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Effect of Moving Bed Biofilm on the Nutrient Removal Efficiency by Using Enhanced Bardenpho Process

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Abstract

Wastewater is usually treated using various of chemical, physical, and biological approaches to remove phosphorus and nitrogen from it. This study looked at an experimental research that used a lab-scale Bardenpho process to evaluate the elimination of nutrients from synthetic wastewater. The purpose of this study is to investigate how HRT affects nutrient removal efficiency at different MBB ratios (0, 10, 20, and 30%) when total HRT is between 9.5 and 17.5 hours and the IR ratio is between 0 and 300%. The results showed a significant improvement concerning the influence of the MBB ratio on COD elimination, and there was a reasonable increase in TN and PO4 elimination as the MBB ratio increased from 0% to 30% and when IR ratio increased from 0 to 300%. Therefore, the optimum MBB ratio and total HRT for this research would be around 30% and 17.5 hr, respectively, with maximum removal efficiencies of 97.97% , 85.33% and 77.78% for COD, TN and PO4 respectively.

Introduction:

When wastewater with high phosphorus and nitrogen levels is released into the environment, it can lead to a number of issues, including eutrophication, oxygen consumption, and toxicity [1]. Most wastewater treatment facilities that are in operation today are conventional ones. This wastewater treatment plant is capable of efficiently removing organic materials from the wastewater, but its ability to remove phosphorus and nitrogen compounds is constrained [2]. Over the past 20 years, nutrients have developed to be a significant factor in wastewater treatment plant design and operation. Nutrient management and removal from the discharged system have been addressed using a variety of treatment approaches, including biological, chemical, and physical processes. A biological treatment system can be used to remove nutrients since it is a dependable, affordable, and efficient method [3]. Among suspended biomass processes, activated sludge is the most widely utilized. Under conditions of high hydraulic and organic loads, these methods may have certain disadvantages. Reactor biomass would need to be improved to the limit by the settling tank in order to optimize process performance. Significant reactors and clarifier needed for these processes, as well as sludge settleability, can also be issues [4]. Both suspended bacterial and attached growth in the reactor is made possible by the moving bed biofilm (MBB) process, which uses biocarriers [5]. It can be a more effective treatment for wastewater influent that requires an adequate and balanced substrate input for growth of biomass than the conventional activated sludge process. Additional benefits of the MBB process include low sludge production, no sludge thickening, a diversified bacterial population for treatment, high efficiency of treatment, respectable resistance to shock loading, and a high level of biomass production [6]. Therefore, for treating wastewater with low organic load, high nitrogen concentration, and low and high C/N ratio, MBB may offer a practical alternative. However, studies was done on the MBB biofilms utilized to treat different types of C/N wastewater. Kenaf media and a rotary drum screen were added to an existing five-stage Bardenpho plant to help retain the larger particles from the secondary settling tank while wasting the flocs in a targeted manner. With moving bed biofilms, startup took five months and the (SVI) decreased from >200 to 50 mL g/1[7]. In addition to treating nitrogen and organics in wastewater, the moving-bed biofilm approach effectively removed phosphorus since enough separated biomass containing orthophosphate was disposed of. Additionally, the concentration of suspended biomass dramatically decreased and SVI enhanced from 700 to 100 mL/g with the addition of the biofilm carrier [8]. High removal eliminations were attained for the (TN), ammonium, (COD), and (TP), in a modified 5-stage Bardenpho-moving bed biofilm reactor (MBBR) process for eliminating organic matters and nutrients from domestic wastewater. These efficiencies were roughly 92.54%, 96.50%, 98.20% and 94.70% respectively [9]. Anaerobic, anoxic, and moving bed biofilm reactor, or MBBR, is a three-stage process that has been investigated for its potential to remove organic compounds and nutrients from secondary WWTP effluents at different (HRT) and (IR). The percent eliminations of total nitrogen and phosphorus were enhanced by using the response surface method (RSM). Under ideal conditions (HRTtotal = 12.8 hr and IR = 1.5), significant reductions in COD, TN, and TP were achieved at rates of approximately 95.5%, 96.2%, and 94.70%. The MMBR effectively eliminated organic matter and nutrients at low HRT and IR. Increased %TNremoval was achieved by increasing HRT up to 1.5 hours at IR of 2[10]. It was determined how effective the Sponge-Based Moving Bed Biofilm Reactor (S-MBBR) was at treating municipal wastewater. With a particular surface area of 260 m^2/m^3, the polyurethane sponge utilized as a carrier in the laboratory-based treatment plant. The treatment facility employed four different organic load rates: OLR1 = 0.4 kg BOD/m3 per day, OLR2 = 0.6 kg BOD/m3 per day, OLR3 = 0.8 kg BOD/m3 per day, and OLR4 = 1.0 kg BOD/m3 per day. The maximum removal efficiency was achieved at an OLR of 0.4 kg BOD/m^3.day. The values for COD, SS, TN, and TP were 85.0 ± 12.9%, 40.3 ± 0.2%, 68.9 ± 1.7%, and 85.7 ± 5.3%, respectively [11].

In this research, the effect of the MBB with ratio (0%, 10%, 20%, and 30%) was found at a total hydraulic retention time (17.5, 13.5, and 9.5 hours) when the internal recycle was ranging (100%, 200%, and 300%).

Materials and Methods:

The pilot scale plant utilized in this study consisted of the following five primary parts: anaerobic, first anoxic, first aerobic, second anoxic, and second aerobic. The diagram of the Pilot scale for runs 1, 2, and 3 was (36.4, 29.2, and 19.8) L, as may be shown in Fig. 1. Air diffusers were placed at the bottom of the aeration tanks to ensure proper mixing of the contents and to supply the required amount of oxygen. Additionally, mixers were incorporated into the anaerobic tanks to ensure that the contents were well mixed. After these units was a settling unit with a cone-shaped in base and a cylindrical at top that could support a small pump for returning a portion of the settled biomass to the first reactor (anaerobic reactor) in order to keep a particular biomass concentration. The lab scale received the synthetic wastewater at a flow rate of 50 litters per day. Hydraulic retention times (HRT) for anaerobic, first-anoxic, first-aerobic, second-anoxic, and second-aerobic processes were 2, 4, 6, 4, and 1.5 hours, respectively, in the first run; HRT for these processes was 1.5, 3, 5, 3, and 1 hour, respectively, in the second run; and HRT for these processes was 1, 2, 4, 2, 0.5 hours, respectively, in the third run. The process required wasting a sufficient amount of MLSS per day, with a 15-day mean cell residence time (MCRT). Standard methods for analysing water and sewage were used to assess the samples in a number of tests conducted in the laboratories of Tikrit University's Department of Environmental Engineering. The concentrations of phosphorus and nitrogen compounds were measured using the UVD-3000 spectrophotometer. For the COD test, the HACH DRB200 apparatus was also utilized.

At this stage, the activated sludge was ready and the pilot scale was operating. This activated sludge was allowed to grow by introducing a sample of seeds from the Tikrit Wastewater Treatment Plant. Two 10-liter laboratory tanks were used to hold this sludge for each. The purpose of these lab tanks was to both adapt and multiply the bacteria. The experimental stage was allocated into three runs, each of which focused on altering the overall hydraulic retention time, IR ratio and MBB ratio. The MBB was added to first aerobic tank with (0, 10, 20 and 30) percent from the volume of reactor, Table 1 which shows the Specifications of Moving Bed Biofilm (MBB).

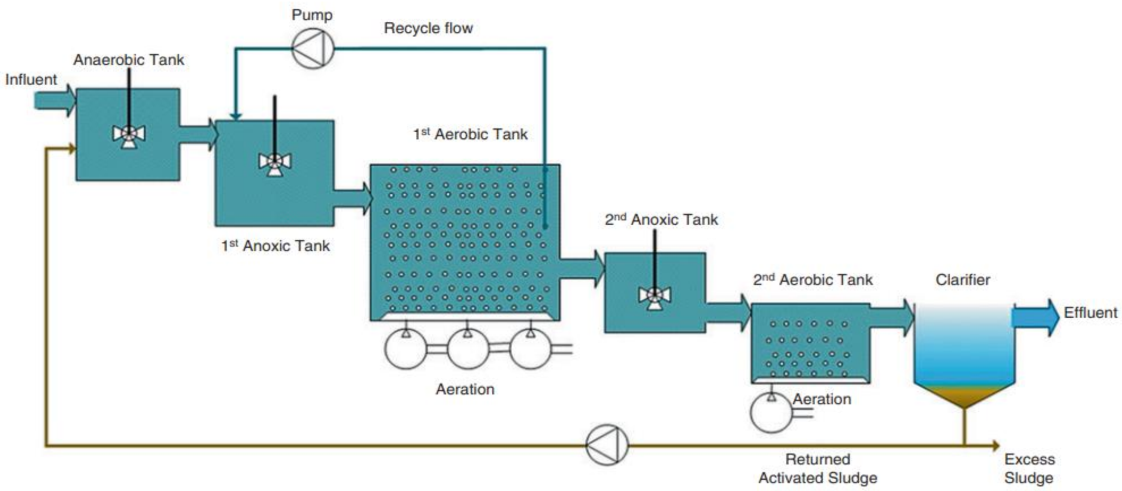

Fig. 1. Pilot scale's diagram

The composition of the influent wastewater is listed in Table 2. A continuous operation system was used to run the laboratory system. A small 15-liter tank was used to supply the tanks with gravity-fed water. A special valve controlled the plastic pipe that the drainage moved through to carry the fed wastewater to the tanks. The system was designed so that the feed water arrives at the 15-liter tank from a larger tank with a 200-liter capacity, maintaining a constant pressure. Wastewater is transferred via a plastic pipe that has a valve at the end from the large tank to the minimal tank. This tank was positioned above the water level in the small tank. a cutoff that, once the water level in the 15-liter tank reaches a certain point, prevents the drain from the tank. Wastewater characterization results are shown in Table 3.

Table 1. Specifications of Moving Bed Biofilm (MBB)

Item	Specification
Type	B1-10-8
Holes	4
Diameter	10 mm
Height	8 mm
Density	0.96 g/cm^3
Total surface area	Greater than 750 m^2/m^3
Fill rate	15-50%
Material	100% HDPE

Table 2. Composition of Synthetic Wastewater [12]

Component	Concentration (mg/L)
Starch (C6H10O$_5$)	100
Ammonium chloride (NH_4CL)	85
Sucrose ($C_{12}H_{22}O_{11}$)	75
Urea ($CO(NH_2)_2$)	5
Sodium chloride (NaCl)	70
Magnesium chloride ($MgCl_2.7H_2O$)	75
Iron Sulphate ($FeSO_4.7H_2O$)	1.7
Potassium dihydrogen phosphate (KH_2PO_4)	65
Calcium chloride ($CaCl_2.2H_2O$)	35
Manganese sulphate ($MnSO_4.H_2O$)	1.1
Zinc sulphate ($MnSO_4$.H2O)	1.7
Copper sulphate ($CuSo_4.5H_2O$)	0.86
Yeast extract	0.86
Milk (mL/L)	15

Table 3. Characteristics of Synthetic Wastewater

Component	Unit	Concentration (mg/L)
COD	mg/L	413±10
TN	mg/L	35±5
NO_3-N	mg/L	2
PO_4	mg/L	15±2
pH		7-7.5
Temperature	Cº	17-25

Results and Discussion:

Effect of MBB on System Efficiency

The average elimination for the three main parameters (COD, TN, and PO_4) were calculated using Eq. (1). The fact that exceptionally high clearance values were attained in every situation showed that the synthetic wastewater had been well treated.

$$\textit{Efficiency} = (C_{in} - C_{out})/C_{in} * 100\% \quad (1)$$

Where C_{in} is the concentration in influent, mg/L and C_{out} is the concentration in effluent, mg/L.

Effect of MBB on COD Removal Efficiency at IR=100%

When total HRT increased, there was a logical improvement in the way the MBB impacted COD elimination. According to previous research [12, 13], the percentage of COD elimination varied moderately with changes in MBB ratio. Fig. 2 illustrates how different total hydraulic retention times and IR=100% affect COD removal in relation to MBB ratio.The findings showed that the COD elimination efficiency was improved with increasing in MBB ratio and total HRT due to the increase in total HRT gives enough time to complete the uptake these compound by biomass. At 100% internal recycle ratio, the highest removal efficiency was 94.12% at MBB of 30% and 17.5 hr total HRT.

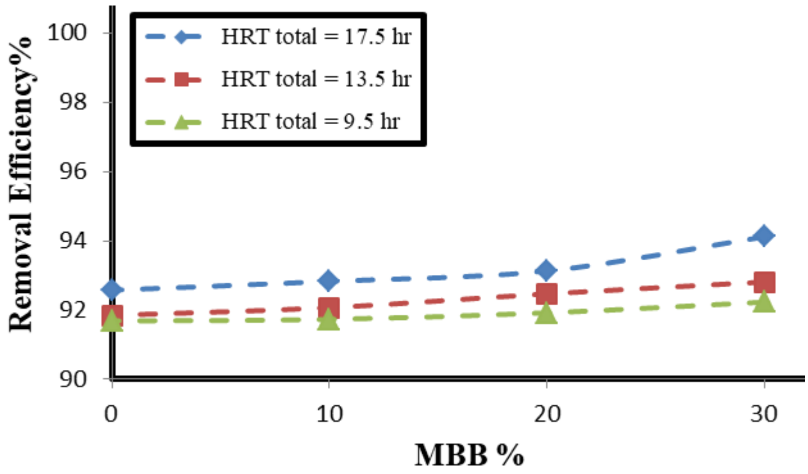

Fig. 2. Effect of MBB Ratio on COD Removal at IR=100%

Effect of MBB on COD Removal Efficiency at IR=200%

Fig. 3 indicates the effect of MBB ratio on COD elimination at IR=200% and various total hydraulic retention time. The results indicated that the COD elimination efficiency was increased when MBB ratio and total HRT increased due to the increase in total HRT gives enough time to complete the uptake these compound by biomass [14 – 16]. The maximum COD removal efficiency was 95.934% when MBB ratio and total HRT were 30% and 17.5 hr, respectively.

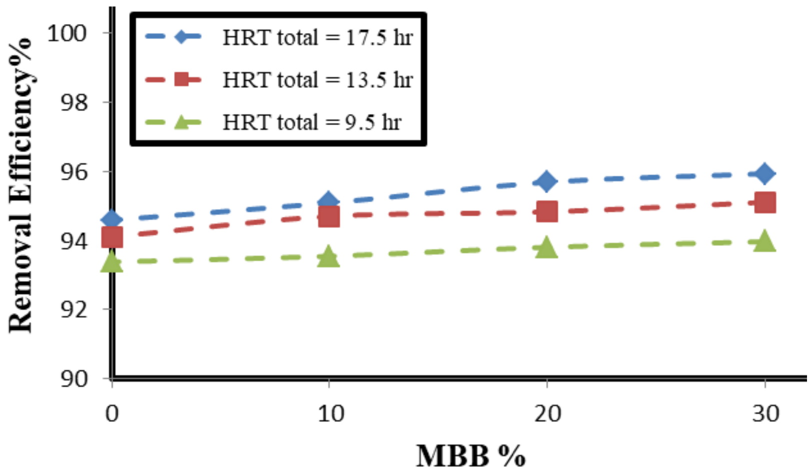

Fig. 3. Effect of MBB Ratio on COD Removal at IR=200%

Effect of MBB on COD Removal Efficiency at IR=300%

When the MBB ratio improved, the COD elimination efficiency was increased as shown in Fig. 4. The highest COD removal efficiency was 97.97% at 30% MBB ratio and 17.5 hr total HRT.

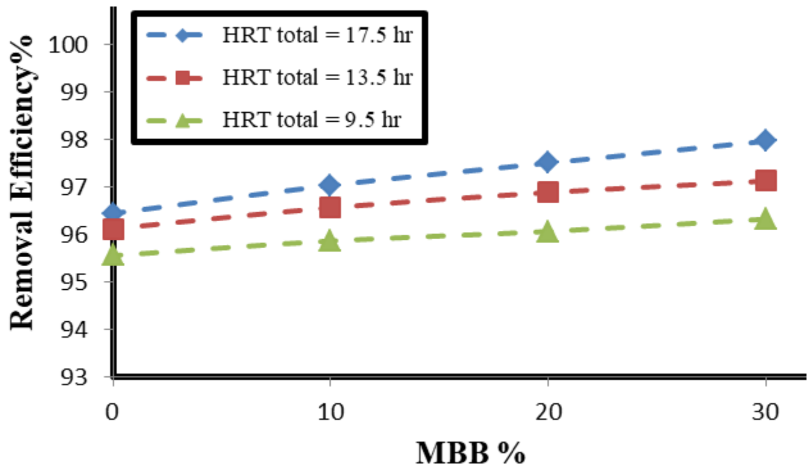

Fig. 4. Effect of MBB Ratio on COD Removal at IR=300%

Effect of MBB on TN Removal Efficiency at IR=100%

Fig. 5 represent the relationship between removal efficiency and MBB ratio at various total HRT. The findings indicated that the TN removal efficiency was increased when the MBB ratio and total HRT were increased due to the extension in the denitrification process [12, 17]. The maximum TN removal efficiency was found to be 77.41% when the MBB ratio of 30% and total HRT 17.5 hr.

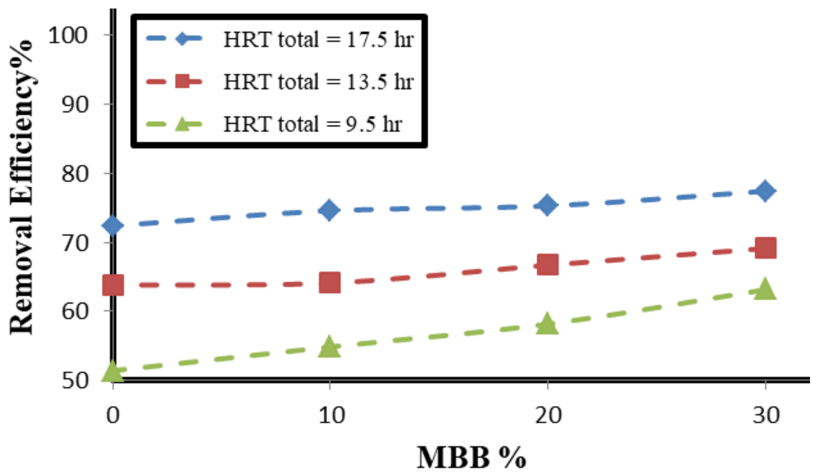

Fig. 5. Effect of MBB Ratio on TN Removal at IR=100%

Effect of MBB on TN Removal Efficiency at IR=200%

When the MBB ratio increased, the TN removal efficiency was increased due to the extension in the denitrification process as shown in Fig. 6. The highest TN removal efficiency was 91.45% at 30% MBB ratio and 17.5 hr total HRT [18 – 23].

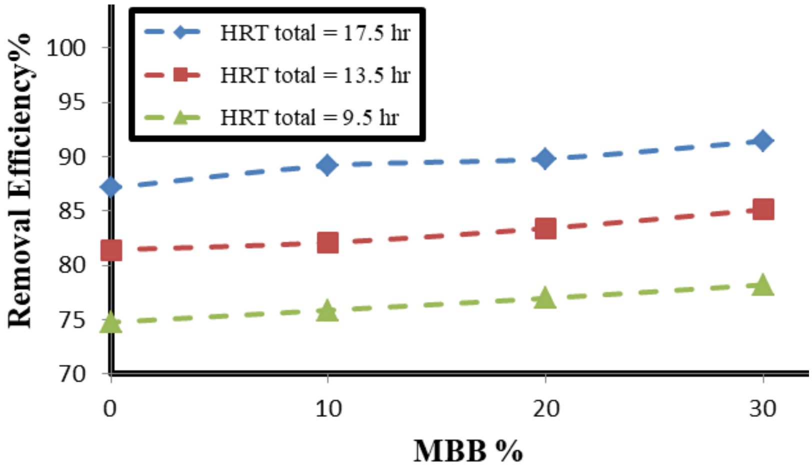

Fig. 6. Effect of MBB Ratio on TN Removal at IR=200%.

Effect of MBB on TN Removal Efficiency at IR=300%

The impact of MBB ratio on TN elimination at IR=300% and different total hydraulic retention times is displayed in Fig. 7. The findings showed that the TN elimination efficiency was increased when MBB ratio and total HRT increased due to the extension in the denitrification process and the increase in total HRT gives enough time to complete the uptake these compound by biomass [18, 22]. The maximum TN removal efficiency was 85.334% when MBB ratio and total HRT were 30% and 17.5 hr, respectively.

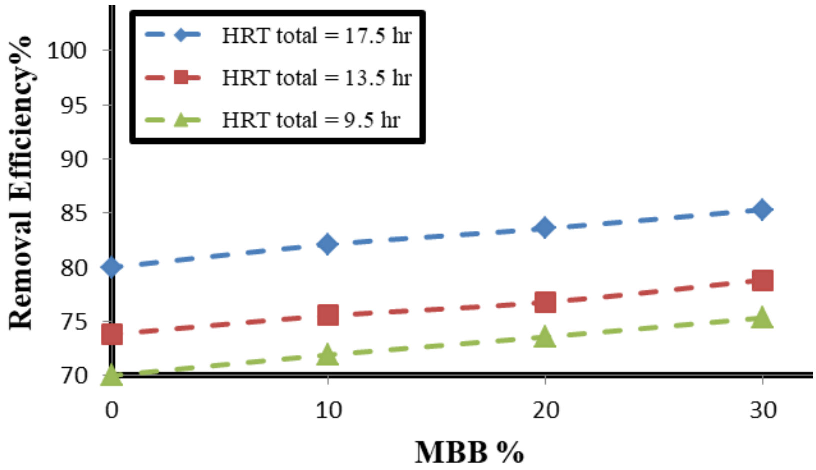

Fig. 7. Effect of MBB Ratio on TN Removal at IR=300%

Effect of MBB on PO_4 Removal Efficiency at IR=100%

The relationship between PO_4 removal efficiency and MBB ratio at various total HRT and 100% IR ratio was shown in Fig. 8. The results showed that the maximum PO4 removal efficiency was found to be 66.71% in case of 30% MBB ratio and 17.5 hr total HRT. The reason of this because the increase in total HRT gives enough time to complete the uptake these compound by biomass and because of the increasing in biomass concentration and the diversity and composition of the bacterial community [18, 22].

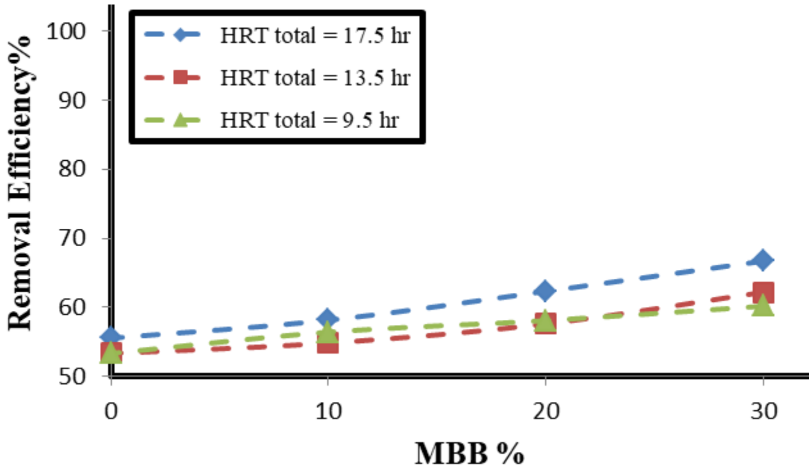

Fig. 8. Effect of MBB Ratio on PO_4 Removal at IR=100%

Effect of MBB on PO_4 Removal Efficiency at IR=200%

The results indicated that the PO_4 removal efficiency increased clearly when the MBB ratio and total HRT also increased from 0 to 30% and from 9.5 to 17.5 hr, respectively. It is due to the increase in total HRT that gives enough time to complete the uptake these compound by biomass and because the increasing in biomass concentration as well as the bacterial community's diversity and composition [18, 22]. Fig. 9 shows that the highest PO_4 removal efficiency was found to be 82.23% at 30% MBB ratio and 17.5 hr total HRT.

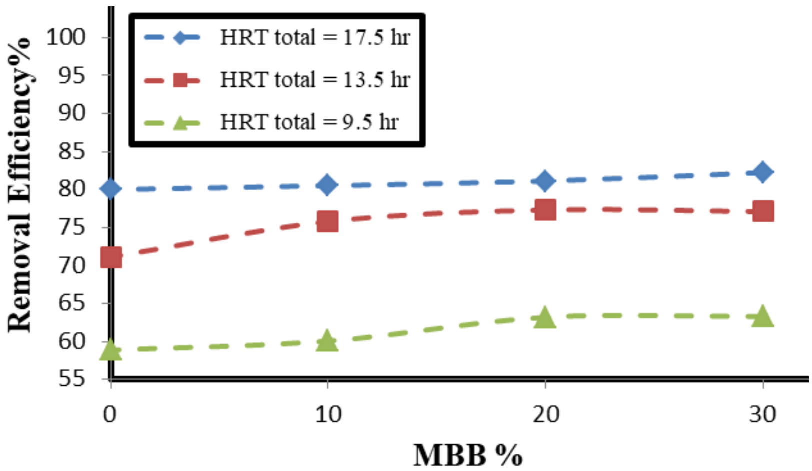

Fig. 9. Effect of MBB Ratio on PO_4 Removal at IR=200%

Effect of MBB on PO_4 Removal Efficiency at IR=300%

MBB ratio can increase the PO4 removal efficiency when it increased from 0 to 30%. Moreover, the increasing in total HRT causes increasing in PO4 removal efficiency when the IR ratio was 300%. The reason of this because the increase in total HRT gives enough time to complete the uptake these compound by biomass and because of the increasing in biomass concentration as well as the bacterial community's diversity and composition [18, 22]. Fig. 10 illustrates the impact of MBB ratio on PO4 elimination efficiency when IR ratio 300%. The findings showed that the highest elimination efficiency was 77.78% at 30% and 17.5 hr MBB ratio and total HRT, respectively.

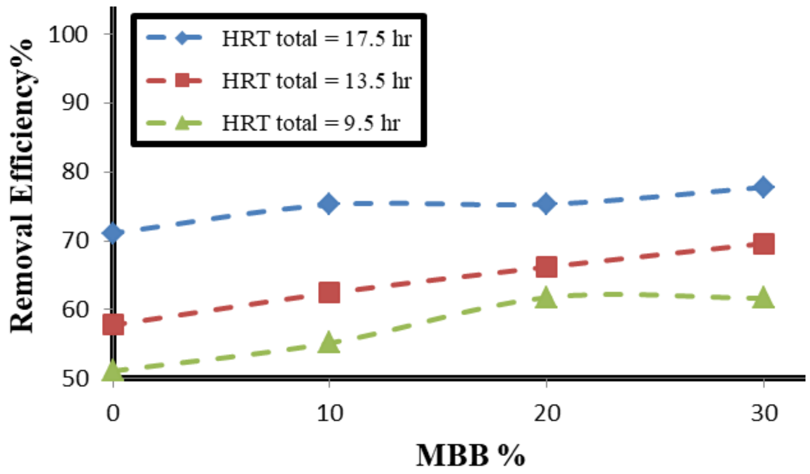

Fig. 10. Effect of MBB Ratio on PO4 Removal at IR=300%

Conclusion:

This paper assessed the COD, TN, and PO4 performance related with a Bardenpho process treating synthetic wastewater with total HRT (9.5hr to 17.5hr) and MBB ratio ranging from 0 to 30% at various IR ratio ranging from 0% to 300%. The results showed very high elimination levels were achieved for all three-performance factors. There appeared to be significant enhancement concerning the effect of the MBB ratio on COD elimination. However, there was a reasonable increase in TN and PO_4 elimination as the MBB ratio increased from 0% to 30% and when IR ratio increased from 0 to 300%.

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