9	50
O&G	in	60	to	277	122	±45	
	out	28	to	150	83	±27	4
H_2S	in	12.1	to	46.4	28.0	±8.7	
	out	0.34	to	17	5.6	±3.7	3
CL	in	209	to	424	318	±35	
	out	189	to	344	271	±31	600

Iraqi effluent limits for BOD_5, COD, TSS, NH_3, PO_4, and H_2S are shown in Table 1. These limits are applied to all water bodies in the country. The quality and ability to tolerate pollutants, or the temporal or spatial variation are not considered in these limits. It is not clear how these limits were proposed and set, but it is clear that they are way less restricted than many other discharging limits around the world. In a state like Florida, U.S., one common set of wastewater discharging limits is 5 mg/L, 5 mg/L, 3 mg/L, and 1 mg/L for BOD_5, TSS, total nitrogen, and total phosphorous, respectively [12].

Suspended Solids

Most of grits and suspended solids have to be removed during the preliminary and primary treatment stages, respectively. If not removed properly, in addition to the problem of high TSS in the effluent, they would create more problems in the remaining stages of the processes. Results show that in some cases the concentration of suspended solids in effluent is higher than the influent to the plant, indicating that suspended solids are accumulated in the trickling filters or clarifiers which may cause the clog of some pipes and creating some anaerobic conditions in the bottom of some tanks.

Secondary treatment usually imposes a maximum effluent suspended solids concentrations of 30 mg/L [12]. Iraq's standard for suspended solids is 60 mg/L. The average concentration of TSS in the effluent was 111 mg/L, which is beyond the 60 mg/L limit. In significant number of sampling events, the plant was not able to comply with this limit. Among 72 sampling events taken in years 2015-2016 for the concentration of suspended solids in the effluent, none of them was below the 30 mg/L standard. The reduction in suspended solids for these 72 sampling events was averaged only 40% indicating high deficiency in the plant's processes. This deficiency in suspended solids removal is suspected to be related to the short retention time in the primary and secondary clarifiers due to overloading beyond the design capacity after the connection of three residential areas to the sewer system in year 2012. To show the impacts due to increase in flow to the plant, data for suspended solids and flow rate from previous years were gathered and arranged in Figures 1 and 2.

Figure-1 shows the total suspended solids concentrations in the plant's influent and effluent for the period between January 1st, 2006 and December 25th, 2016. The Figure also shows the Iraqi's acceptable limits for total suspended solids. The Figure shows that since mid-2012 effluent from the plant start to exceed the acceptable limits, and since that time plant was not able to comply with standards except in a few events. Figure 2 shows the monthly flow rate to the plant for the period between 2006 and 2012. The flow meter in the plant was disabled since August 2012 and no flow data was obtained until today. Negligence of correcting this situation and continuing operations on the same manner would highly hit the aquatic environment in Kufa River. High suspended solids concentration in wastewater discharged to rivers or lakes may cause settling of solids in the bottom and sludge build up. It also contributes to high decomposition causing more oxygen to be depleted, and reducing amount of light available for the photosynthesis of aquatic plants [13, 14]. Suspended solids may also function as carriers of toxics and pathogens that readily hang to the particles' sides [15, 16].

Figure 3 shows the annual percentage of non-compliance to standards for six parameters in the effluent of Barakia WWTP for the period from 2006 to 2016. The figure shows that noncompliance of total suspended solids concentrations in effluent was increased with time from 20% in year 2006 to 100% in the years 2012 and after. The lack of maintenance and spare parts is suspected to be another reason for high suspended solids in the discharged wastewater to the river. Economic crisis in the country had highly affected plants' ability to maintain an acceptable level of treatment. Although the continuous degradation in the quality of the wastewater discharged to river, no correction measure was carried out since that time.

Oxygen Demand

A serious environmental pollution may come from high levels of biochemical oxygen demand (BOD) or chemical oxygen demand (COD) in a stream. Contamination with these contaminants may deplete dissolved oxygen and create anaerobic state which may harm the aquatic life. The BOD_5 entering the plant ranged between 10 to 380 mg/L with an average concentration of 160±46 mg/L, while the wastewater leaving the plant ranged from 10 to 100 mg/L with an average of 44±25 mg/L. Over two years of operations, the maximum reduction of BOD_5 was 91%. However, the average reduction in BOD_5 was 70±10%.

The Iraq's BOD_5 standard for wastewater discharged to surface water is 40 mg/L. In two years (2015-2016), among 61 sampling events for the effluent BOD_5 concentration, 26 samples (43%) exceeded the 40 mg/L level (Figure 3). The plant was able to reduce the concentration of BOD_5 from 160 mg/L in the raw wastewater to 44 mg/L in the discharged wastewater. The reduction in BOD_5 wasn't in compliance with limits due to lack of spare parts and effective maintenance.

Figure 4 shows the BOD_5 in the influent and effluent wastewater and the standard concentration for a period of ten years. The Figure shows that most incompliance to the standards was occurred during the years 2012 and after most likely due to increase in the influent flow rate received by the plant, and the accumulation of solids during period of high flow rate started in 2012. The other expected reason is the insufficient aeration provided to wastewater in the trickling filters due to some anaerobic condition in the tanks, and impairment in some mechanical devices in clarifiers due to frequent power outage.

Chemical Oxygen Demand (COD) is usually higher than the BOD since it includes organic and inorganic substances that are difficult to be oxidized biologically, and can be oxidized chemically. COD was also reduced from an average of 364 mg/L in the raw wastewater to an average of 135 mg/L in the discharged wastewater for years 2015-2016. Iraqi's standards for concentration of COD in the discharged wastewater are not to exceed 100 mg/L. As can be seen in Table 2, among 69 sampling events for the COD concentration in effluent in two years, only 2 samples (3%) were lower than the 100 mg/L standard. These two samples were slightly lower than the 100 mg/L limit, and had initially low COD concentrations in the raw wastewater.

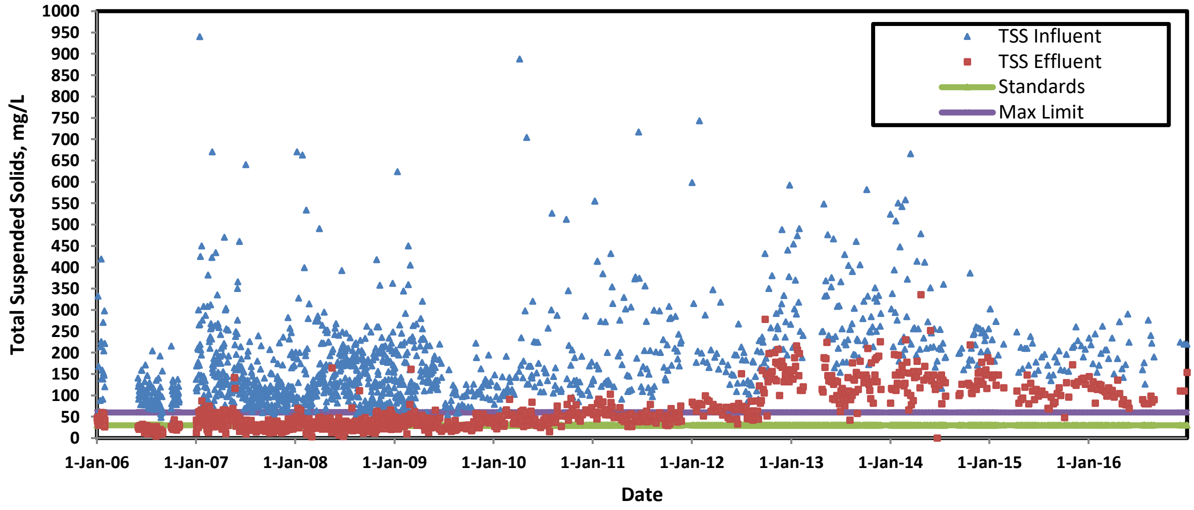

Figure 1. Total Suspended Solids in Influent and Effluent of Barakia WWTP for the Period from January 1st, 2006 to December 25th, 2016.

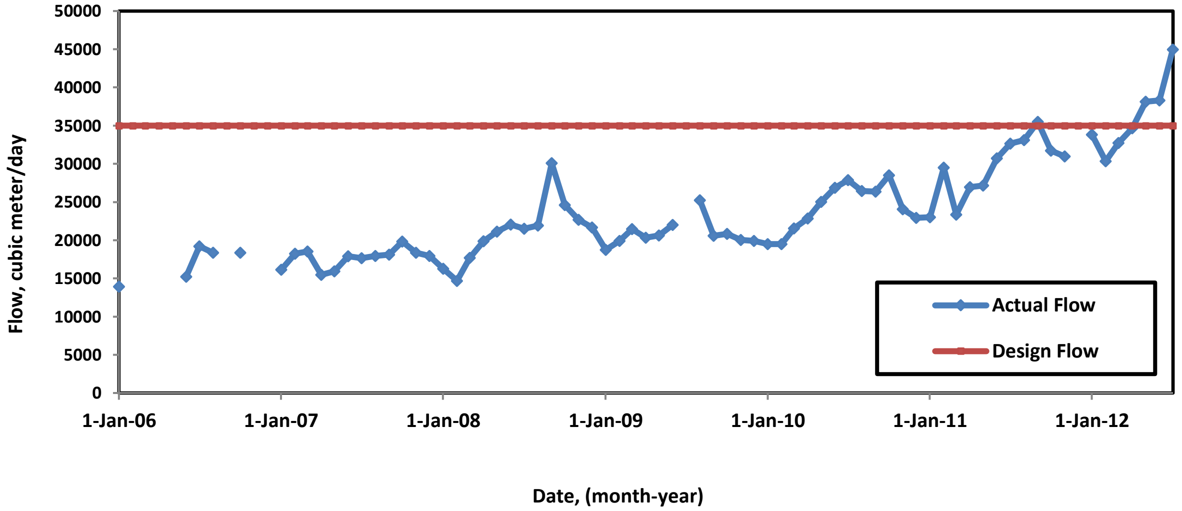

Figure 2. Average Monthly Flow Rate to Barakia WWTP for the Period between 2006 and 2012.

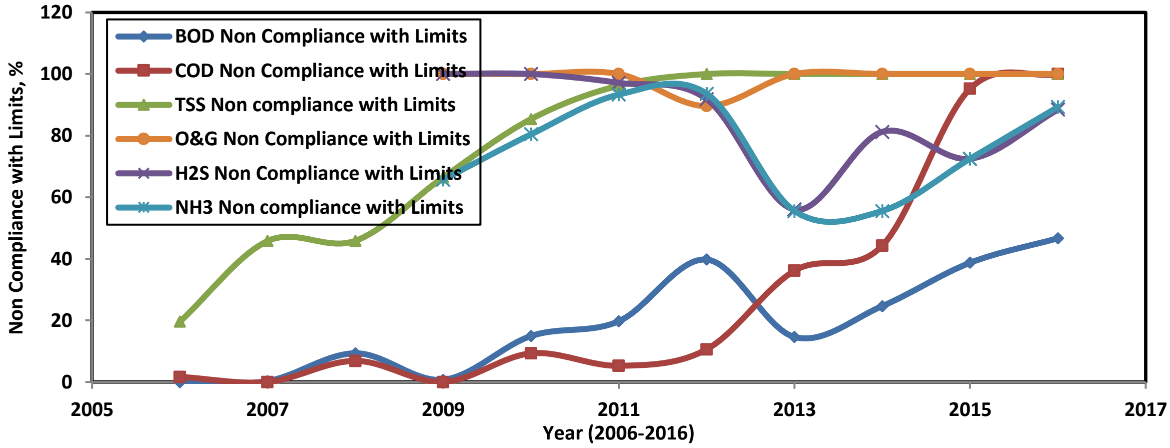

Figure 3. Annual Percentage of Non-compliance to Standards of Six Parameters in the Effluent of Barakia WWTP for the Period from 2006 to 2016.

To investigate the trend of COD of wastewater entering and leaving the plant, Figure 5 shows the concentration of COD for 1008 sampling events for the influent and effluent wastewater in the plant during the period between 2006 and 2016. As can be seen in the Figure, the plant was not able to comply with local limits since December 2014 only in a few events which highly indicate the need for correction action to stop the contamination of Kufa River. The non-compliance to COD limits was increased from 2% in year 2006 to 100% in year 2016 (Figure 3). As in BOD, the expected reason for exceeding standards is the increasing in flow rate in year 2014 and after.

BOD_5/COD ratio is calculated in order to predict the biodegradability of the wastewater introduced to rivers. If the biodegradability ratio is around 50% or more, the wastewater considered to be easily treated biologically. If the ratio is around 30% and less, the wastewater may contain toxic components [17]. The biodegradability ratio (BOD_5/COD) in raw sewage was averaged 0.40±0.12 (range 0.17-0.71) referring to the idea that non-biodegradable impurities represents high percentage of the total impurities in the raw wastewater (around 60%). The ratio was 0.32±0.18 (range 0.08-0.79) in the discharged wastewater which represents a small reduction in the biodegradable portion of the wastewater. High percentage of non-biodegradable materials can impose big harm to the aquatic life and represents high risk on using Kufa River for human utilization. Low BOD_5/COD ratio in the wastewater discharged to river indicates that water is polluted with high toxic components and non-biodegradable materials. This ratio also indicates that the self-purification process in river will not be able to attenuate pollution independently. High concentrations of micro-plastics and hazards chemicals such as pesticides are expected to be the major contamination to rivers in which highly threatening human lives of communities downstream who depend on this water for their domestic use.

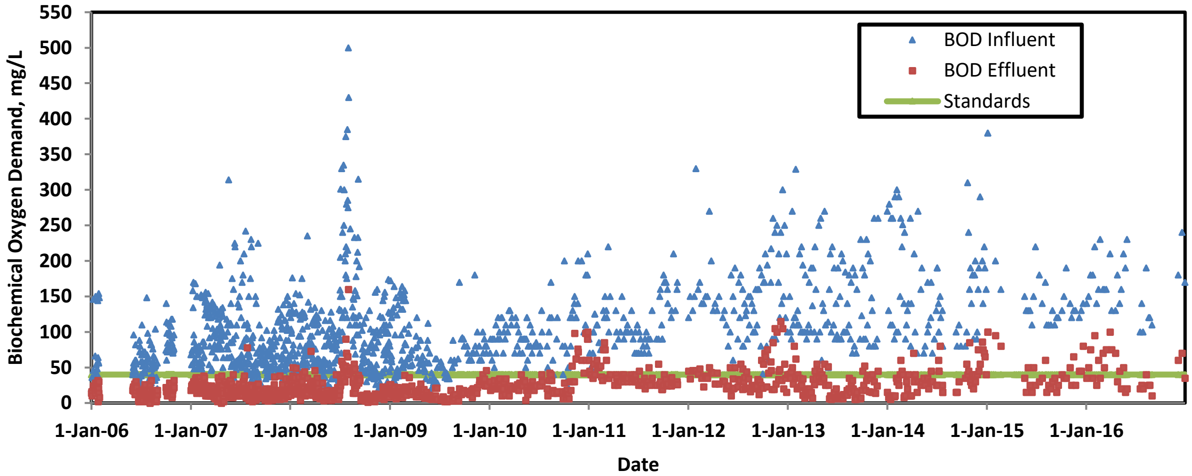

Figure 4. Biochemical Oxygen Demand in Influent and Effluent of Barakia WWTP for the Period between 2006 and 2016.

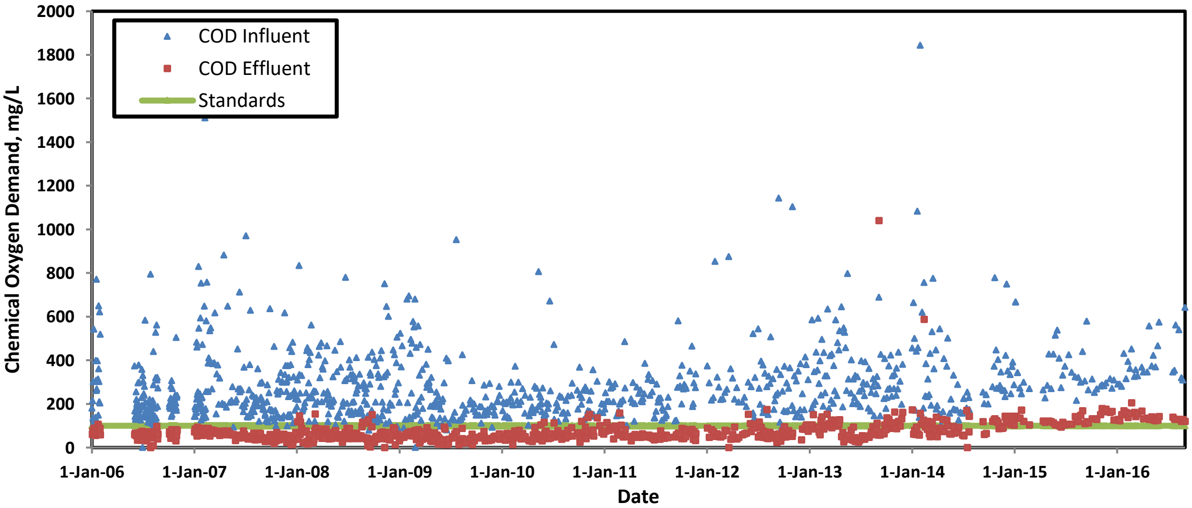

Figure 5. Chemical Oxygen Demand in Influent and Effluent of Barakia WWTP for the Period from 2006 to 2016.

Nutrients

Phosphorus in natural waters and wastewaters is usually present in the form of phosphates (PO_4^{+3}). PO_4^{+3} in the raw wastewater entering the plant averaged 5.7 mg/L, while it averaged 3 mg/L in the discharged wastewater. No chemicals are added to reduce the level of phosphorous in the plant. The reduction in the level of phosphorous may relate to the reduction of total suspended solids, and other contaminants. However, among 68 samples tested during years 2015-2016, 15 of them were over the local standards (3 mg/L) and all of them exceeded the typical American standards (1 mg/L).

High concentrations of nitrogen and phosphorous may cause serious threat to the balance of habitats and to flora and fauna in water. These nutrients are the primary reason for algae blooming and eutrophication in lakes and rivers [18].

Ammonia concentration was reduced through the treatment process. Raw wastewater concentration of ammonia averaged 20.3±3.7 mg/L, while the average effluent was reduced to 13.3±4.5 mg/L. Comparison between influent vs. effluent samples shows significant reduction in the level of ammonia but this reduction did not bring the level of ammonia below the standards in significant number of sampling events. Noncompliance to standards was 73% in year 2015 and 89.3% in year 2016. It is obvious that the absence of nitrification process is responsible for these high concentrations of ammonia in the discharged wastewater to Kufa River. The plant designed with no process dedicated to ammonia removal, and although years of noncompliance to Iraqi standards as can be seen in Figures 3 and 6, no action was taken to reduce the level of ammonia to the river. The plant has to consider reducing the level of phosphorous and ammonia in the treated wastewater to reduce the damage it causes to aquatic life in Kufa River.

One of the problems related to the low performance is the power off problem which reduces the ability of processes to perform adequate nitrification of ammonia. The power off problem is contributing also to the problem of accumulation of solids in the bottom of the tanks in the plant, creating some anaerobic condition.

Figure 6 shows the ammonia concentrations in influent and effluent wastewater of Barakia WWTP for the period started in year 2009 to year 2016. The Figure shows high deficiency in the reduction of ammonia below the standards throughout the treatment. In most cases, the ammonia level exceeded the local standard (10 mg/L). Also, for those samples that showed lower concentrations than the standards, it is obvious that the low concentration in the raw wastewater is the reason for this compliance. The Figure shows the need for retrofitting an extended ammonia treatment stage (nitrification) in the plant in order to comply with the local standards.

With the decrease in the concentration of ammonia in the discharged wastewater, an increase in the concentration of nitrate in the effluent was expected [19]. The average concentration of nitrate in the raw wastewater averaged 2.5±1.6 mg/L, and it was increased to 15.6±7.9 mg/L in the discharged wastewater. The increase in the average nitrate level indicates the presence of nitrifying organisms in the trickling filters. The level of nitrate discharged to Kufa River also needs to be monitored. Although the average effluent from the plant in years 2015-2016 was within the limits (nitrate standards is 50 mg/L), data from previous years 2009-2014 showed that nitrate level exceeded the 50 mg/L level in 13 of 222 sampling events. The effluent maximum nitrate level in previous years 2009-2014 may reach up to 95 mg/L. If the plant retrofits a nitrification process to reduce the high level of ammonia in the effluent, a careful evaluation must be made to consider the expected increasing in the nitrate level which may require a de-nitrification process.

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is formed from the anaerobic decomposition of organic matters that containing sulfurs [17]. The average concentration of H_2S in the raw sewage was 28±8.7 mg/L referring to a high septic condition and odor pollution. In addition to odor problems, high levels of H_2S in the sewer system may cause health risks to operators, and deteriorate the structural reliability of sewer system. H_2S attacks concrete, copper, iron, and silver, and cause sewer systems and wastewater treatment plant's structures to be corroded [20]. It is corrosive to metals such as iron, zinc, copper, lead and cadmium [21]. It is highly recommended for the City of Najaf to seek out a solution for the problem of high H_2S in its sewer system. The expected reason for the high level of H_2S is the malfunctioning of vacuum pumps in the central collection tanks in the sewer system.

During the processes in the plant, the average concentration of H_2S was reduced to an average of 5.6±3.7 mg/L in the discharged wastewater. This average is higher than the taste and odor thresholds. H_2S taste and odor thresholds are estimated to be between 0.05 and 0.1 mg/L [22]. According to world health organization (WHO) guidelines for drinking water; "hydrogen sulfide should not be detectable in drinking water by taste or odor" [23]. Iraq's standard for H_2S in the discharged wastewater is 3 mg/L. Among 66 effluent samples tested in the plant in years 2015-2016, only 14 samples were below this standard. Sulfides, especially hydrogen sulfide (H_2S), are quite soluble in water and are toxic to both humans and fish. H_2S is the most common odorous gas associated with domestic wastewater collection and treatment systems.

Average sulfate concentration in the treated wastewater was increased. In the hot or humid conditions, H_2S oxidized into sulfate or sulfuric acid by Thiobacillus bacteria (Gram-negative) [17]. This sulfuric acid is corrosive and attacks the wastewater and sewage treatment infrastructure. The average concentration of sulfates reduced slightly from 861±210 mg/L in the raw wastewater to 771±141 mg/L in the discharged wastewater. The high level of sulfate in discharged wastewater indicates another problem in the regulatory system in the country. Currently, no limits are imposed for sulfate level in the discharging wastewater to streams. As for drinking water, the level of sulfate is limited to 400 mg/L by Iraqi's standards and WHO, and 250 mg/L by American Secondary Standards. The average concentration of sulfate in the discharged wastewater did exceed the two criterions.

The high concentration of sulfate in the discharged wastewater from the plant may cause an increasing level of sulfate in Kufa River, and bring detrimental effects on downstream aquatic life [24], and farmers whom using this water for cattle feeding. Wagner (2008) shows that a steer in feedlot consuming water with a concentration of 1000 mg/L sulfate is at a risk of developing sulfur toxicity [25]. High concentrations of sulfate in drinking water for cattle may lead to the risk of sulfur toxicity.

Oil and Grease

Oil and grease refers to fats, oils, waxes, and other related constituents found in wastewater. Large amounts of oil and grease in wastewater can cause clog in sewer lines, failure in sewer lift stations, and maintenance problems in wastewater treatment plant. Oil and grease are compounds of alcohol or glycerol with fatty acids. The liquid glycerides of fatty acids at ordinary temperatures are called oils, while those that are solids are called greases or fats [17]. If not removed properly in WWTP, oils and greases may interfere with the biological life in the surface water creating unsightly films. Due to their low solubility in water, microbial degradation is less effective on oils and fats. Petroleum derived oils such as kerosene, lubricating, and road oils are toxic to human and aquatic life. If not treated properly, they may cause damage to species in lakes or rivers.

The average concentration of oil and grease in years 2015-2016 was 122±45 mg/L (ranged between 60 to 277 mg/L) in the raw wastewater. This level of oil and grease was reducing only to an average of 83±27 mg/L (ranged between 28 to 150 mg/L). For 315 sampling events between years 2009 and 2016, none of them were able to comply with the local discharging limit (4 mg/L) except 5 samples in year 2012. One major reason for this high concentration is the malfunctioning of skimmers for floating materials in grit chambers, and secondary sedimentation tanks. Through all these years, the plant did not implement any correction measure or modification to change this situation. Figure 7 shows that level of oil and grease in the raw wastewater may raise as high as 412 mg/L which represents high pressure on the wastewater treatment processes, and may imposes severe damage to drinking water sources and aquatic life if not treated properly.

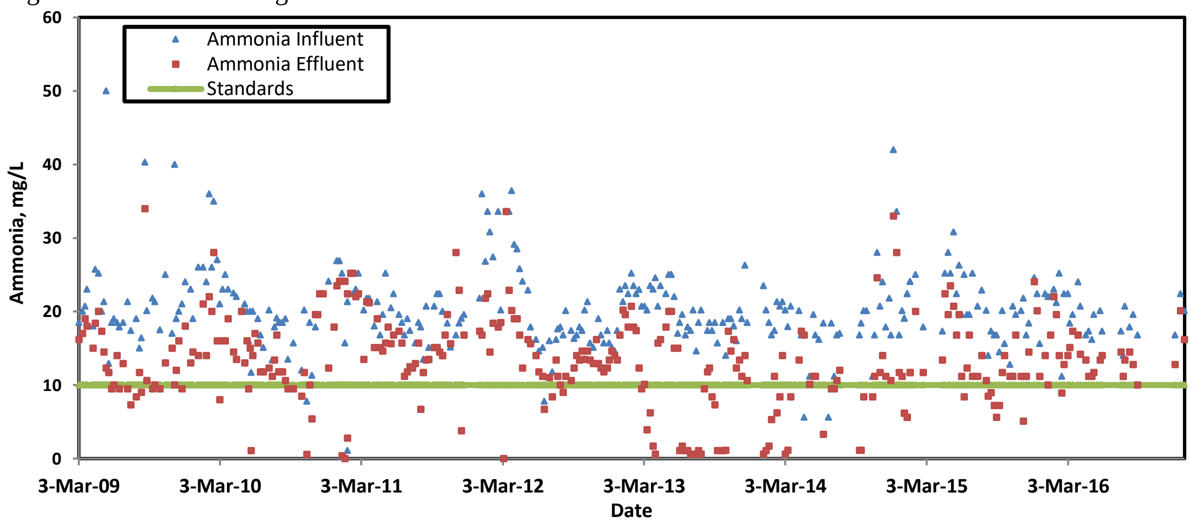

Figure 6. Ammonia Concentrations in Influent and Effluent to Barakia WWTP for the Period between 2009 and 2016.

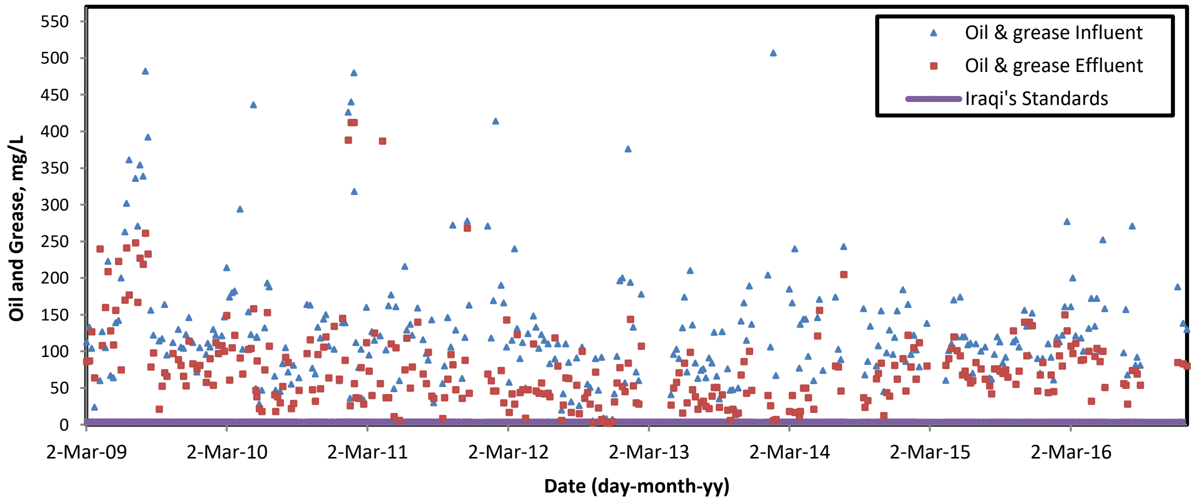

Figure 7. Oil and Grease Concentrations in Influent and Effluent Wastewater of Barakia WWTP for the Period from March 2009 to December 2015.

Conclusions

Wastewater treatment plant in Barakia Najaf is one example of the deteriorating conditions of wastewater treatment in Iraq. Because of the negligence to environmental impacts associated with inefficient treatment, wastewater is being discharged with little treatment to rivers. Plant's evaluation allow following conclusions:

1- The lack of an efficient primary, nor secondary treatment, combined with lack of experience in managing operations and performing maintenance cause raw wastewater to receive no to little treatment in Barakia wastewater treatment plant.
2- The plant was not able to reduce contaminants such as COD, TSS, oil and grease, or nutrients. As many plants in the country, the plant failed to comply with local and international regulations to reduce most of tested contaminants.
3- Based on a flow rate of 35,000 m^3/day, the plant contaminated Kufa River with approximately 1727 tons of COD, 1420 tons of suspended solids, 170 tons of ammonia, 200 tons of nitrates, 1062 tons of oil and greases, 9864 tons of sulfates, and 72 tons of hydrogen sulfides in two years 2015-2016. These levels of contamination sort the plant as the leading point source polluter in the area.
4- Problems related to the low performance is the high flow beyond capacity, power off problem, the need to retrofit advanced treatment such as filtration and nutrients removal, and the faulty of some of the mechanical equipment which reduces significantly the reliability of the treatment.
5- Like most of plants in the country, with the current trend of degradation of treatment, the Barakia Najaf plant is recommended to establish a detailed strategy that may contain increasing maintenance, expanding of treatment capacity, and retrofitting advanced treatment in order to reverse the trend.

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