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Wastewater Treatment in Developing Countries: Case Study from Al-Muthanna, Iraq

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Abstract: Alsamawah City is the center of Al-Muthanna Province in The South of Iraq. The wastewater treatment plant that serves the cityisconsist of inefficient secondary treatment stage only. The plant isfacing major problems related to improper designand/or implementation of structural plan, lack of professional operators, power shortage, and lack of maintenance. In order to evaluate the performance of this plant, data ofBOD_5, COD, TSS, TDS, CL^-, H_2S, oil and grease, and nutrients for the influent and effluent to Alsamawah wastewater treatment plant for the period from Feb. 10, 2012 to Jan. 25, 2015were collected, evaluated,and compared to national and some international standards.
The plant was not able to reduce the tested contaminants properly, and failed to comply with standards.Effluent average concentration of oil and grease, TSS, CL^-, NH_3, COD, and H_2S was 42.0, 5.4, 3.5, 1.6, 1.2, and 1.2 timeshigher than the local standards, respectively. It comply only at the events when a contaminant is originally had low concentration in the raw sewage.In most sampling events, the results shows that wastewater was leaving plant with no treatment, turning the plant into the top point source polluter in the province (approximately 20,000 m^3/day). Beside the need for the addition of preliminary, primary, and advanced treatment to the existing processes, designed and implemented under professional experts, the plant is recommended to startan extensive maintenance for its components (basins, pumps,and pipes) in order to reach the acceptable level of treatment.
Keywords:wastewater treatment, primary, secondary, and advancedtreatment, developing countries, Iraq

I. INTRODUCTION

Wastewater Treatment

The purpose of the wastewater treatment is to remove or reduce water contaminants that impose threats to human and environmentif discharged to surface and/or ground waters without proper treatment. Most common contaminants in wastewater are such as;biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), Nutrients such as nitrogen and phosphorous, and oils & greases. BOD and COD represent a serious environmental pollution if they were in high levels in a stream. If the process of breaking down and decomposing these materials happens in the natural streams instead of the treatment plant, it will deplete the dissolved oxygen level and create anaerobic condition which may negatively affects the aquatic life.

Suspended solids are defined as the particles in water that will not pass through a 2-micron filter[1]. If high suspended solids discharged to a river, they may settle to the bottom of the river resulting in sludge build up, and when decomposition occurs, more oxygen will be used causing oxygen depletion. A dissolved oxygen drop below 3-4 mg/L representsharmful effects on the aquatic species.High concentrations of suspended solids result in less light passing through water, which reduces the photosynthesis of aquatic plants, and can lead to rapid heating of water that might adversely affect the aquatic life that has been adapted to a lower temperature [2]. In addition, suspended solids can serve as carriers of toxics such as pesticides that readily cling to the particles' surfaces [3]. It also serves as carriers of pathogens. Studies showed high relation between suspended solids and Protozoa [4] and fecal coliform bacteria[5].

There is an increasing concern abouthigh concentrations of ammonia (NH_3) because of the serious threat it poses to the balance of habitats and to flora and fauna in rivers and lakes.Two forms of nitrogen are found in municipal raw wastewater; organic nitrogen and ammonia[6]. The untreated wastewater may contain little or nonitrite (NO_2) and nitrate (NO_3).Nitrite is less stable and usually presents in much lower amounts than nitrate. Organic nitrogen is decomposed to ammonia which in turn, in the presence of nitrifying bacteria, oxidized to nitrite then nitrate.The most predominant form of phosphorous is the orthophosphate. Nutrients like nitrogen and phosphorous are the leading cause for algae blooming and eutrophication in lakes and rivers.
A high total dissolved solid (TDS) is related to the presence of number of dissolved salt compounds in water. Dissolved saltsmay be organic or inorganic. According to American Standards for drinking water, TDS is

considered as a secondary pollutant[7].TDS is used as an indicatorfor aesthetic characteristics of drinking water and the presence of a broad number of chemical contaminants [7].High TDS in the discharged wastewater to a stream may cause toxicity to aquatic life through increasingsalinity and changing the ionic composition of the water.

Sulfates are not considered toxic to plants or animals at normal concentrations. In humans, concentrations of 500 - 750 mg/L cause a temporary laxative effect. However, doses of several thousand mg/L did not cause any long-term illness effects. Problems caused by sulfates are most often related to their ability to form strong acids which changes the pH. Sulfate ions are involved in complexing and precipitation reactions which affect solubility of metals and other substances.High concentrations of sulfate in drinking water for cattle may lead to the risk of sulfur toxicity. As stated by the National Research Council in U.S. "the requirement for sulfur is 0.15% of diet dry matter and maximum tolerable level is listed as 0.40% of diet dry matter" [8].Sulfides, especially hydrogen sulfide (H_2S), are quite soluble in water and are toxic to both humans and fish.Hydrogen sulfide is the most common odorous gas associated with domestic wastewater collection and treatment systems. It is corrosive to metals such as iron, zinc, copper, lead and cadmium [10]. Hydrogen sulfide formed from the anaerobic decomposition of organic matters that containing sulfur [6]. Hydrogen sulfide generation is related to flow rate. Wastewater with low flowrates is more likely to have high concentrations of hydrogen sulfide.

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 [6]. 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.

Wastewater Discharge Limits

The purpose of wastewater treatment is to maintain the natural assimilation ability to biodegrade pollutantsin water which could be lost if high amount of pollutants were introduced. Discharging limits are proposed by each country to protect its own natural water system. In U.S., and according to Clean Water Act, any wastewater discharger has to comply with discharging limits. These limits are calculated based on the maximum amount of pollutants that can enterthe receiving waterbody. With an objective of managing or maintaining water quality, thetotal maximum daily load (TMDL)works as a calculationmeanwhich relies on evaluating the condition of surface waters and setting limitations on the amount of pollutants that the water can be exposed to without having adversative effect on the beneficial uses of those waters[9].Under section 303(d) of the Clean Water Act, statesare required to identify impaired waters. The list of impaired waters isthose waters that do not meet their water quality standards. The law requires that the states develop a TMDL for these waters.US Environmental Protection Agency (USEPA) isthe agency that is required to review and approve the list of impaired waters and each TMDL.

In Iraq, no studies were conducted to classify waters according to a similar TMDL system. Iraqi effluent standards for BOD_5, COD, TSS, NH_3, and PO_4 are 40 mg/L, 100 mg/L, 30-60 mg/L, 10 mg/L, and 3 mg/L respectively. These standards are applied to all water bodies without respect of their quality and ability to tolerate pollutants. It is not clear how these standards were adopted but it is obvious that they are way less restricted than any other standards from a country like U.S. For example, one common set of effluent limits in Florida is 5 mg/L, 5 mg/L, 3 mg/L, and 1 mg/L for BOD_5, TSS, total nitrogen, and total phosphorous, respectively [11].Generally, wastewater discharge standards in many developing countries are eitheradopted from WHO standards or other international standards withoutadapting them to suit local conditions [12].

Wastewater Treatment Plants

To achieve the desired removal of contaminants, the treatment in a wastewater treatment plant may consist of several stages. These stages are: 1) the preliminary treatment on which materials that could damage plant equipment are removed from wastewater, 2) the primary treatment on which the settleable and floatable solids are removed, 3) the secondary treatment where the demand for dissolved oxygen and colloidal suspended organic matter are removed by biological actions of microorganisms (converting organics into stable solids, carbon dioxide, and more organisms), and 4) the advanced treatment that uses physical, chemical, or biological processes for suspended solids polishing and nutrients removal. The processes also consist of disinfection and sludge handling.

Several methods are used for treatment, and in particular, the biological treatment is one of the most common. The method mimic the natural self-purification that is already exist in lakes, rivers, and streams. In the conventional biological wastewater treatment operations, the grits and suspended solids are removed first through gravity settling basins, and then organics and nitrogenous compounds are biodegraded by actions of aerobic microorganisms. These microorganisms require large amounts of oxygen for their biochemical activities. Mechanical devices, such as surface aerators or air compressors and blowers are used to introduce air (oxygen) into reactors.

Wastewater Treatment Plants in Iraq

While developed countries are continuing working on setting more efficient treatment processes in the WWTPs or establishing new technologies to meet the increasing demand for water, the predeveloped countries are still straggling to establish the required infrastructure for treatment. Although the damage from lack of such infrastructure is obvious, public objection are still limited due to the influence of political conflicts in many of these countries. Improper wastewater treatment is acute in countries suffering crisis like Iraq. Natural water system in Iraq is facing massive destruction and quality degradation mainly due to the absence of effective protection regulations against direct discharge of pollutants, and the inefficient wastewater treatment at Iraq's sewage treatment plants. Decades of wars and sanctions in Iraq combined with limited environmental awareness in both public and governmental representatives, have highly contributed to the destruction of Iraq's national water management system.According to the United Nations report [13], six million people 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. 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" [13].

Currently, the lack of permanent governmental programs for environment protection, lack of expenses, unavailability of professionals, engineers, and skilled operators, unprofessional design and treatment of most of existing plants,and lack of public awareness about the danger of direct discharge of wastewater to water courseshad led to serious deficienciesin operationsin the country's wastewater treatment plants. Most of these plants were not designed based on a proper local data and were constructed by inexperienced companies. 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. In many cases untreated raw sewage is directly discharged into Rivers, endangering the health of residents and downstream populations.

Many studies performed to evaluate the wastewater treatment in Iraq [14, 15, 16; 17; 18, 19, etc.).Al-Rawi and Altayar evaluated the wastewater treatment operations of a plant in the City of Al-Mosul [20]. They concluded that the absence of an experienced operators and the lack of dissolved oxygen are the main reason for the deficiency in treating organic contents. Alsaqqar et al. evaluated the performance of a WWTP in Al-Diwaniya, one of cities 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 [21].For more understanding to the country's wastewater treatment system, more studies are needed, especially for those plants that were not subjected to detailed evaluation. Little studies were conducted to evaluate the performance of current wastewater treatment plants in Al-Muthanna Province.

Study Objectives

Wastewater treatment evaluation usually performed through the calculation of percentage removal of contaminants such as BOD, TSS, or nutrients [22]. The objective of this study is to evaluate the performance of Alsamawahwastewater treatment plant, one of the southern cities in Al-Muthanna Province-Iraq,to identify the deficiencies locations in the process and specify solutions and recommendations to enhance performance.

II. MATERIALS AND METHODS

AlsamawahWastewater Treatment Plant

Alsamawah WWTP is located on the East part of Alsamawah City. The plant was designedto treat37,500 m^3/day. The plant consists of preliminary and secondary treatment processes. The preliminary stage consists of a bar rack screen and twogrit chambers for grit removal. The grit chambers were not designed properly as the wastewater is not confined for enough retention time to allow grit settling.From grit chambers, the water is moved to aeration basins. For unknown reason, no primary treatment exists in the plant. The secondary treatment process is an activated sludge process consists of four aeration basins and four secondary clarifiers. Floated surface aerators (propeller type) are used to provide air to aeration tanks.

Prior to discharge to Alsamawah River, effluent from the secondary clarifiers flows into a chlorine chamber for disinfection. For unknown reason, no de-chlorination unit was designed for the plant. Wasted sludge is taken from the secondary clarifiers and is pumped into twogravity thickeners where the supernatant is pumped back to the distribution chamber and the settled sludge is pumped to the drying beds. Figure 1 shows the flow sheet for wastewater treatment processes in the plant.

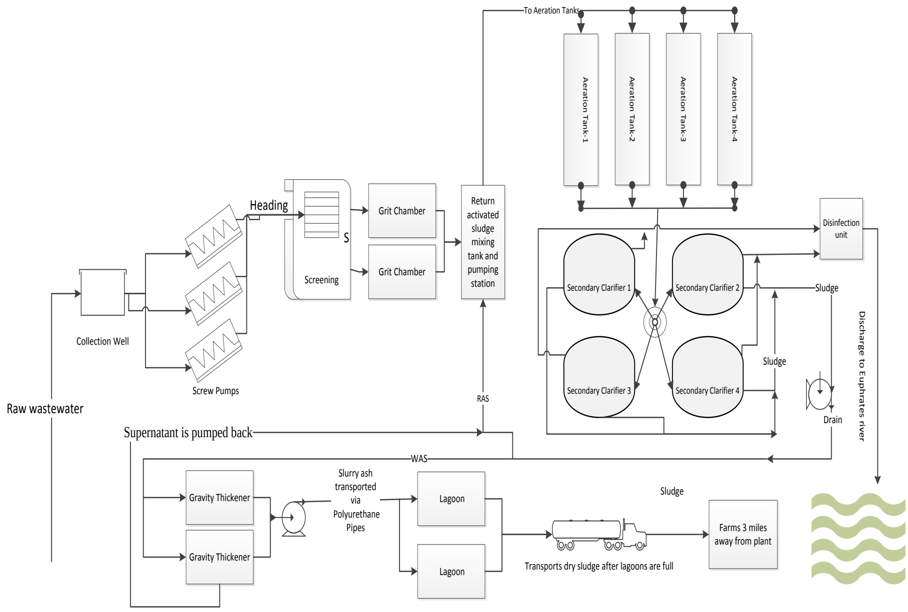

Figure 1. Flow Sheet for Wastewater Treatment Processes in Alsamawah WWTP.

Data Collection

Data used in the evaluation was provided from Alsamawah WWTP Laboratory. A total of 89 sampling event were performed for the period from October 2nd, 2012 through January 27th, 2015. Influent and effluent of thewastewater treatment process were testedfor biochemical oxygen demand(BOD_5), chemical oxygen demand(COD),total suspended solids(TSS), phosphates(PO_4), Nitrates(NO_3),ammonia(NH_3), chlorides(CL), oil and grease(O&G), and hydrogen sulfide (H_2S).These parameters were used to compare with standards and evaluate the process's efficiency.

III. RESULTS AND DISCUSSION

Table 1 shows the characteristics of the influent and effluent of wastewater treatment processes. 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 Alsamawah WWTP.

Parameter, mg/L	Date	# of Tests	Range	Average	Median	St. Deviation	Iraq's Standards
BOD_5	Influent	69	10-230	104	100	46	
	Effluent	64	5-105	36	33	19	40
COD	Influent	81	20-380	217	220	66	
	Effluent	80	12-188	118	120	33	100
TSS	Influent	79	20-2040	455	440	275	
	Effluent	89	20-540	325	360	114	30-60
TDS	Influent	71	1240-9020	5701	5700	1869	
	Effluent	79	1280-7800	5717	6220	1515	-
SO_4	Influent	76	57-3884	1267	1210	566	
	Effluent	76	92-3872	1355	1317	526	-
PO_4^{-3}	Influent	85	0.02-1.07	0.3	0.3	0.2	
	Effluent	83	0.01-0.30	0.1	0.1	0.1	3.0
NO_3	Influent	69	3-50	13.3	10.0	9.2	
	Effluent	70	1-46	11.7	8.5	10.4	50
CL^-	Influent	89	222-3937	2104	2060	857	
	Effluent	89	222-3365	2086	2245	738	600
NH_3	Influent	58	0.5-32.8	15.3	15.5	7.0	
	Effluent	53	0.7-43.6	16.2	14.5	7.9	10.0
O&G	Influent	42	38-560	220	140	165	
	Effluent	38	18-480	168	80	144	4.0
H_2S	Influent	70	3.4-51.0	23.1	21.6	11.1	
	Effluent	28	0.4-10.6	3.8	3.2	2.6	3.0

Secondary treatment usually imposes a maximum effluent BOD_5 and suspended solids concentrations of 30 mg/L [11]. Although Iraq's standard for suspended solids is beyond this maximum level (30-60 mg/L), in significant number of sampling events, the plant was not able to comply.

The average suspended solids concentrations in the discharged wastewater was 325 mg/L and the median is 360 mg/L. Among 89 sampling events for the concentration of suspended solids in the discharged wastewater, only 2 samples were below the 60 mg/L standard. The average reduction in suspended solids for 79 sampling events was limited to only 10% indicating high deficiency in the plant's processes. This deficiency in suspended solids removal is mainly related to the unprofessional design or implementation of grit chambers, the absence of primary clarifiers, lack of maintenance, and the bypass of wastewater directly to the aeration tanks during malfunctioning of screw pumps.Grits and suspended solids are supposed to be removed during the preliminary and primary treatment phases, 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. Recently, grits and suspended solids in this case study are accumulated in the aeration tanks and secondary clarifiers, clogging some piping, and creating some anaerobic conditions in the bottom of the aeration tanks.

Figure 2 shows that only two samples in year 2012 was reduced below the maximum limit of 60 mg/L, and only one sample was below the 30 mg/L standard. After year 2012, the plant was never able to achieve acceptable TSS concentration. This result is not surprising when noting that plant did not export any sludge outside facility since start working in year 2012. The solids entering the plant are either discharged to the river or accumulated in plant's basins.

Bulking is another reason for the high solids concentration in effluent. Settlebility test was performed in the plant. No sludge was settled in the bottom of the graduated cylinder even after 24 hours indicating the presence of filamentous organisms in the system. So far, no action been taken to overcome this problem.

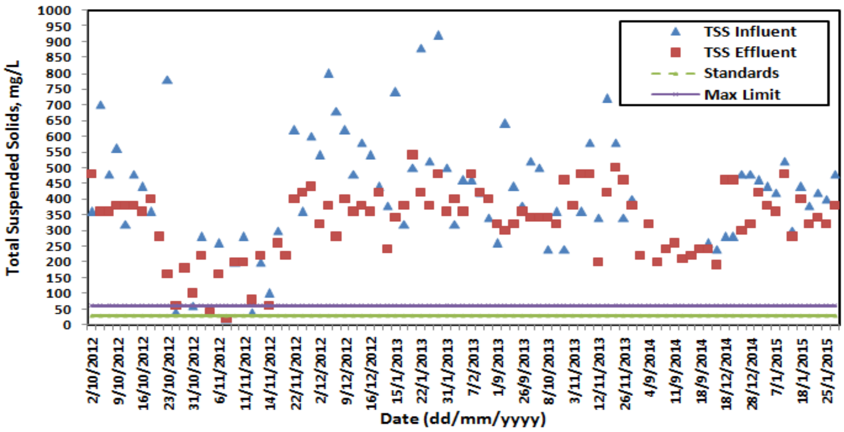

Figure 2. Total Suspended Solids in Influent and Effluent of Alsamawah Wastewater Treatment Plant for the Period from 2/10/2012 to 25/1/2015.

The BOD_5entering the plant ranged between10 to 230 mg/L with an average concentration of 104 mg/L and standard deviation of 46 mg/L, while the wastewater leaving the plant ranged from 5 to 105 mg/L with an average of 36 mg/L and standard deviation of 19 mg/L.Over the entire period of operations, the maximum reduction of $BOD_5$was 95% while in some cases; an increasing in BOD_5does occur at a rate up to 150%. However, the average reduction in BOD_5 was 55% (SD. of 43%)

According to the plant's employees, the Iraq's treated wastewater standard for BOD_5 is 40 mg/L while Dunia Frontier Consultants (2013) indicated that the standard is 3 mg/L [19]. However, among 64 sampling events for the effluent BOD_5 concentration, 16 samples (25%) exceeded the 40 mg/L level. The plant was able to reduce the concentration of BOD_5 from 104 mg/L in the raw wastewater to 36 mg/L in the discharged wastewater. Since the plant is receiving 40% to 50% of the designed flow rate, the reduction in BOD_5 was achievable due to long retention time at the aeration tank.

Biological unit working in the mode of extended aeration activated sludge, hydraulic detention time at aeration tank is 24hours (according to the average flow of the plant) but during peak flow the detention time may be at the range of (12-16 hours). The designated mean cell residence time is more than 20 days.

Figure 3 shows the BOD_5 in the influent and effluent wastewater and the standard concentration (40 mg/L). The Figure shows that most incompliance to the standards was occurred during the years 2013 through 2015 most likely due to accumulation of solids short period after the facility were started in 2012. The other expected reason is the insufficient aeration provided to wastewater in the aeration tank due to impairment in some mechanical aerators and frequent power outage. No measurements of dissolved oxygen (DO) or specific oxygen uptake rate (SOUR) are available in the plant.

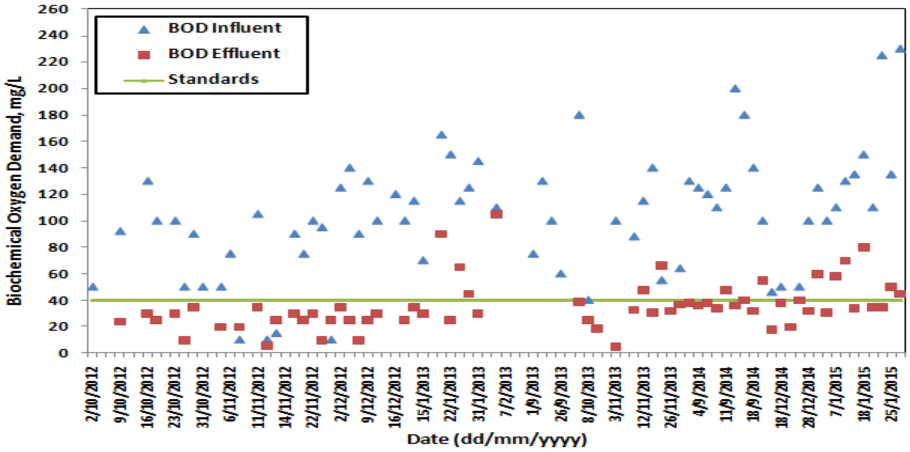

Figure 3. Biochemical Oxygen Demand in Influent and Effluent of Alsamawah Wastewater Treatment Plant for the Period from 2/10/2012 to 25/1/2015.

COD was also reduced from an average of 217 mg/L in the raw wastewater to an average of 118 mg/L in the discharged wastewater. But, Iraqi's standards for concentration of COD in the discharged wastewater arenot to exceed 100 mg/L. Among 80 sampling events for the COD concentration in effluent, only 11 samples (13.8%) were lower than the 100 mg/L standard. Among these 11 samples, six of them had initially low COD concertation in the raw wastewater.

Figure 4 shows the concentration of COD for 80 sampling events for the influent and effluent wastewater in the plant with the limitation (standard) of 100 mg/L. As can be seen in the Figure, the plant was not able to comply with local limitation since December 2012 only in a few events.

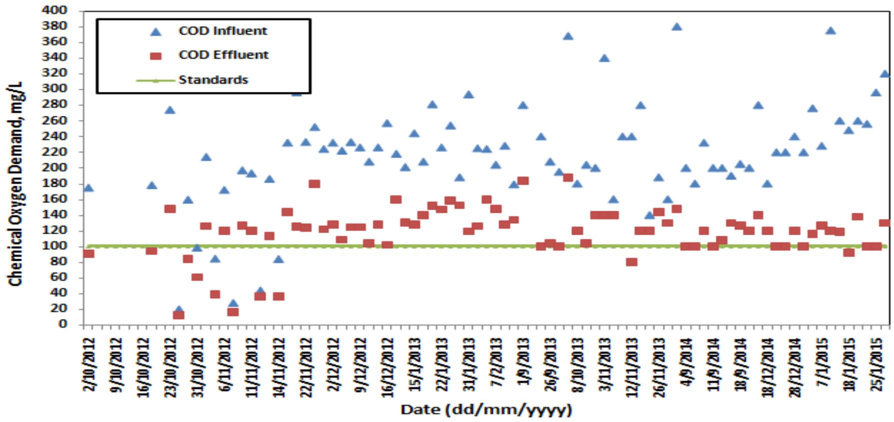

Figure 4. Chemical Oxygen Demand in Influent and Effluent of Alsamawah Wastewater Treatment Plant for the Period from 2/10/2012 to 25/1/2015.

The biodegradability ratio (BOD_5/COD)in raw sewage was averaged 0.5±0.31 (range 0.04-2.5) referring to the idea that inorganic impurities represents around 50% of the total impurities in the raw wastewater. The ratio was 0.34±0.21 (range 0.04-1.25) in the discharged wastewater which represents a reduction in the organic portion of the wastewater. High percentage of non-biodegradable materials can be removed if suspended solids removed.

As for the nutrients, PO_4^{-3} in the raw wastewater averaged0.29mg/L, while it averaged 0.13 mg/L in the discharged wastewater. No chemicals are added to reduce the level of phosphorous concentration in the plant. The reduction in the level of phosphorous may relate to the presence of anaerobic condition in the aeration tanks.However, all effluent samples tested during the period of study were below the local standards (3 mg/L) and the typical American standards (1 mg/L).

Even though the extended hydraulic retention time in aeration tank, ammoniaconcentration was not changed through the treatment process. Raw wastewater concentration of ammonia averaged 15.3 mg/L (median of 15.5 mg/L and SD of 7.0 mg/L), while the average effluent was increased to 16.4 mg/L (median of 14.5 mg/L and SD of 8.0 mg/L). Comparison between 54 influent vs. effluent samples, shows an average of zero reduction in the level of ammonia.In spite of lack of testing equipment, it is obvious thatthe lack of enough oxygen is responsible for the absence of nitrification process. Ammonia normally requires 3 to 4 times the aerobic capacity required for BOD removal.One of the problems related to the low aeration is the power off problem. The average hours supplied from national grid is 18 hours per day. The power off problem is contributing also to the problem of accumulation of solids in the bottom of the aeration tanks, creating some anaerobic condition. Another problem is the faulty of some of the mechanical aerators which reduces significantly the amount of air provided.

Figure 5 shows the ammonia concentrations in influent and effluent wastewater of AlsamawahWWTP for the study period. The figure shows high deficiency in the reduction of ammonia throughout the treatment. In most cases, the ammonia level exceeded the acceptable 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 ammonia treatmentstage (nitrification) in the plant in order to comply with the local standards.

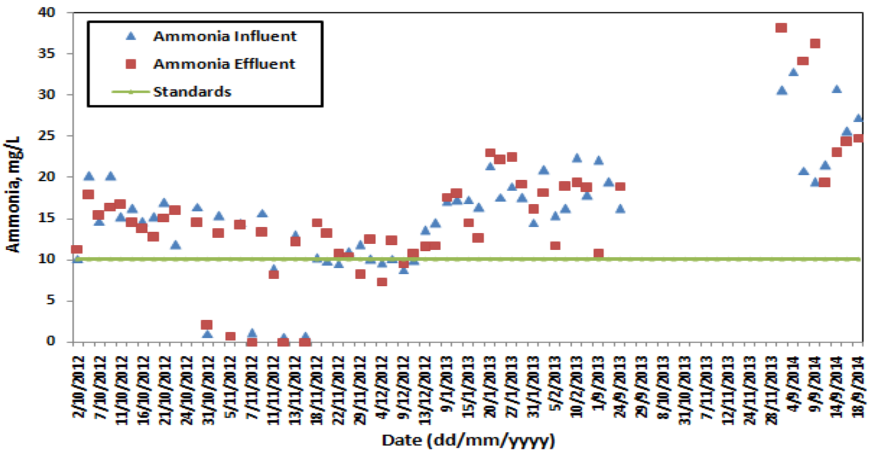

Figure 5. Ammonia Concentrations in Influent and Effluent Wastewater of Alsamawah Wastewater Treatment Plant for the Period from 2/10/2012 to 18/9/2014.

With high concentration of ammoniain the raw wastewater and extendedhydraulic retention time in the aeration tank, an increase in the concentration of nitrate in the effluent was expected [23]. But, the average concentration was decreased. Concentration of nitratein the raw wastewater averaged 13.3 mg/L (median of 10.0 mg/L and SD of 9.2 mg/L), and it was decreased to11.7 mg/L (median of 8.5 mg/L and SD of 10.4 mg/L) in the discharged wastewater. Thelittle decrease in the average nitrate level may indicate some anaerobic condition in the bottom of aeration basins which lead to the formation of gaseous form of nitrogen.

As for the TDS concentrations, no reduction was occurred through the process. The range of TDS in the effluent wastewater was 1280 mg/L to 7800 mg/L. The average was 5717 mg/L (SD=1515 mg/L). This high concentration of TDS can cause extreme damage to the aquatic life and to the source of drinking water in the area. Although, wastewater treatment plants have no limits for discharging their effluent with high TDS to streams, this case study indicate the need for such limits to protect aquatic life. One approach for setting limits for TDS may base on the water quality suitable for drinking.American standard for TDS in drinking water is limited to 500 mg/L, while the WHO standard is 1000 mg/L. For example in 2010, TheEnvironmental Quality Board in the State of Pennsylvania in the U.S. set a new wastewater treatment requirement for TDS. The goal of the regulation was to ensure that the concentration of TDS in Pennsylvania's streams does not exceed the water quality criterion of 500 mg/L [24]. Data from office of environment protection in the City of Alsamawahindicated that Alsamawah River already exceeded these levels. The average concentration of TDS in the river for August and September, 2015 was 3050 mg/L representing 300% exceedance for WHO standards and 600% for American standards. Figure 6 shows the dissolved solids concentration for influent and effluent. The figure also shows the American and WHO standards. The figure shows that none of the samples tested during the period from October 2nd, 2012 to December 28th, 2014 did comply with these standards, indicating serious environmental problem introduced to Alsamawah River and indicating the need for treatment process modification as well. The concentration of TDS in the effluent could reach as high as 7800 mg/L.The figure also shows the need for imposing limits for TDS discharge from wastewater treatment plants.

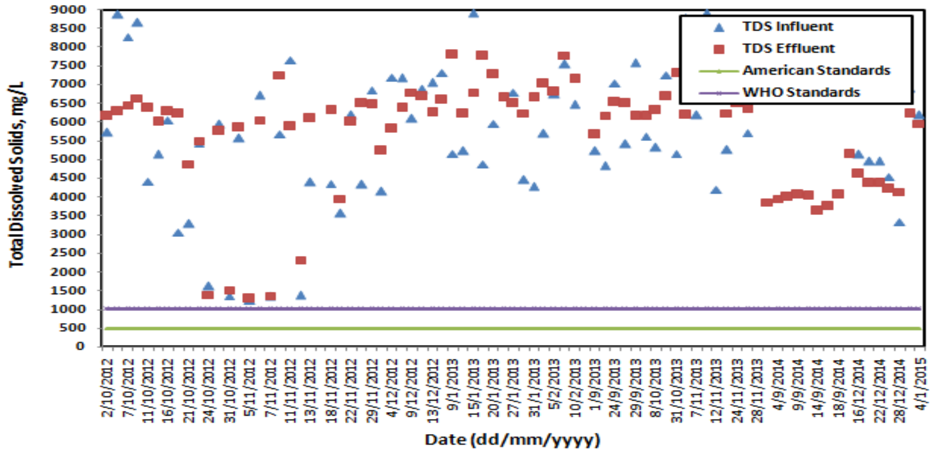

Figure 6. Total Dissolved Solids Concentrations in Influent and Effluent Wastewater of Alsamawah Wastewater Treatment Plant for the Period from 2/10/2012 to 28/12/2014.

The average concentration of H_2S in the raw sewage was 23.1 mg/L indicating high septic condition and odor pollution. In addition to odor problems, the current levels of H_2S in the sewer system maycause health risks to operators, and deteriorate the structural reliability of sewer system.Hydrogen sulfide attacks concrete, copper, iron. and silver, and cause sewer systems and wastewater treatment plant structures to becorroded [25].

During the processes in the plant, the average concentration of H_2S is reduced to an average of 3.8 mg/L in the discharged wastewater. This average is higher than the taste and odor thresholds. Hydrogen sulfide taste and odor thresholds are estimated to be between 0.05 and 0.1 mg/L [26].In U.S., a maximum concentration of 0.5 mg/L of undissociated hydrogen sulfide has been reported in fresh water [27].The WHO guidelines for drinking water states that “hydrogen sulfide should not be detectable in drinking water by taste or odor” [28].Iraq’s standard for hydrogen sulfide is 3 mg/L. Among 28 effluent samples tested in the plant, only 15 samples were below this standard.It is highly recommended for the City of Alsamawah to seek out a solution for the problem of high hydrogen sulfide in its sewer system. The expected reason for the high level of hydrogen sulfide is the malfunctioning of vacuum pumps in the central collection tanks in the system.

Average sulfate concentration in the treated wastewater was increased. In the hot or humid conditions, hydrogen sulfide oxidized into sulfate or sulfuric acid by Thiobacillus bacteria (Gram-negative). This sulfuric acid is corrosive and attacks the wastewater and sewage treatment infrastructure.The average concentration of sulfates increased from 1267 mg/L in the raw wastewater to 1355 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 contribute to the increasing level of sulfate in AlsamawahRiver. The average concentration of sulfate in the river for August and September, 2015 was 708 mg/L.This may bring detrimental effects on downstream 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 [29].

Chloride is dependent on the agricultural and residential drainage activity upstream. Salts may accumulate in the receiving water and may represent threats to drinking water supplies and waters that support aquatic life [30-31]. No significant difference in the average concentration of chloride in wastewater entering and leaving plant. Chloride concentrations were 2104 mg/L and 2085 mg/L in the raw and discharged wastewater, respectively. The range of discharged wastewater was 222 mg/L to 3365 mg/L and thelower bound of this range is very close to 230 mg/L.230 mg/L is the chronic water quality criteria for chloride set by USEPA [32]. As can be seen in Figure 7, only few sampling events during 2012 were below the Iraqi’s standards (600 mg/L) for discharging chloride into surface water.Data from office of environment protection in the City of Alsamawah indicated that Alsamawah River already exceeded these levels. The average concentration of chloride in the river for August and September, 2015 was 800 mg/L. The plant has to focus on the implementation of chloride treatment or it will continue to degrade the aquatic life in the river.

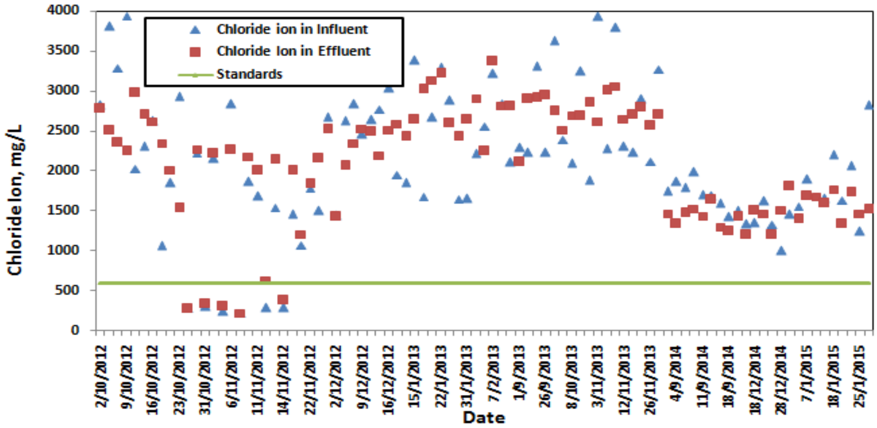

Figure 7. Chloride Ion Concentrations in Influent and Effluent Wastewater of Alsamawah Wastewater Treatment Plant for the Period from 2/10/2012 to 25/1/2015.

As for oil and grease, the average concentration was 168 mg/L (ranged between 18 to 480 mg/L). Figure 8 shows that for 38 sampling events, none of them were able to comply with the local discharging limit (4 mg/L). One of major reasoning for this high concentration is the malfunctioning of skimmers for floating materials in grit chambers, and secondary sedimentation tanks. However, the figure shows noticeable increase in the concentration of oil and grease in December, 2014 through January 2015. The plant did not implement an investigation to detect the reason behind this change. The figure shows that level of oil and grease may raise as high as 480 mg/L which may impose severe damage to drinking water sources and aquatic life.

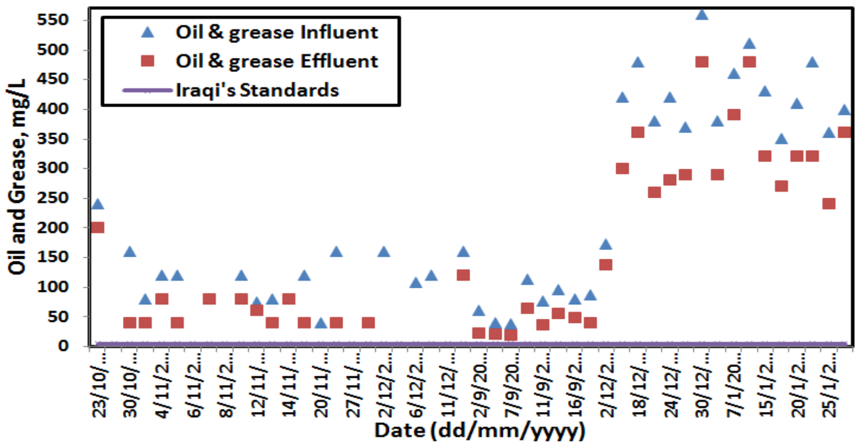

Figure 8. Oil and Grease Concentrations in Influent and Effluent Wastewater of Alsamawah Wastewater Treatment Plant for the Period from 23/10/2012 to 25/1/2015.

IV. CONCLUSIONS AND RECOMMENDATIONS

The lack of efficient grit removal and primary treatment, combined with lack of experience in managing operations and performing maintenance causeraw wastewater to receive no to little treatment in Alsamawah wastewater treatment plant. The plant was not able to reduce contaminants such as COD, TSS, oil and grease, or nutrients.The plant failed to comply with local regulations to reduce all tested contaminants. It comply only at the events when a contaminant is originally had low concentration in the raw sewage.More studies are needed to test if current local standards can improve the quality of water in the river? The plant is recommended to do the following to reach an acceptable level of treatment:

1. Vacuum pumps need to be installed in the central collection systems to avoid farther damages to the collection system.
2. Install a centrifugal pumps to avoid bypassing wastewater during screw pump's malfunctioning.

3. The plant will need a primary treatment and advanced treatment phases to be designed and installed.Grits also need to be removed prior to treatment through finishing the missing walls in the grit champers.Oil and grease skimmer need to be installed.
4. Plant will need an air blowers system to be added to the aeration tanks.
5. Frequent and scheduled maintenance should be reserved.
6. For future the plant may need anaerobic digestion or another method to stabilized solids.

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