

**RESULTS OF SCIENTIFIC RESEARCH ON MEMBRANE
BIOREACTORS IN INDUSTRIAL WASTEWATER TREATMENT**
Third Report

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ABSTRACT

Effluents from food industry determine pollution problems due to high of COD and BOD concentrations. Compared to other industrial divisions, food industry requires large amounts of water, which is used for most of the plant operations, such as production, cleaning, sterilization, cooling, and materials transport etc. Membrane Bioreactors (MBR) has been proven as an efficient single step process to treat this type of wastewater and produces a very good effluent quality suitable for reuse. In this study, MBR was based on submerged hollow fibers membranes functioning by low vacuum. Two test runs of bioreactor system were carried out with different hydraulic retention times of 8 hours and 24 hours. One hundred and ninety-two tests were carried out on sixteen water samples collected from the influent and the effluent of the bioreactor during the two runs. NaOCl compound was added to the bioreactor with backwashing process for these tests at HRTs for each run, and same compound was added with mixed liquor for the second test at period 24 hour of aeration. The samples were tested for twelve water quality tests, these are: Temperature, Dissolved Oxygen, pH, Turbidity, Total Suspended Solids, Mixed Liquor Suspended Solids, Chemical Oxygen Demand, Biochemical Oxygen Demand, Nitrate Nitrogen, Ammonia Nitrogen, Total Phosphate, and Ortho Phosphate. The results indicated that the bioreactor system can be used efficiently to treat industrial wastewater from the food industry.

The efficiency of the technology was evaluated with sodium hypochlorite addition to remove the adherent bacteria on the surface area of hollow fibers. The results showed that the bioreactor under the conditions of the second run was excellent in removing turbidity, TSS, COD, and BOD₅ with a removal efficiency higher than 99.97%, 91.28%, 92.27%, and 99.19% respectively when added 82 ml of NaOCl in the bioreactor tank, and was very good in removing of NH₄-N, TP, Orth-P with removal efficiency of about 80%, 36%, and 27%, respectively. Lower removal efficiency was obtained under the conditions of the first test.

Keywords: MBR, Food Industry, NaOCl, Conventional Aeration.

1. Introduction

Most countries suffer from water shortage and poor quality due to population growth, climate variability, and human activity, which leads to a food gap and decreasing of water resources. The situation is worsening by the pollution of freshwater resources, due to the discharge of untreated industrial and municipal wastewater into freshwater sources, thus constituting the main source of water pollution [1]. Industrial wastewater varies in the flow and pollution strength. The industrial wastewaters contain suspended, colloidal and dissolved (mineral and organic) solids. The wastewater may contain inert, organic or toxic materials and possibly pathogenic bacteria. The wastes may be drained to the sewer system provided if not have a noxious effect on treatment efficiency on the sewer system. Full treatment is necessary when the waste is discharged directly into surface or groundwater [2]. The membrane bioreactor, MBR is one of the leading technologies currently used in countries around the world for water reuse. Because of advances in technology and declining costs, MBR technology application for water reuse has increased sharply over the past few years [3]. MBR systems have been used to treat wastewater as a potential technique, especially for industrial wastewater treatment. MBR is an alternative biological treatment method associated with the conventional activated sludge process with its smaller footprint, less sludge production, and ability to operate under the production of high-quality effluent, [4]. The basic parameters for industrial wastewater characteristics include chemical oxygen demand, COD, biochemical oxygen demand BOD₅, suspended solids, SS, ammonium nitrogen, NH₄-N, pH, turbidity, and Dissolved Oxygen, DO. Food industry wastewater is considered industrial wastewater which contains residues that consume the oxygen in receiving streams. Oxygen demand and nitrogenous pollutants in wastewater are a potential threat to the aquatic environment and hence to public health. The oxygen demand and ammonium nitrogen NH₄-N can result in dissolved oxygen DO consumption of the received water body [5]. The most important criteria used for food industry wastewater to determine the quality of water are chemical oxygen demand, COD, and biochemical oxygen demand, BOD₅. These parameters are important to evaluate the efficiency of wastewater treatment. Hollow fiber ultrafiltration UF membranes are flexibility during water treatment and can be used in a number of configuration processes to meet advanced effluent treatment objectives. These membranes used for removal of particular and colloidal contaminants. Also, can be combined with biological or chemical treatment to dispose of dissolved pollutants. In this study, the analytical results obtained during the experimental tests for wastewater treatment of the food industries in a meat processing plant in Romania will be presented using the activated sludge method with MBR system type ZW-10 producing from Zenon[®] (General Electric) Company.

2. Materials and Methods

Figure 1, shows the schematic diagram of hollow fiber MBR system used in this study. The membrane module ZW-10 is a polyethylene hollow fiber manufactured by Zenon-General Electric with an OCP chemistry, with a pore size of 0.036 μm and total active area of 0.93 m^2 . The pilot plant used during the experiments was made available by the company Zenon KFT Hungary. This pilot plant is located in the hydraulic laboratory of the Technical University of Civil Engineering in Bucharest UTCB, Romania. This membrane module is a unique outside-in hollow fiber module that operates under a low vacuum instead of high pressure [6]. The membrane is installed in 26 liters volume of bioreactor plastic tank with dimensions of 18×18×80 cm. The aeration of the activated sludge was performed by fine air bubble diffusers. A Verder gear pump located in the center of the MBR system was used to create a negative suction head at the membrane module to sustain the permeate stream flow rate. This pump permits for the reversal of the flow in the pump according to the power requirements, to ensure reverse supply role in the backwashing process of the membranes. The bioreactor was operated in two runs, (RI, RII), with different hydraulic retention times HRT. Industrial wastewater provided by food industry factory of meat processing was used as a sample of wastewater in this study. The conventional aeration method for activated sludge was used by two runs. The first run, RI was conducted in 09/Nov./2017, while the second run, RII, was conducted in 29/Nov./2017. The HRTs of two tests were selected to be 2, 4, and 8 hours for RI, and 2, 4, 8, and 24 hours for RII respectively with the adding 6 ml of NaOCl compound in the bioreactor tank during backwashing process, also, 82 ml of NaOCl during RII was added in the bioreactor tank with mixed liquor at 24 hours of HRT. In these tests, the recycling pump was operated in the plastic tank (storage tank) to ensure the mixed between the sludge and the wastewater sample and activate the all aerobic bacteria. Activating sludge is the first step that was carried out before operating the bioreactor system to treat the wastewater. To activating sludge in the first test, 550 liters of industrial wastewater sample was pumped into the plastic tank (storage tank) with 20 liters of mixed liquid of activated sludge at concentration 3.542 gr/l and then was aerated continuously at a rate of 13 l/hr by using 4 air dispensers during the duration of the experiment, while 1000 liters of the wastewater sample taken from the same source was pumped into the plastic tank with 40 liters of mixed liquid of activated sludge at concentration 3.234 gr/l for sludge activation purpose of the second test as a pre-treatment process. During the aeration process, the liquid mixture was pumped from the plastic tank into the activated sludge tank of the pilot plant by using two peristaltic pumps with flow rate 32.31 and 28.31 l/h, then to the bioreactor tank by overflow pipe fixed inside the activated sludge tank. The aeration in the activated sludge tank was performed at the air flow rate of 6 l/min. Six milliliters of the sodium hypochlorite, NaOCl was added in the bioreactor tank during the backwashing process by used a peristaltic pump with flow rate 6 ml/min distributed by 3 ml per 30 seconds, while 82 ml of NaOCl was added by another peristaltic pump to the bioreactor tank with the mixed liquid in the last HRT during RII test (24 hour of aeration) at a flow rate 4.1 ml/min. The treatment process and backwash process was programmed at time 600 sec, and 30 sec respectively. The air was pumped from the base of the membrane at flow rate 50 l/min to prevent the adhesion of sludge on the surface area of the membrane.

3. Water Quality Parameters and Sampling Tests

During each run of the bioreactor system, a number of water quality parameters were carried out to examine the influent and effluent physical, biological, and chemical properties.

These quality parameters were DO, pH, Temperature, Turbidity, TSS, MLSS, BOD₅, COD, NO₃-N, NH₄-N, TP, and Orth-P.

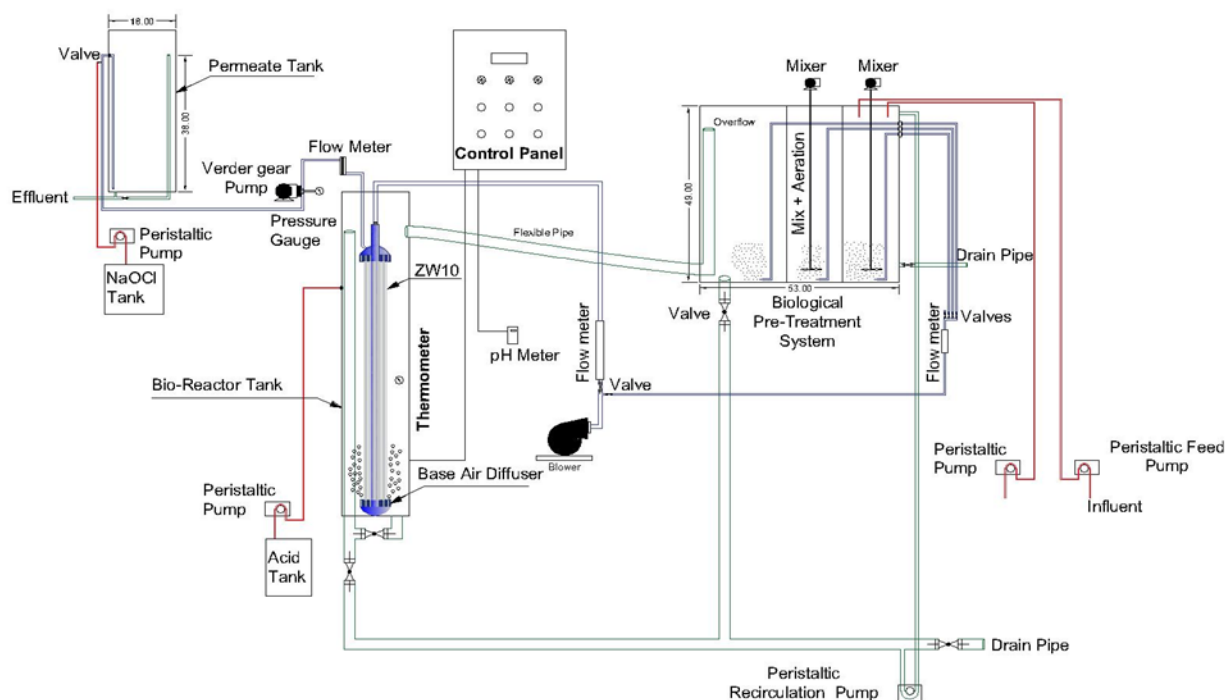


Fig. 1. Schematic diagram of ZW-10 MBR system.

Sixteen samples were collected to analyze physical and biochemical tests. The samples were taken from the plastic tank (storage tank), activated sludge tank, and effluent tank. Regarding the first test RI, seven samples were taken with 2, 4, 8 hours of aeration time, the first sample it is a raw wastewater sample that was taken from the plastic tank at reached to the laboratory in 09-Nov.-2017, at 9:45 am. While, on the second test RII, nine samples were taken for 2, 4, 8, and 24 hours of aeration time, the first sample was taken from the plastic tank when the raw wastewater reached to the laboratory in 29-Nov.-2017, at 10:45 am. These times were selected in the treatment process to determine the BOD removal efficiency, COD removal efficiency, and suspended solids removal efficiency, as well as determine the effect of the chemical compound represented by NaOCl on the treatment efficiency. The DO, pH, and temperature were measured on-site before sampling.

4. Results and Discussions

The collected samples were tested for twelve of physical and biochemical tests. The biochemical tests were analyzed in the chemical laboratory of UTCB, which consists of mixed liquor suspended solids, MLSS, total suspended solids, TSS, biochemical oxygen demand, BOD₅ chemical oxygen demand, COD, turbidity, nitrate nitrogen, NO₃-N ammonium nitrogen, NH₄-N, total phosphate, TP, and orthophosphate, Orth-P, while the physical tests were carried out on the site which consists of dissolved oxygen DO, pH, and temperature. The codes of influent samples were I1 and I2 during RI and RII runs respectively, while the codes of Effluent were E1, E2, during the RI and RII runs respectively. Analysis of these results is presented in the following subsections.

4.1. Temperature

The temperature of the wastewater samples for RI varied between 19 and 20.5°C with gradual increasing during the operating time as shown in figure 2, The maximum and minimum temperature of I1 was found, 20.3°C and 19.7°C, respectively, while, the maximum and the minimum of E1 was found 20.5°C and 19.9°C respectively.

The temperature of the wastewater samples for RII varied between 16.8 and 18.3°C with gradual increasing during the operating time except at time 24 hr, where it was decreased as shown in figure 3, The maximum and minimum temperature of I2 was found, 17.4°C and 17°C, respectively, while, the maximum and the minimum of E2 was found 18.3°C and 17.5°C respectively.

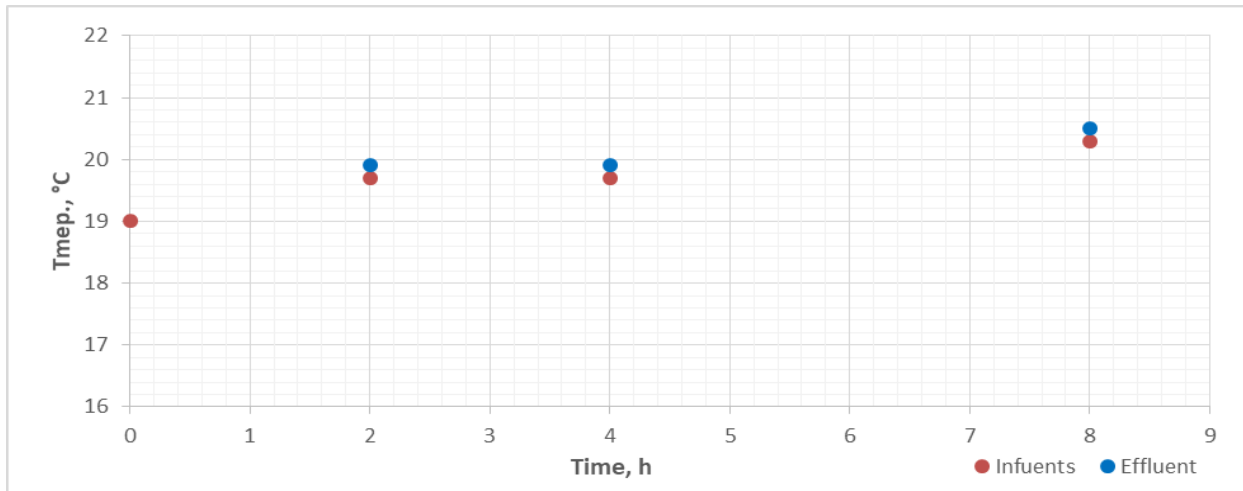


Fig. 2. Variations of the temperature in RI.

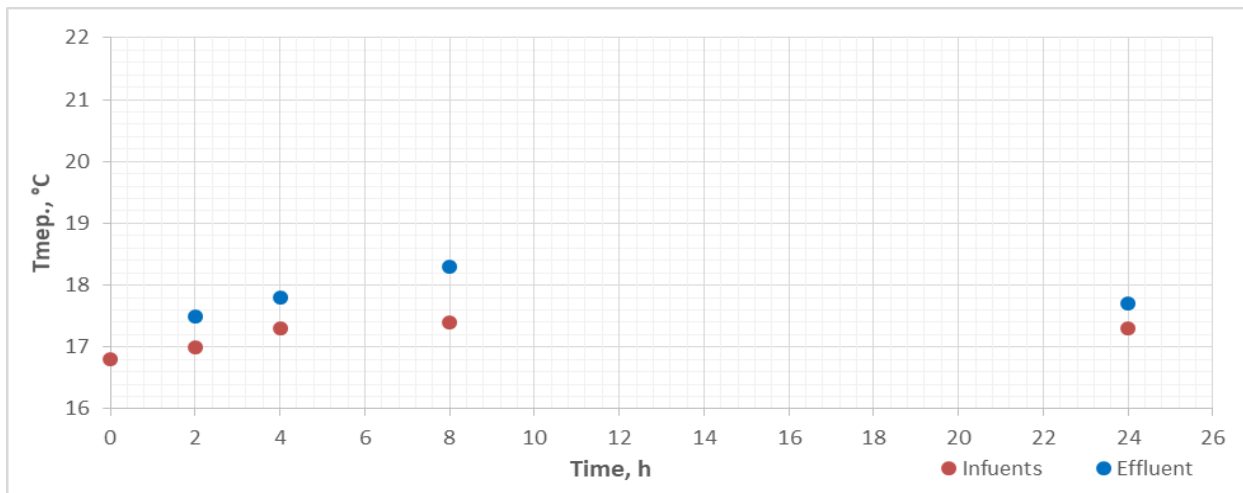


Fig. 3. Variations of the temperature in RII.

The temperature during RI was slightly higher than RII, this may have been due to the variation of weather conditions. The effluent temperatures were in general higher than the influent, due to the biochemical processes of microorganisms in the bioreactor.

4.2. Dissolved Oxygen, DO

The dissolved oxygen concentrations of the wastewater samples during RI varied between 0.04 and 4.98 mg/l as shown in figure 4. The maximum and minimum DO of I1 was 1.48 and 0.45 mg/l respectively, while, the maximum and minimum of E1 were found 4.98 and 2.14 mg/l respectively. All DO concentrations in influents during RII run were found to be close to zero. Generally, the DO concentrations during RII run varied between 0.09 and 8.4 mg/l with low concentrations in the influents, as shown in figure 5.

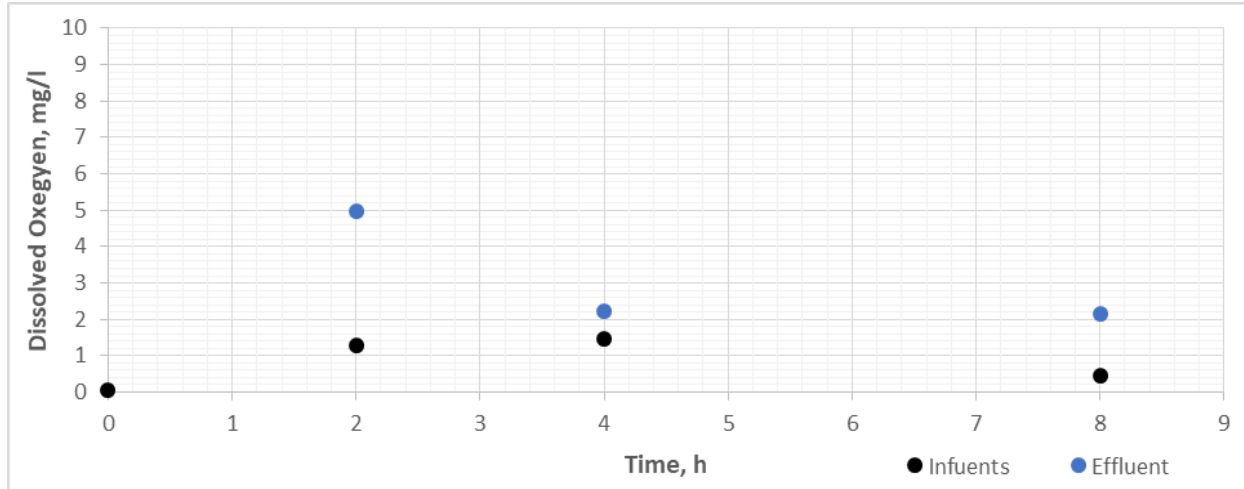


Fig. 4. Variations of the DO in the RI.

The maximum and minimum of E2 were 8.4 and 5.64 mg/l respectively. The low value of DO at I2 may be referring to the Oxygen depletion in the pretreatment process represented (activated sludge tank) by the microorganisms for growth and organic biodegradation comparing with short to long HRTs.

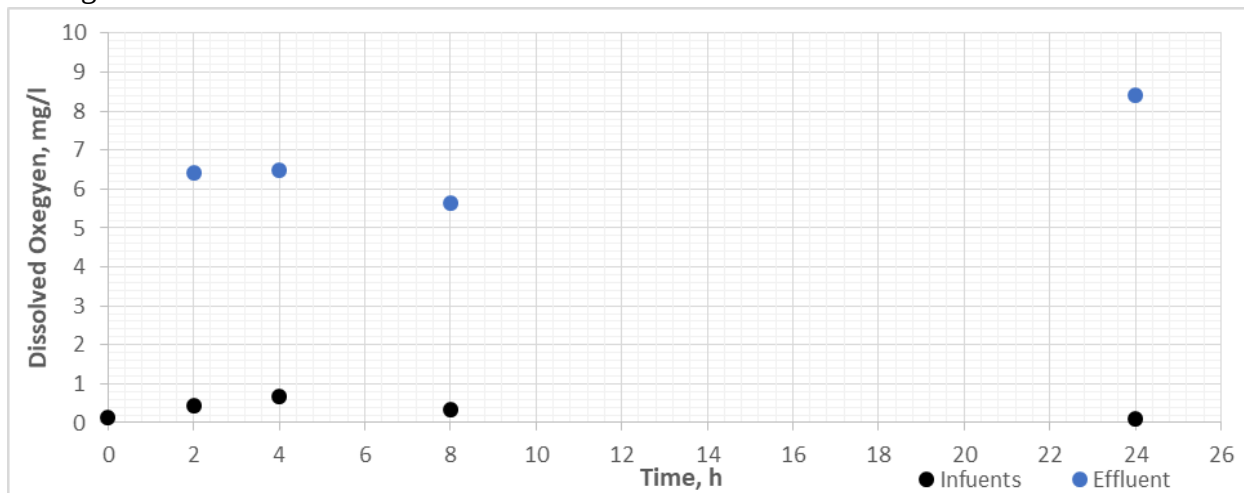


Fig. 5. Variations of the DO in the RII.

4.3. pH

The variation values of pH during RI and RII runs are shown in figures 6 and 7 respectively. All the influent values of pH were higher than 7 except the raw wastewater, where was less than 7. The average, maximum, and minimum pH value of I1 was 7.54, 7.71, and 7.23, respectively,

while the average, maximum, and minimum pH value of I2 was 7.32, 7.59, and 7.07, respectively. The pH values of the effluents during the tests RI and RII were higher than that of the influents, because of NaOCl effect in the bioreactor and indicate an alkaline solution. The average pH values of E1 and E2 were 7.91 and 8.21 respectively.

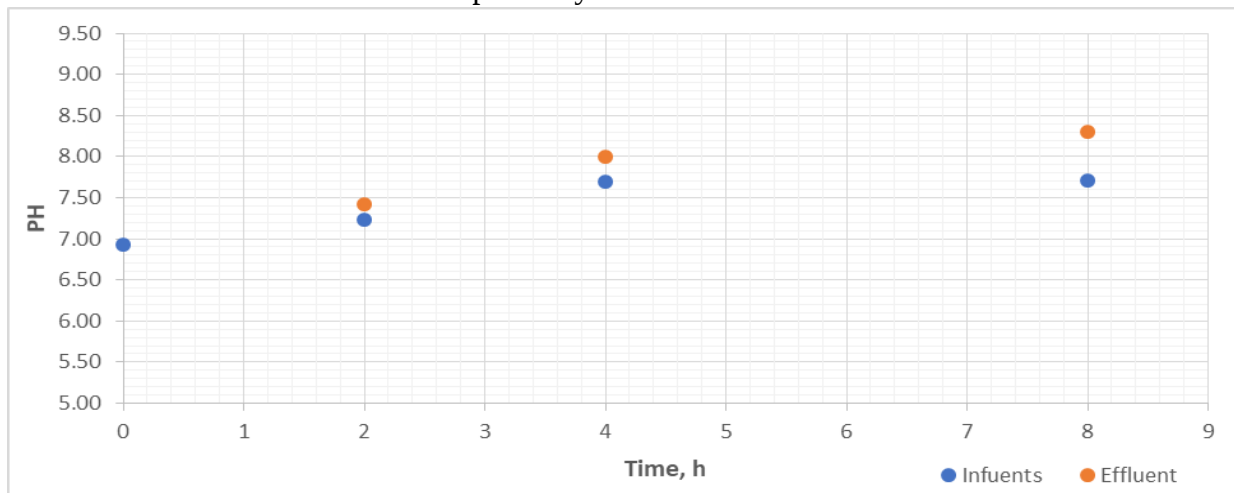


Fig. 6. Variations of the pH in the RI.

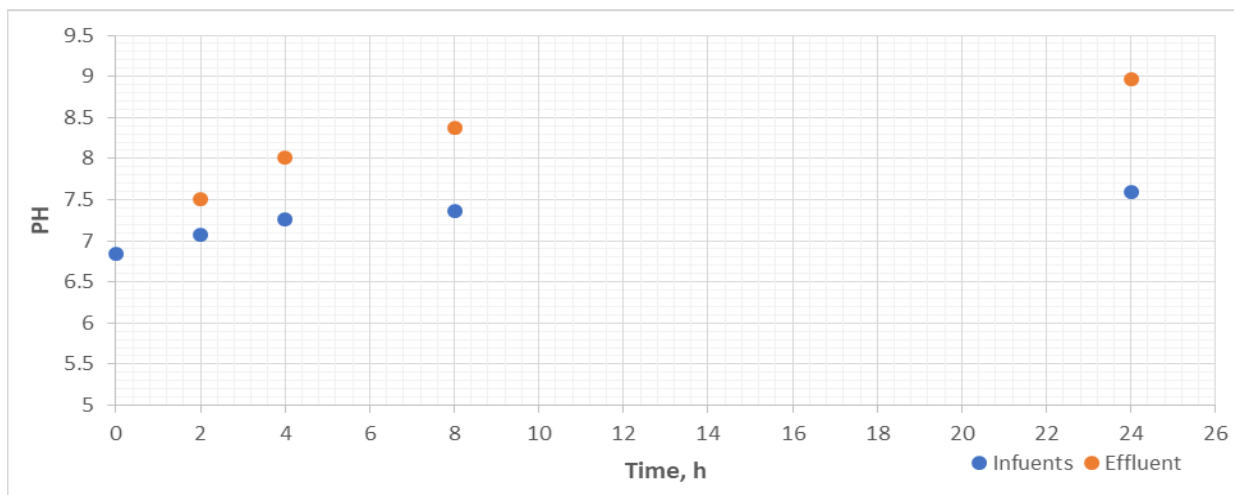


Fig. 7. Variations of the pH in the RII.

4.4. Turbidity

The tested values of the turbidity during RI run are shown in figure 8. The turbidity concentration of raw wastewater was 205 NTU and, the average, maximum, and minimum value of I1 was 271, 305, and 217 NTU respectively, while the average, maximum, and minimum value of E1 was 1.11, 1.51, and 0.37 NTU respectively.

Figure 9 shows the values tested of turbidity concentration during RII run. The turbidity value of raw wastewater was 250 NTU and the average, maximum, and minimum value of I2 was 310, 347, and 292 NTU respectively, while the average, maximum, and minimum value of E2 was 2.28, 4.35, and 0.1 NTU respectively.

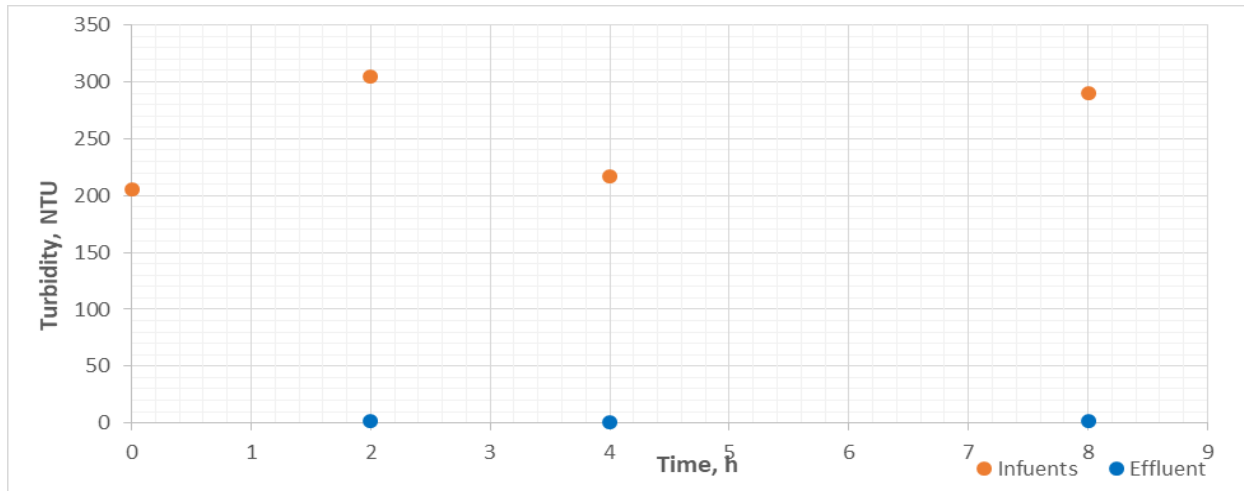


Fig. 8. Variations of the turbidity in the RI.

The membrane filter showed an excellent turbidity removal, where the removal of turbidity during all tests carried out varied between 99.48 and 99.83% for RI run and 99.27 and 99.97% for RII run. In general, all the turbidity of effluents during runs RI and RII were much less than that of the influents, this indicates that the membrane filter was very efficient in retaining solids.

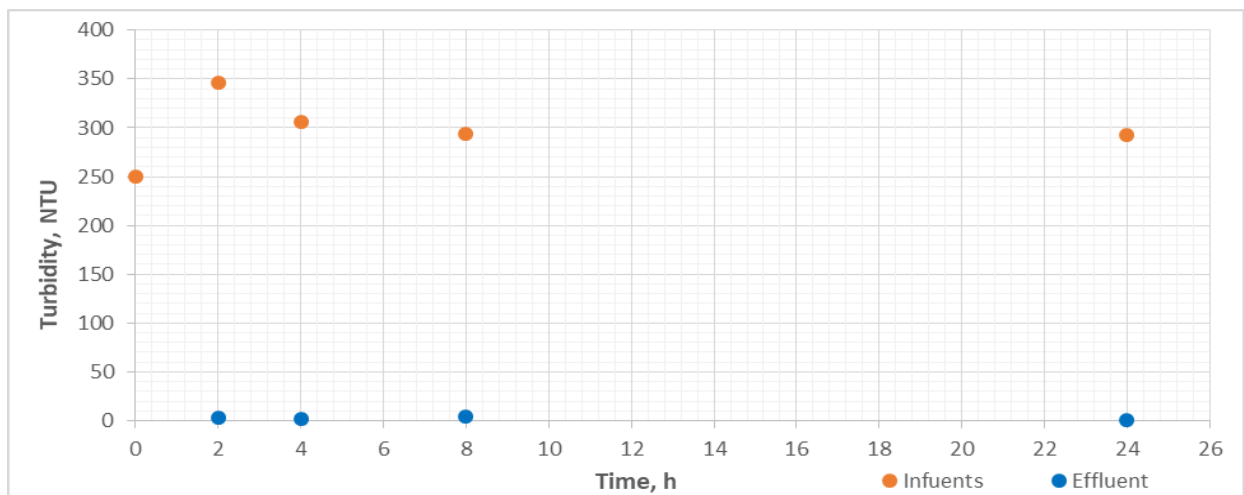


Fig. 9. Variations of the turbidity in the RII.

4.5. Total Suspended Solids, TSS

The results of tested values for total suspended solids during the RI and RII runs was shown in figures 10 and 11. The results obtained from these tests are the raw wastewater and effluents. On the first test, the TSS value of raw wastewater sample was 522 mg/l, and the average, maximum, and minimum value during E1 run was 121, 132, and 112 mg/l respectively. The removal of TSS during all tests performed during RI run varied between 75.22 and 82.14%.

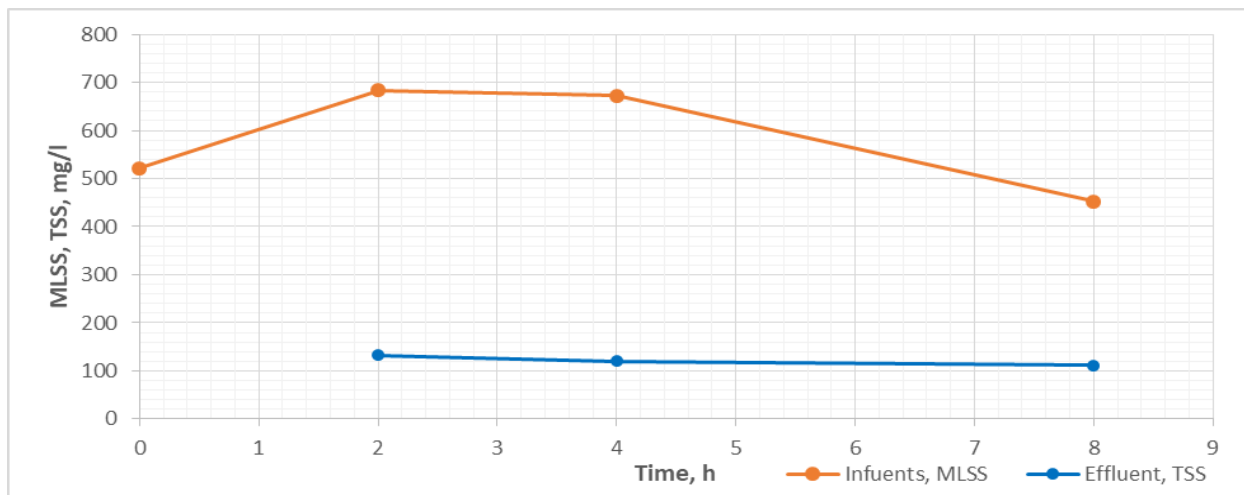


Fig. 10. Variations of the MLSS and TSS in RI run.

Figure 11 shows the results of tested values for TSS during the RII run. The TSS value of raw wastewater sample was 744 mg/l, and the average, maximum, and minimum value during E2 run was 164, 242, and 78 mg/l respectively. The removal of TSS during all of RII run varied between 67.47% and 91.28%. Total suspended solids are greatly related to the turbidity. Generally, the results obtained showed the excellent removal of TSS with increased of the NaOCl amount, that means the addition of sodium hypochlorite may help in high of removal efficiency.

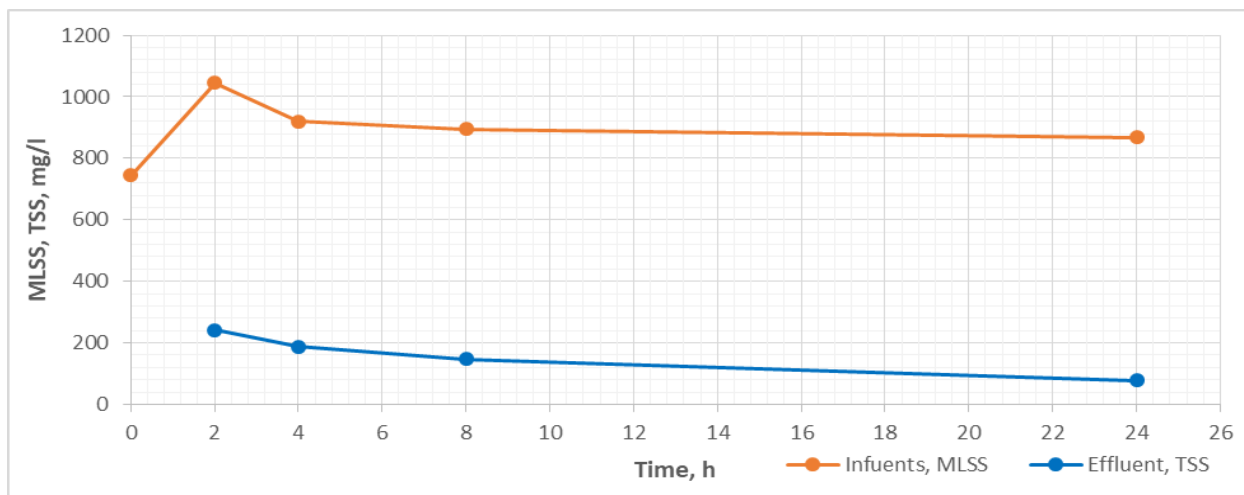


Fig. 11. Variations of the MLSS and TSS in RII run.

4.6. Mixed Liquor Suspended Solids

The results of mixed liquor suspended solids, MLSS tested values was taken from influent during the RI and RII runs were shown in figure 10 and 11. The average, maximum, and minimum value of MLSS during the I1 was 603, 684, and 452 mg/l respectively, while the average, maximum, and minimum value during the I2 was 932, 1046, 868 mg/l respectively. The results obtained are shown that decreased of MLSS concentrations with the time during aeration process, that means the decline of the number of microorganisms represented by sludge due to the consumption of organic matter in the wastewater.

4.7. Biochemical Oxygen Demand, BOD₅

The tested values of BOD₅ during RI and RII runs are shown in figures 12 and 13, respectively. The tested values of BOD₅ of both influents, I1 and I2, depended on the incoming organic load in the sample of raw wastewater, wherein in the first test, RI was found 1442 mg/l, and 1864 mg/l in the second test, RII. The BOD₅ values of influents for both I1 and I2 fluctuated between 1398 and 946 mg/l during RI run, and between 1808 and 1483 mg/l during RII run, respectively. During RI run, the BOD₅ values of the effluent, E1 decreased gradually and reached to 340 mg/l. While for RII run, the BOD₅ of the effluent, E2 has been significantly decreased and reached to 12 mg/l after 24 hours of aeration due to the effect of NaOCl.

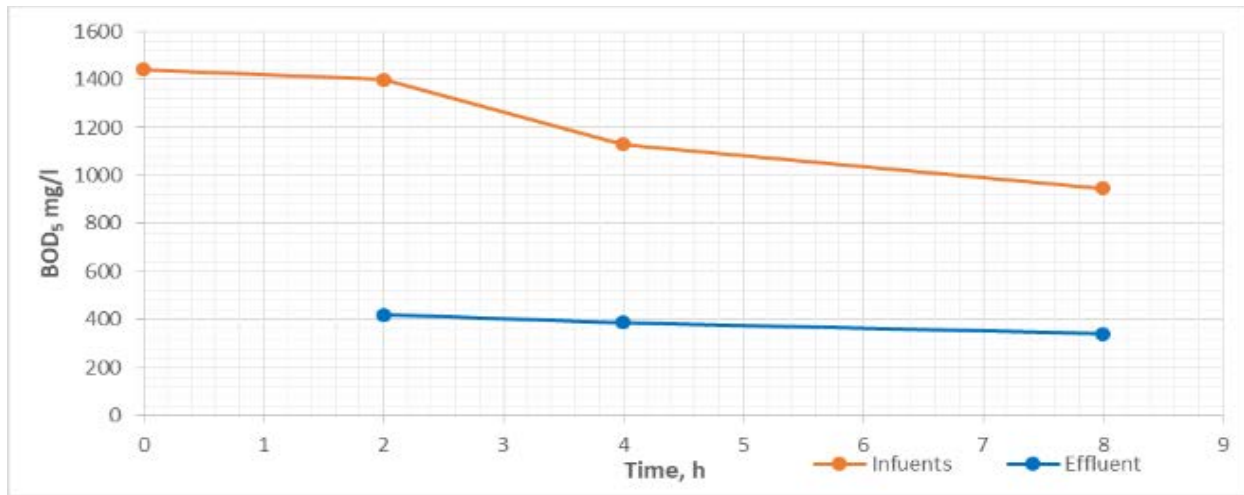


Fig. 12. Variations of the BOD₅ in RI run.

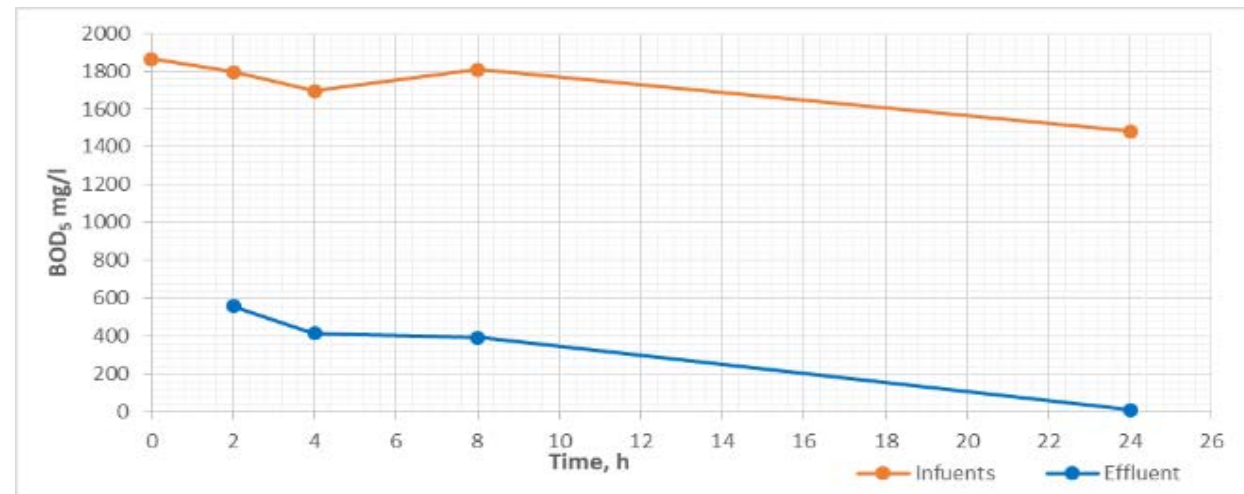


Fig. 13. Variations of the BOD₅ in RII run.

The removal efficiency of BOD₅ during the RI run varied between 64 and 70%, while the removal efficiency during RII run varied between 69 and 99%, respectively. The fourth test during RII showed the highest removal efficiency, due to the addition 82 ml of NaOCl into the bioreactor tank with the mixed liquor during bioreactor process, while the lowest removal on the first test and increased with the operating time of the treatment system. The difference in removal between RI

run and RII run may be due to the temperature and NaOCl addition. The temperature represents an effective factor in the solute extraction because it has a strong influence on the bioreactor reaction rate, [7].

4.8. Chemical Oxygen Demand, COD

The tested values of the Chemical Oxygen Demand, COD during RI and RII runs are shown in figures 14 and 15, respectively. The COD tested values of both raw wastewater samples in RI and RII runs were found 2458 and 2534 mg/l respectively. The average, maximum, and minimum concentration of COD value of influent for I1 were 1830, 2227, and 1421 mg/l, respectively, while the average, maximum, and minimum concentration of COD value of I2 were 2256, 2458, and 2112 mg/l, respectively.

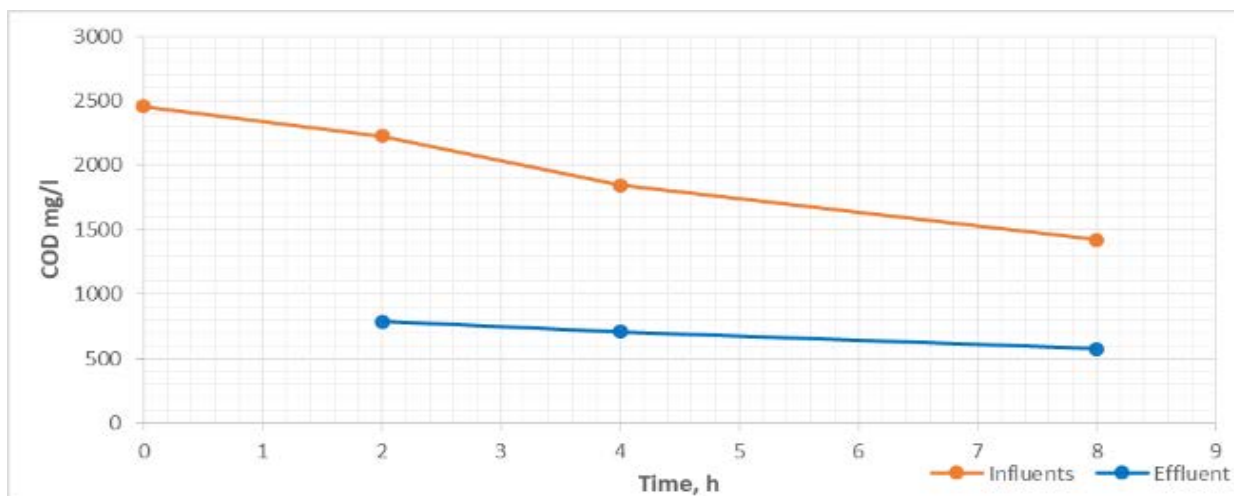


Fig. 14. Variations of the COD in the RI run.

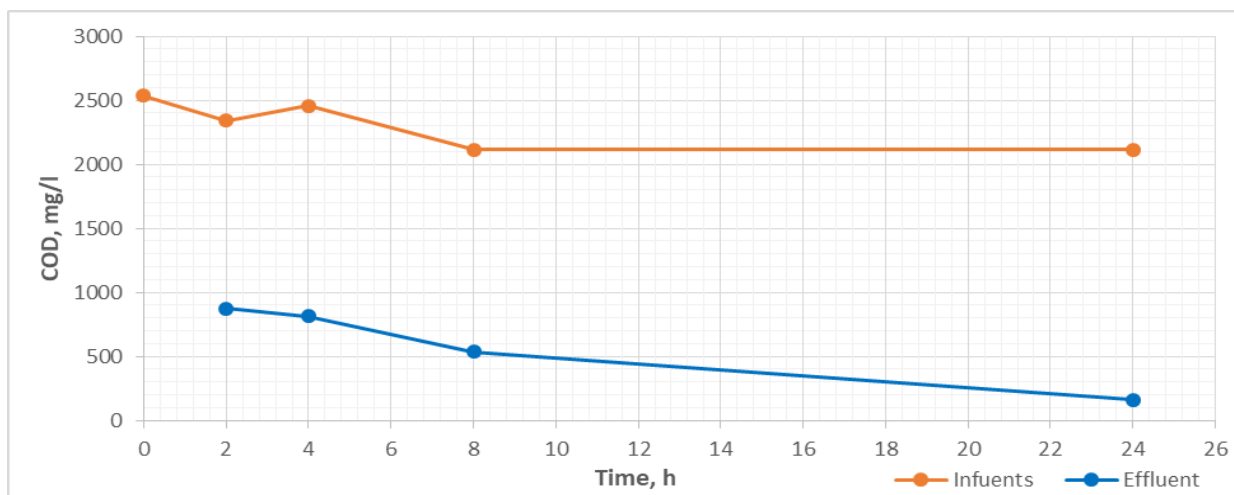


Fig. 15. Variations of the COD in RII run.

During RI run, the values of COD of the effluent, E1 decreased gradually and reached to 576 mg/l with the average concentration 691 mg/l, while the COD of the effluent E2 during RII run has been significantly decreased and reached to 163 mg/l at HRT 24 hr due to the effect of NaOCl, with the

average concentration 598 mg/l. Most of removed COD was due to BOD removal and most of the remained part is for the biologically was degradable of organic matter. The removal efficiency of COD during the RI run varied between 59 and 65%, while the removal efficiency during RII run varied between 63 and 92%, respectively. The results show a reduction in COD values when 82 ml of NaOCl was added in the fourth test during RII run, thus achieving the highest removal efficiency.

4.9. Nitrate Nitrogen NO₃-N

The tested values of the NO₃-N during RI and RII runs are shown in figures 16 and 17, respectively. In these tests, the NO₃-N values of both raw wastewater in RI and RII runs were found 2.87 and 2.92 mg/l respectively. Regarding influents, the average, maximum, and minimum of NO₃-N concentration during I1 was 2.76, 2.89, and 2.53 mg/l, respectively, while the average, maximum, and minimum of NO₃-N concentration during I2 were 3.17, 3.47, and 2.73 mg/l, respectively.

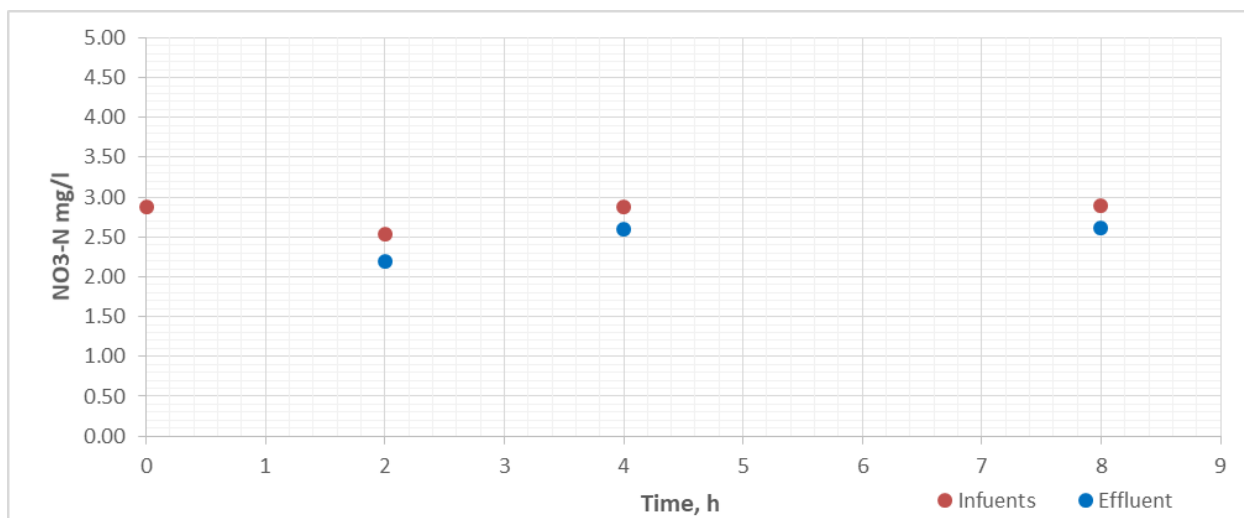


Fig. 16. Variations of the NO₃-N in RI run.

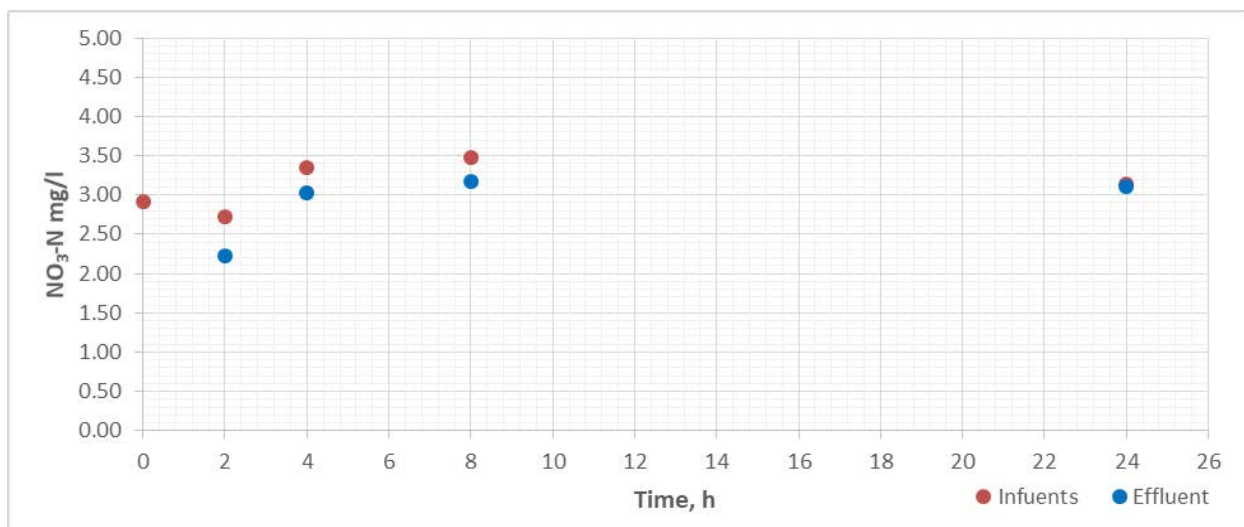


Fig. 17. Variations of the NO₃-N in RII run.

In these tests, there was no significant effect on the removal of $\text{NO}_3\text{-N}$ effluents, therefore, the average, maximum, and minimum during EI run were 2.47, 2.62, and 2.2 mg/l respectively, and the average, maximum, and minimum of effluent during E2 run was 2.89, 3.18, and 2.22 mg/l respectively.

4.10. Ammonium Nitrogen $\text{NH}_4\text{-N}$

The tested values of the $\text{NH}_4\text{-N}$ during RI and RII runs are shown in figures 18 and 19, respectively. The $\text{NH}_4\text{-N}$ values for raw wastewater samples on these tests were found 19.5 and 16.5 mg/l, respectively. The variation of the concentrations of the $\text{NH}_4\text{-N}$ within the influent and effluent follow the same trend during RI and RII runs. In RI tests, the $\text{NH}_4\text{-N}$ removal within the effluents varied between 39% and 68%, while, in RII tests the $\text{NH}_4\text{-N}$ removal varied between 34.4% and 80.2%. The main biochemical process in the aerobic bioreactor is nitrification in which a biological conversion of ammonia to nitrate. Sodium hypochlorite NaOCl had an effective role in the removal process, where the highest removal efficiency was obtained when the chemical compound was added to the bioreactor tank.

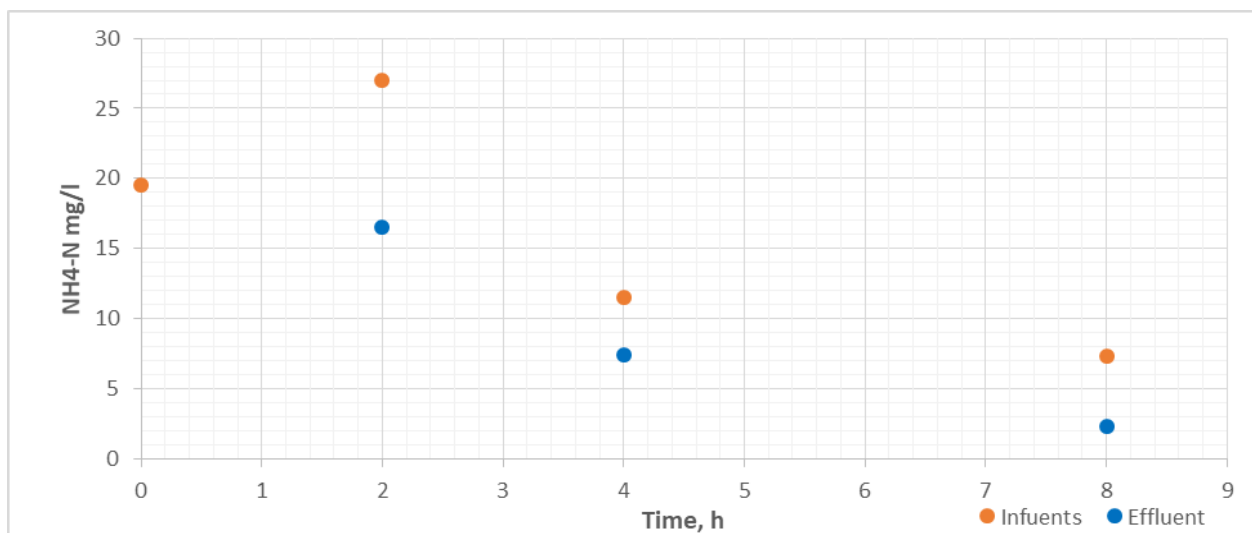


Fig. 18. Variations of the $\text{NH}_4\text{-N}$ in RI run.

During RI, The average, maximum, and minimum value of influent I1 were 15.29, 27, and 7.32 mg/l respectively. While, the average, maximum, and minimum value of effluent E1 were 8.77, 16.5, and 2.37 mg/l, respectively. The average, maximum, and minimum value of the influents I2 were 15.5, 25 and 11.62 mg/l respectively, during RII, whereas, the average, maximum, and minimum value of the effluents E2 were 6.89, 12.68, and 2.3 mg/l respectively.

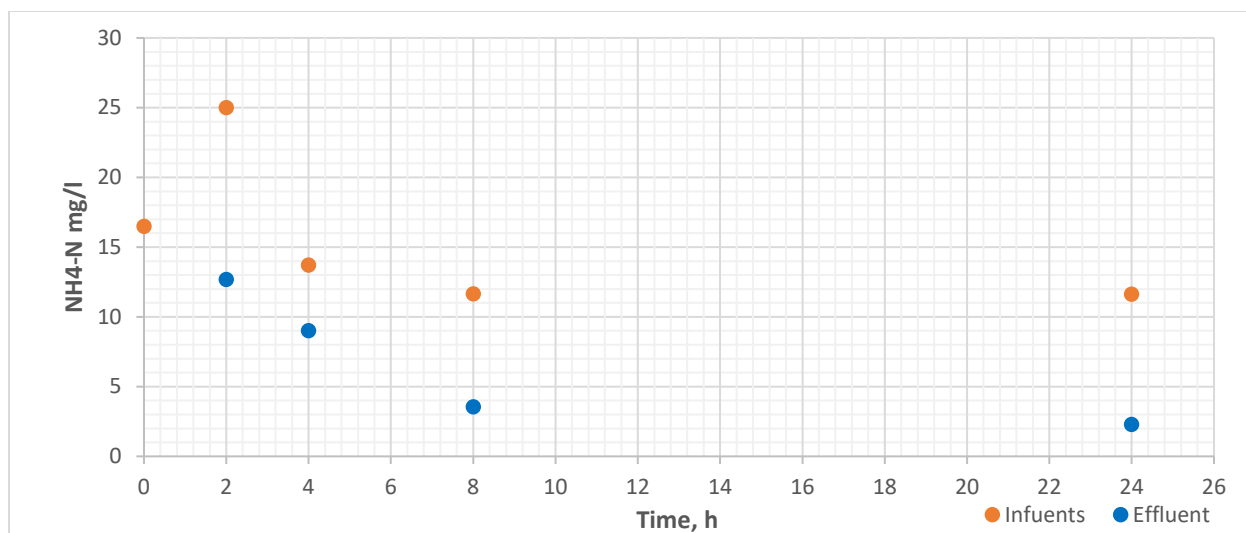


Fig. 19. Variations of the NH₄-N in RII run.

4.11. Total Phosphate PO₄-P

The variations of TP concentration during RI are shown in figure 20, and that during RII are shown in figure 21. The concentration of TP of raw wastewater samples in RI and RII was 19.4 mg/l and 28.8 mg/l respectively, and the concentration of TP for I1 during RI run fluctuated between 20.1 and 20.4 mg/l, while the concentration of TP of I2 during RII run fluctuated between 28.6 and 33.5 mg/l depending on the concentrations of TP within the influent. The effluents generally have lower concentration values of TP than that of the influents, and the removal efficiency of E2 higher than that in E1. The highest TP remove was during RII because of the NaOCl effect, where the sodium hypochlorite compound had an effect on decreasing the total phosphate concentrations and thus obtaining the highest removal value, where was 36%. The low removal efficiency of TP refers to the system works aerobically.

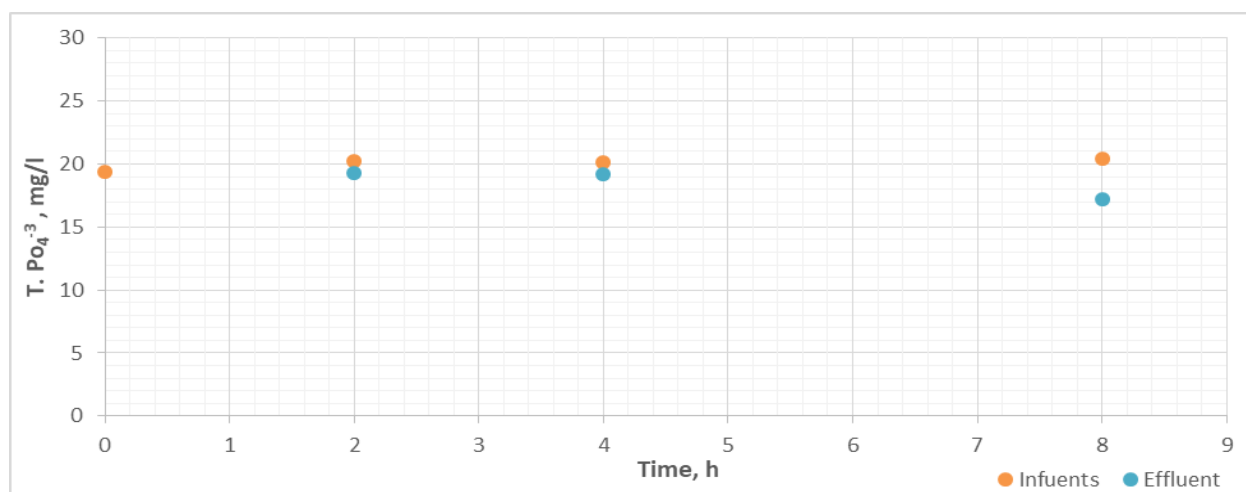


Fig. 20. Variations of the TP in RI run.

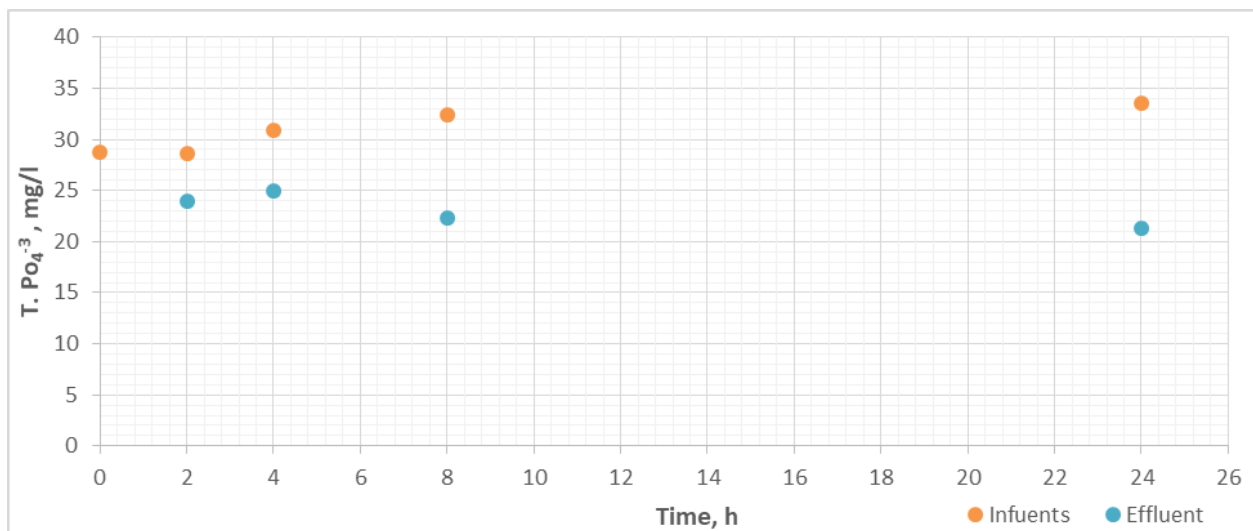


Fig. 21. Variations of the TP in RII run.

During RI, The average, maximum, and minimum value of effluents E1 were 18.57, 19.3, and 17.2 mg/l respectively. While, the average, maximum, and minimum value of effluents E2 during RII were 23.15, 25, and 21.3 mg/l, respectively.

4.12. Orthophosphate $PO_4\text{-P}$

The orthophosphate, Orth-P is the form of phosphate that can be used and consumed by the microorganisms. The organic phosphate can be converted to orthophosphate after decomposition. The tested values of the orthophosphate during RI and RII runs are shown in figures 22 and 23, respectively. The concentration of Orth-P of raw wastewater samples in RI and RII was 18.2 mg/l and 17 mg/l respectively, and the concentration of Orth-P of I1 during RI run fluctuated between 18.6 and 18.7 mg/l, while the concentration of Orth-P of I2 during RII run fluctuated between 17.4 and 23.2 mg/l depending on the concentrations of Orth-P within the influent. The difference between the influent of Orth-P and TP represents the polyphosphate.

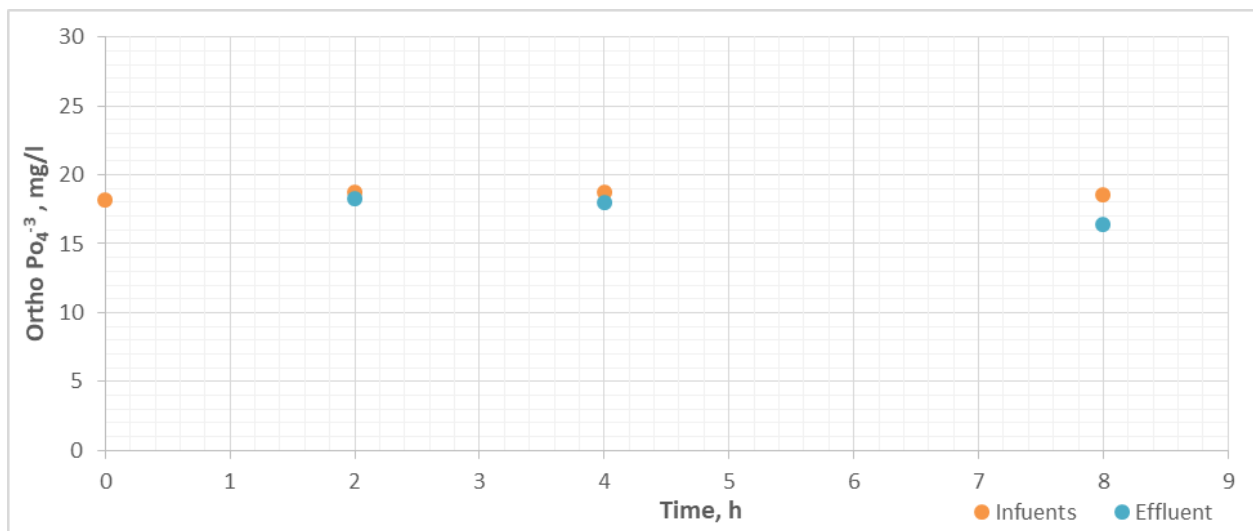


Fig. 22. Variations of the Orth-P in RI run.

The effluents generally have lower Orth-P concentration values than that of the influents and follow the same trend of fluctuation as in the TP.

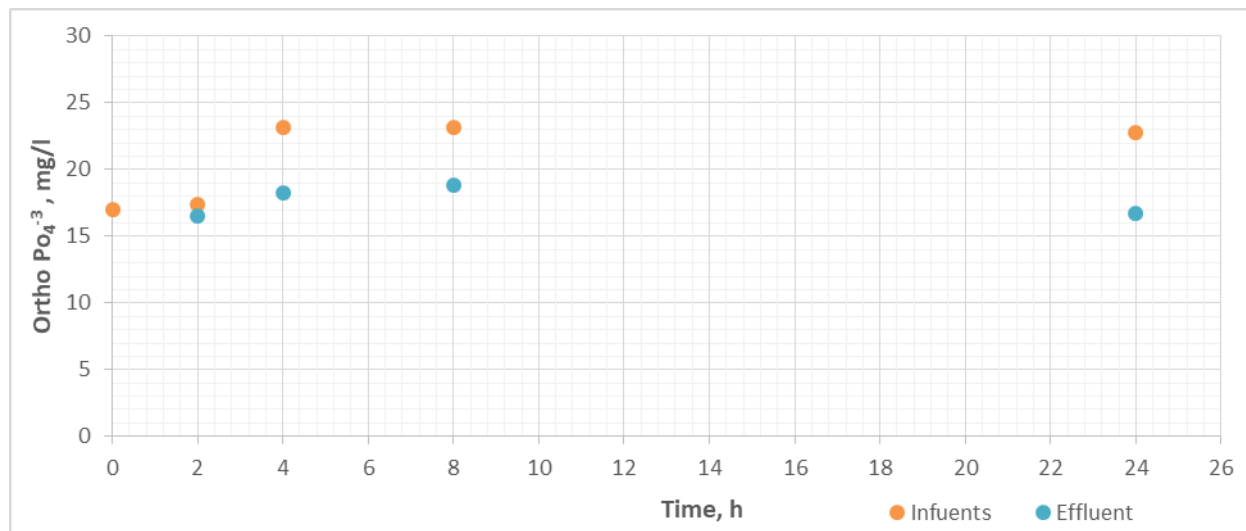


Fig. 23. Variations of the Orth-Pin RII run.

The removal efficiency of E2 was higher than that of E1. The highest Orth-P remove was during RII because of the NaOCl effect, where this compound had an effect on decreasing the orthophosphate concentrations and thus obtaining the highest removal value, where was 27%. The low removal efficiency of Orth-P refers that the system works aerobically. The average, maximum, and minimum concentration of Orth-P effluents E1 during RI were 17.57, 18.3, and 16.4 mg/l respectively, while the average, maximum, and minimum concentration of Orth-P effluents E2 during RII were 17.58, 18.8, and 16.5 mg/l respectively.

5. Conclusions:

The two tests of MBR system were carried out with HRTs of 2-8 h and 2-24 h showed that the bioreactor can be used efficiently to treat industrial wastewater. The wastewater was treated by using ZW10 hollow fiber membranes. On the first test, RI, sodium hypochlorite has been added to the bioreactor tank with backwash process as a sterilizer in water as well as to prevent clogging in the pores of the membranes. On the second test, RII, sodium hypochlorite has been added to the bioreactor tank with backwash process at 2-24 h of HRTs, also at 24 h of aeration, 82 ml of NaOCl was added with mixed liquor in the bioreactor tank to study its effect on the treatment process. The results obtained can be summarized as follows:

1. The pH value had gradually increased with HRT during the aeration process for both tests, where the pH value during RI increased from 6.9. to 7.71, while during RII, the pH value increased from 6.84 to 7.59. The reason for this increase is the disintegration and oxidation of the organic matter during the aeration process, which leads to the formation of CO₂. Some part of the CO₂ released as a gas from the aeration tank, that resulting in a decreasing of acidity in the water thus increasing the pH value. Generally, the pH value for the effluents was higher than that of influents, due to the effect of the NaOCl on the treatment process, which indicates that it is an alkaline solution.

2. For the treatment process, The membrane filter showed an excellent turbidity removal, where the removal of turbidity during all tests performed varied between 99.48 and 99.83% for RI runs and 99.27 and 99.97% for RII runs, thus indicates that the membranes filter was very efficient in retaining solids. the highest removal efficiency observed when adding 82 ml of NaOCl in the bioreactor tank for RII runs.
3. For TSS, BOD and COD removal during the treatment process, a very good removal has obtained for TSS, BOD₅ and COD concentrations during RI runs where ranged between 75.22-82.14% and 64-69.96% and 59.49-64.66% for TSS, BOD₅, and COD respectively, while the effect of sodium hypochlorite on effluent during RII was observed. The best results were obtained after 24 hours of aeration when added 82 ml of NaOCl to the bioreactor tank with mixed liquor, where the treatment process was excellent in removing of TSS, BOD₅, and COD with removal efficiency 91.28%, 99.19%, and 92.27% for TSS, BOD₅, and COD respectively.
4. For nitrogen and phosphorus removal, no high removal concentration observed for nitrogen represented by NO₃-N and NH₄-N in the bioreactor treatment, As well as in the removal of phosphorus represented by total phosphate and Orthophosphate concentration during RI runs where ranged between 9.34-13.04% and 35.5-67.62% for the NO₃-N and NH₄-N respectively, and 4.46-15.69% and 2.14-11.83% for TP and Ortho-P respectively, while the effect of sodium hypochlorite on the removal efficiency of NO₃-N, NH₄-N, TP, and Ortho-P on the effluent during RII was observed, wherein the percentage of removal concentration of NO₃-N was decreased from 5.36% to 0.96% due to added 82 ml of NaOCl, that means, this compound has a negative effect on the NO₃-N removal, while the percentage of NH₄-N removal was increased from 69.47% to 80.21% due to added 82 ml of NaOCl in the mixed liquid during the treatment process. Also, the removal efficiency for both of TP and Ortho-P was increased due to adding 82 ml of NaOCl to the mixed liquid during the treatment process from 31% to 36% for total phosphate and 19% to 27% for orthophosphate.

6. References

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