Performance Evaluation of Al-Muamirah Wastewater Treatment Plant

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Abstract. Wastewater treatment is a process, which is being done on the wastewater to change its quality to be within the required specifications of water discharged to the surface waterway or water used for different purposes. In the present study, the performance of the oxidation ditch system related to Al-Muamirah wastewater treatment plant in Hilla city, province of Babylon, Iraq, in removing the pollutant of municipal were evaluated. The samples were taken from input wastewater and output treated water of the plant to measure the pollutant parameters. These parameters are the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Ammonia (NH3), Phosphorus (PO4), and the quantitative measure of the acidity or basicity (pH). Data were analyzed by using Excel software. The results show that the efficiency of removal of BOD, COD, TSS, NH3 and PO4 was 91%, 78%, 93%, 69% and 68%, respectively on a monthly basis. Accordingly, it can be recommended that the Al-Muamirah wastewater treatment plant has an acceptable efficiency of wastewater treatment and producing water in accordance with Iraqi environmental standards of water discharged to the surface water or water of other uses.

Keywords: BOD; COD; Oxidation ditch; Performance evaluation; Removal efficiency; Wastewater treatment plant (WWTP)

1. Introduction

Water scarcity would affect about 9 billion people worldwide by 2075, according to forecasting research [1]. Many countries are suffering from the negative effects of climate change, which have resulted in decreasing freshwater resources. Iraq is located in the Middle East's eastern region, which is dry to semi-arid. On the other hand, because of the rising population, the need for freshwater is projected to rise. This adds to the pressure already exerted on water facilities. Furthermore, water contamination has grown substantially as a result of rapidly expanding industrial activities. This region, in general, has a water scarcity, which is likely to worsen in the future due to the effects of numerous causes, including climate
change, rapid population expansion, fast economic development, rises in per capita consumption and contamination. The Tigris and Euphrates Rivers are the major sources of freshwater in Iraq. From 2009 to 2014, these revisers faced severe water shortages, which are likely to worsen as a result of climate change and rising water demand upstream. Furthermore, in Iraq, where all settlements were centered on the Tigris and Euphrates rivers, freshwater supplies were a critical component in the emergence of cities to ensuring the flourishing of both industry and agriculture [2]. Additionally, several studies have shown that the continual release of wastewater into the environment is exacerbating the problem of water scarcity by polluting freshwater supplies [1]. As a result, municipal water security is critical for achieving a sustainable environment in modern cities, particularly in light of global warming and socioeconomic factors. Furthermore, most cities are near freshwater sources. Freshwater shortage is a typical challenge for policymakers for the reasons stated. Recently, the World Economic Forum confirmed that water scarcity is one of the largest international risks because of the limited amount of accessible freshwater (approximately 0.014% of the total amount of water on Earth). Other important causes that lead to water shortage include inadequate management of freshwater sources. As a result, water utilities should assist and improve municipal water system management [3].

Water makes up 99.9% of wastewater, while the remaining 1% contains organic and inorganic contaminants, both dissolved and suspended, as well as microorganisms, and the wastewater treatment aims to remove these pollutants [4]. Several factors affect the wastewater characteristics, including the reason for which the water was used, the environment, the population's social and economic conditions, and others [5]. The general concept of biological wastewater treatment is that the water contains a large number of microorganisms that have the potential to reduce organic pollutants and nutrients in wastewater. The characteristics of wastewater and the purpose of the treatment process influence the selection of a suitable biological wastewater treatment technology [6].

Wastewater treatment plants have great environmental importance, which requires maintaining their efficiency so that the concentrations of pollutants that discharge to the rivers after treatment should be within acceptable limits. [7] Wastewater treatment plants are traditionally designed using experimental equations and simplified systems specifications using references or guidelines that can be used for designing purposes and sizing treatment units by selecting the wastewater characteristics, operating conditions, and deciding the effluent requirements [8].

Oxidation ditch (extended aeration) is a biological treating technique for activated sludge that removes biodegradable organics by using long solids retention times (SRTs). Usually, oxidation ditches are full mix system, but they can be changed to reach plug flow states [9]. A single or multichannel structure in an oval, circle, or horseshoe-shaped tank with mechanical aeration and mixing equipment is the typical design for oxidation ditch treatment systems. Water that has been screen and degritted enters the channel and is mixed with the activated sludge that has been returned. The tank design, as well as the aeration and mixing equipment, support unidirectional channel flow, allowing the energy used for aeration to provide mixing in a system with a long hydraulic retention period. The aeration/mixing system used produces a velocity in the channel of 0.25 to 0.30 m/s (0.8 to 1.0 ft/s), which is sufficient to keep the activated sludge suspended. The mixed liquor completes a tank circulation in 5 to 15 minutes at these channel velocities, and the magnitude of the channel flow can dilute the influent wastewater flowrate by a factor of 20 to 30. As the wastewater leaves the aeration zone, the DO concentration decreases and denitrification may occur downstream from the aeration zone. Brush-type or surface-type mechanical aerators are used for mixing and aeration [10]. Hydraulic retention periods in the oxidation ditch range between 6 to 30 hours in most municipal wastewater treatment plants. [9]. Small- and medium-scale wastewater treatment plants often use oxidation ditches. Simple construction, low sludge production, flexible operating mode, and special capability of nitrification and denitrifications in the same tank are all advantages of oxidation ditches. [11]. Because of the longer aeration period, the energy cost is higher in
In general, the process is divided into two aeration basins, one anoxic and the other aerobic. The first reactor, which operates under anoxic conditions, receives wastewater and returned activated sludge (RAS). The mixed liquor is then pumped into the second reactor, which is set up to operate under aerobic conditions. The process is then reversed, with the second reactor operating in an anoxic conditions[9]. The oxidation ditch is usually preceded by preliminary treatment such as bar screens and grit removal. While primary settling before an oxidation ditch is often used, it is not common in this design. Depending on the effluent conditions, tertiary filters can be needed after clarification. Prior to final discharge, disinfection is required, and reaeration may be required. The flow to the oxidation ditch is aerated and mixed with secondary clarifier return sludge. Figure 1 shows the sketch of the oxidation ditch process.

Figure 1. Sketch of Oxidation ditch process [10]

[13] Presented a study to evaluate a wastewater treatment plant in India working with a flow rate of about 23MLD as a conventional activated process and the results showed that the efficiency of the plant to remove BOD and TSS are 94.56% and 93.72% respectively. [14] Presented a study to evaluate a wastewater treatment plant in Egypt and the results showed that the efficiency of removal is more than 90% for COD, BOD, and TSS. This means that the performance of the plant was acceptable and in agreement with the specifications. [15] In a small-scale wastewater treatment facility, conducted an analysis to analyze and evaluate a biological treatment unit. They found that the effluent concentration of TSS, BOD, and COD was less than 10 mg/L, 20 mg/L and 98 mg/L respectively, which means that the WWTP has a good level. The extended aeration method, which is commonly utilized to handle the wastewater in small communities, has the highest BOD removal rate among activated sludge systems, with an efficiency of 90-98 percent [16]. Because of its advantages, the extended aeration triggered sludge system is the most common method for safe wastewater treatment in a residential tower, resots, palaces, hostels, restaurants, and health centers, infirmaries, labor camps, and offices in manufacturers, companies, and organizations. [17]. [18] converted a conventional activated sludge system to extended aeration in order to improve removal efficiency. According to [16], the COD removal efficiency of the extended aeration powered sludge system was 73.3 percent, and the linear alkyl benzene sulfonate removal efficiency was 96.7 percent. The average efficiency of removal of pollutants BOD$_5$, TSS, and COD, according to [19] was 57.7%, 70.8 percent, and 61.4 percent, respectively. [14] showed that the efficiency of removal is more than 90% for COD, BOD, and TSS. According to [20], the efficiency of removal of COD, TSS, and BOD$_5$ from industrial wastewater was 98.2 percent, 97.6 percent, and 96.66 percent, respectively.

The aim of our research is to evaluate the performance of the oxidation ditch system at eliminating pollutants of municipal wastewater in Al-wastewater Muamirah's treatment plant in the province of
Babylon. Up to our knowledge, this study is considered the first one on the performance evaluation of the oxidation ditch system in wastewater treatment in the region.

2. Case study

Al Muamirah WWTP was established in 2019. The total area of the treatment plant is 57 Acres, and it serves about 970,000 people in the city of Hilla, the capital of Babel Governorate, central Iraq. The plant operates with activated sludge system, oxidation ditch process. The treatment plant's discharge capacity is 107,000 meter cubic per day. The average daily input flow to the treatment plant is about 30000 meter cubic per day, the small input amount related to the incomplete pipelines conveying the sewers of Hilla. Al Muamirah WWTP plant shown in figure 2 is consists of four stages of treatment:

I. Preliminary (physical) treatment:
   a) The primary lift station: It contains 4 submersible pumps with a capacity of 2,400 cubic meters for each pump to raise the water to the grit chamber facility.
   b) Screens: It contains 3 fine screens and 3 coarse screens use for disposal of coarse and fine solid waste.
   c) Grit chamber: It contains 2 sand removal basin, and 2 Archimedes pump used to remove sand and oil by a physical machine

II. Secondary (biological) treatment
   a) Anaerobic tanks: A two closed basin each one contains two entry gates, one of which comes from the grit chamber and the other is attached to the return pipe. These ponds represent the first stage of the removal of nitrates and a portion of phosphorus by anaerobic bacteria.
   b) Anoxic tanks: An open basin consists of three basins for each large aeration basin and works to reduce sedimentation and add dissolved oxygen to the water and contains devices for measuring dissolved oxygen content. These basins represent the aerobic treatment stage, which is the second stage of the nitrate removal process and at this stage, gas is released Nitrogen.
   c) Oxidation Ditch: It consists of two main basins each basin is ovoid with a depth of approximately 6 meters and the capacity of each basin is 50,000 cubic meters. It consists of opposite arcs and separate channels. Each basin equipped with five oxygen addition motors and ten submersible mixers that reduce sedimentation in the basin, add oxygen, develop aerobic bacteria, and create turbulence in the water to increase its speed, i.e. increase sludge.
   d) Sedimentation tanks: There are four sedimentation basins each 45 meters in diameter and containing a sweeping bridge. In these ponds, the sludge is disposed of for later treatment and disposal, as well as disposal of floating materials, while the treated water is discharged to the contact basins.
   e) Collection and distribution basin: in which alum is added to increase sedimentation and contains three arcs, in which water is distributed to sedimentation basins, treated water is discharged into contact basins, and sludge is drained back.

III. Purification stage (chlorination): The sterilization process takes place in the contact basins, where chlorine is added to the treated water in these basins to kill microorganisms and microbes. There are two lines for the water to come out according to the specifications.

IV. Sludge treatment unit:
   a) Holding tank: It is used for sludge collection and storage, it contains a mixer to prevent sedimentation, and there is an outlet to the squeezing stage.
   b) Dewatering: The facility contains five squeezing machines, squeezing and condensing sludge, and speeding up fertilizer manufacturing.
   c) Drying beds: It consists of 16 drying basins used to separate the sludge with filter media and sun drying.
3. Data and methods
The purpose of our study was to evaluate the performance of Babylon's Al-Muamirah WWTP over a one-year period (2020). The characteristics of raw wastewater have been studied to know the strength of pollutants before the treatment. Also, concentrations of effluent pollutants after treatment have been examined and compared with the upper limits of Iraqi standard. In addition, percentage removal of each pollutant should be calculated to know the efficiency of the plant. Samples were taken weekly for one year. A total of Forty-eight samples were taken. Two sampling points were identified are the wastewater treatment plant influent and the wastewater treatment plant effluent. The contamination parameters tested for these samples were the biochemical oxygen demand (BOD5), the chemical oxygen demand (COD), total suspended solids (TSS), Ammonia (NH3), Phosphorus (PO4), and the quantitative measure of the acidity or basicity (PH). The protocols required for the sampling process were considered by selecting the appropriate depth, the time of sampling, the equipment used and the transport to the laboratory. Water and wastewater testing standards [21] were followed during the experiments, which were carried out in the plant laboratory. Finally, the values of the tested parameters were analyzed by using Excel 2010 software.

4. Results and discussion

4.1. Raw wastewater assessment
For influent BOD, the average monthly value was 130 mg/L, while the maximum monthly value was 181 mg/L in December. These values are under the design value of Al-Muamirah WWTP (300 mg/L) which means there is no over organic loading during the study year. There is a slight variation in the concentration of influent BOD throughout the year due to the difference in climate and water consumption between months of the year as well as the operational conditions of the lifting stations that pump wastewater to the treatment plant [22]. For influent COD, the average monthly concentration was 217 mg/L, while the highest monthly amount was 328 mg/L in December which are all lower than the design value of Al-Muamirah WWTP (400 mg/L). This variation may be related to the characteristics of
wastewater according to each season and the influent industrial wastewater from industrial regions that reach Al-Muamirah WWTP across the city wastewater network. [22]. For influent TSS, the average monthly concentration was 186 mg/L, while, the highest monthly amount was 344 mg/L in December and these values are less than the design value of the plant (350 mg/L). There is a high variation of TSS concentration among the months of the year and that could be related to the operational conditions of the lifting stations that pump wastewater to the treatment plant [10]. For influent NH3, the average concentration was 13 mg/L while the maximum monthly value was 18.5 mg/L in December. These values are less than the maximum design value of Al-Muamirah WWTP which was 20 mg/L. For influent PO4, the average monthly concentration was 6 mg/L which is lower than the design value of Al-Muamirah WWTP (7 mg/L), while the maximum monthly value was 11.6 mg/L in March that is more than the maximum design value of Al-Muamirah WWTP due to illegal industrial wastewater discharge to the sewerage network. In general, there is no high variation due to the stability of phosphorus concentration over the seasons [23]. The average influent pH was 7.68. The maximum monthly value of pH was 7.95 in June, these values are less than the design value of the plant which is 8. The average effluent BOD/COD ratio was 0.6, this is within the range (0.3 – 0.8) mentioned in [10], the variation in values may be related to the characteristics of wastewater and the amount of biodegradable organic matter [22].

4.2. Treated wastewater assessment

The average monthly effluent concentration of BOD was 12 mg/L, while the BOD maximum monthly concentration was 16 mg/L in January which are all matches the Iraqi standard (less than 40 mg/L). For effluent COD, the average monthly value was 45 mg/L, and the highest monthly concentration value examined for the COD was 80 mg/L in January which does meet with the Iraqi standard (under 100 mg/L). This indicates an effective performance of plant operation. For effluent TSS, the average monthly concentration value was 11 mg/L, and the maximum monthly concentration value examined for the TSS was 14.2 mg/L in November which are all meet with the Iraqi standard (less than 60 mg/L). This may be related to providing sufficient detention time in the sedimentation tanks and in the oxidation ditch. For effluent PO4, the average concentration was 2 mg/L, while the highest monthly concentration value examined for the PO4 was 2.6 mg/L in April which are all meet with the Iraqi standard (less than 3 mg/L). For effluent concentrations of NH3, the average was 4 mg/L, and the maximum monthly amount value examined for the NH3 was 7.33 mg/L in August which are all meet the Iraqi standard (less than 10 mg/L). There is no high variation in effluent pH and the average monthly value was 7.5, and the highest monthly concentration value examined for the PH was 7.7 in each of May and June. It was within the permissible limit (6-9.5). The average effluent the BOD/COD ratio was 0.27 which is within the range (0.1-0.3) mentioned in [10].

4.3. Removal efficiency of the plant

Figure 3 illustrates the average monthly removal efficiency of pollutant parameters in the inflow and outflow of wastewater of the treatment facility. The findings also revealed the efficiency of BOD5, COD, TSS, NH3, and PO4 removal over the course of the study year (2020) as a monthly average. The average monthly value of BOD removal efficiency is 91 % and this good removal may be due to the stability of microorganisms that are working with a good performance due to sufficient transferred oxygen in the aeration tanks [10]. The average monthly value of COD removal efficiency is 78% which can be considered stable but less than the requirements, this may be related to the nature of influent wastewater which contains high non-biodegradable organic matter [23]. The average monthly value of TSS removal efficiency is 93 %, this refers to that the plant is working with high efficiency probably due to the good operation of the sedimentation tanks and a sufficient hydraulic retention time (HRT) [10]. On the other
hand, the average monthly removal efficiency of nutrients NH3 and PO4 is 69% and 68%, respectively. These efficiencies are of moderate values that may be related to the characteristics of influent wastewater. Briefly, all the studied pollutant parameters in the treated wastewater of Al-Muamirah WWTP have met the Iraqi standard of water discharged to surface water or water of other uses. This indicates that the oxidation ditch system work efficiently in removing the studied pollutant parameters. Accordingly, it can be concluded that this plant has a good performance in treating wastewater.

**Figure 3.** The average monthly efficiency of removal of the pollutant parameters studied in the treatment plant's wastewater.

Figures 4-9 show the monthly variation of COD, BOD5, TSS, NH3, PO4, and PH, respectively for the inflow and outflow of wastewater of the treatment plant during the study period. Figure 10 shows the monthly variation of the BOD/COD ratio in the inflow and outflow of wastewater of the treatment plant. The average monthly values of the studied pollutant parameters of the inflow and outflow of wastewater of the Al-Muamirah wastewater treatment plant with a comparison of Iraqi standard are shown in Table 1.

**Figure 4.** The monthly variation of COD in the inflow and outflow of wastewater of the treatment plant.
Figure 5. The monthly variation of BOD in the inflow and outflow of wastewater of the treatment plant.

Figure 6. The monthly variation of TSS in the inflow and outflow of wastewater of the treatment plant.

Figure 7. The monthly variation of NH3 in the inflow and outflow of wastewater of the treatment plant.
Figure 8. The monthly variation of PO4 in the inflow and outflow of wastewater of the treatment plant.

Figure 9. The monthly variation of PH in the inflow and outflow of wastewater of the treatment plant.

Figure 10. The monthly variation of the BOD/COD ratio in the inflow and outflow of wastewater of the treatment plant.
Table 1. The average monthly value of the studied pollutant parameters in the inflow and outflow of wastewater of the Al-Muamirah WWTP with a comparison of Iraqi standard.

| Parameter | Inflow of wastewater (Influent) | Max. design of plant | Outflow of treated wastewater (Effluent) | Iraqi standard |
|-----------|---------------------------------|----------------------|------------------------------------------|----------------|
| BOD (mg/L)| 130                             | 300                  | 12                                       | 40             |
| COD (mg/L)| 217                             | 400                  | 45                                       | 100            |
| TSS (mg/L)| 186                             | 350                  | 11                                       | 60             |
| NH₃ (mg/L)| 13                              | 20                   | 4                                        | 10             |
| PO₄ (mg/L)| 6                               | 7                    | 2                                        | 3              |
| pH        | 7.68                            | 8                    | 7.5                                      | 6-9.5          |

5. Conclusion
The present research was conducted to assess the performance of Al-Muamirah WWTP. The pollutant parameters (COD, TSS, BOD5, NH3, and PO4) with pH parameter are examined for inflow and outflow of wastewater of this plant. According to the results, the efficiency of removal of BOD5, TSS, COD, NH3, and PO4 was 91 percent, 93 percent, 78 percent, 69 percent, and 68 percent, respectively, on a monthly basis. All of the studied pollutant parameters were considered to be below the Iraqi standard. Therefore, it can be advised that this plant has an efficient performance to remove the studied pollutant parameters. This means that the water leaving the station is suitable for discharge into the Euphrates River as well as suitable for non-human use such as agriculture. Additional studies should be carried out on evaluating the performance of the Al-Muamirah WWTP by measuring other pollutants and comparing them with the specification. Other studies should also be carried out on evaluating the performance WWTPs to other cities that operate with the same system.

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