Performance of Sequence Batch Moving Bed Biofilm Reactor under Different Gas/Water ratio for Domestic Wastewater Treatment

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Abstract- The (SBMBBR) method is one of the most effective and economical treatment processes for wastewater. Using a laboratory scale, The treatment system has been developed to treat 80 L/ day of domestic wastewater of SBMBBR technology. The SBR unit is consists of; Primary clarifier of (150 L), SBR reactor of (96 L) .the MBB which used Kaldnes media was applied as a carrier in the reactor at the media fill ratio equal to 50%. The average temperature values were 27.56°C and 27.74 °C respectively in both anoxic and aerobic SBMBBR. the SBMBBR can be used successfully for the pollutant (COD, NH4+-N, TN, TP) in COD test, the results of average removal efficiency at the ratio gas/water (3/1,4/1,5/1,6/1, 7/1,8/1,9/1, and 10/1) were (94.85%, 95.85%, 96.14%, 96.56%, 97.29%, 98.29%, 98.72%, and 99.21%) respectively. And results of average removal efficiency for NH4+-N (93.84%, 94.57%, 95.72%, 96.20%, 97.64%, 98.72%, 99.27%, and 99.60%) respectively, at the average effluent of TN concentrations, the lowest value we got in these ratios is at a ratio 7/1 (23.95 mg/L). On the other hand, at a gas over water ratio of 7/1 (0.81 mg/L) the average effluent of TP concentrations will comply with Iraqi and European-requirements..

Keywords – SBMBBR, Chemical Oxygen Demand, Ammonium, Total Nitrogen, and Total Phosphorus.

I. INTRODUCTION

From 1900 to 1970, wastewater treatment developed. The Systems of treatment focus on the Suspended and floatable materials removal, the treatment of the biodegradable organic matter, and the removal of pathogenic organisms [1]. Wastewater treatment has been one of the most significant relating human health issues for the last two decades, and the Wastewaters are one of the most ecological pollutants and have a wide variety of adverse effects associated with the influence of untreated wastewaters or wastewaters that are poorly handled [2]. Overall, for more than a decade, Iraq suffered as a result of a lack of surface water supplies due to the high retraction of the Euphrates and the Tigris rivers, little rainfall, and the temperature, as well as the rising degree of contamination in the river water due to the clear contraction of rainwater networks with sewage networks and the discharge of most of the sewage water to the major and Secondary rivers, Therefore, it is important to seriously consider the suitability of the New sewage treatment plants are being built using the different global technologies to provide a new supply of water that can be applied for irrigation and drinking [3].

Borkar, R.P, et al. (2013) [4], utilized the Moving Bed process to evaluate the feasibility of wastewater treatment by utilizing the attached and suspended growth method. The change in the type of media carriers through the test work helps to get the expected results in a very beneficial way. And check the possibility of moving the bed Biofilm method that is utilized as a perfect and effective choice for the overall nutrient removal.

Qiqi, Y., Ibrahim, H. T., Qiang, H.(2012) [5], offered the Moving Bed Biofilm (MBB) method as an alternate and successful process to treating a different kind of effluents at the variable conditions due to the concept of the MBB is to collect the various processes that are attached and suspended biomass. in the (MBB) the carrier element let a rise biomass concentration to biofilm reactor to be kept in a reactor compared with suspended growth method the MBBR characteristic To optimize performance, specially built biofilm carriers have been carefully considered for sizing, geometry, and construction materials.

Al-Rekabi, W.S.(2015) [6], offered the combined system by using the MBBR process. The combined process The concurrent removal of nitrogen and phosphorus seems highly promising. The combined process has suspension and attaches growth. The combined process can supply two types of bacteria populations in the process; first Suspended activated sludge bacteria to enhance the removal of phosphorus, and long-sludge-age biofilm bacteria to improve nitrification-denitrification.

Jariwala, H., Shah, D. (2018) [7], presented the feasibility of Sequential Bed Biofilm Reactor (SBBR) together with combined suspended and attached growth method for the domestic sewage. Compared with a Sequential Batch Reactor (SBR) and the Moving Bed Biofilm Reactor (MBBR).so, The results showed the (SBBR) is better compare to (SBR) and (MBBR) can due to better operational performance for COD, BOD, and TKN removal.

The major topic of this research is to study the Sequence Batch Moving Bed Biofilm Reactors (SBMBBR) Technology as An alternative and efficient method to treating Domestic wastewater at AL Samawa city (AL Samawa Sewage Treatment Plant) under different operational processes. And Operation the (SBMBBR) model for a long term period using the optimum operational parameters of gas/water ratio which were found and chose the ratio that gives of the best of remove rates of (COD, NH4+-N, TN, TP).

II. MATERIALS AND METHODS

A. Description of (SBMBBR) Unit –

The SBMBBR unit consists of the primary clarifier is the first part of the SBMBBR unit. It is a cylindrical shape plastic tank with a total volume of (150 L). Raw wastewater is decanted from the manhole and collected in the primary clarifier tank which represents the source of the influent raw wastewater in the SBMBBR reactor, and SBR. the SBR reactor is a square shape glass tank, with a total volume of 96L (working volume = 80 L) with (0.4 m) length and (0.4 m) width and the total height is (0.6 m). The effective depth of the SBR reactor is (0.5 m). The SBR basin has two openings: the first one is at (0.35 m) height from the bottom which is used as an outlet for raw wastewater from the reactor, and the second is the near of center the bottom of the reactor and used for withdrawing the excess sludge out of the SBR unit. Inside the SBR is mixing, The mixing system has two velocities; (40 rpm) for aeration and (80 rpm) for anoxic by the speed regulator manually at the control Board. The Secondary clarifier is the third part of the SBMBBR unit. It is a square shape glass tank with a total volume of (150 L) the length of this tank is (0.75 m) and the width is (0.4 m), and the total height is (0.5 m). Fig (1) shown the schematic diagram of the SBMBBR unit, and the MBB was used; the MBBR media is one type of new bioactive carrier as the house for attached growth bacteria. The MBB is Centered on the reactors that are filled together with plastic carriers to supply a surface that is settled by bacteria that grow into a biofilm. The reactor must be operated through completely nitrification-denitrification processes. Kaldnes media was utilized as a carrier in the reactor at a media fill ratio equal to 50%. The Kaldsnes carrier elements are made of plastic and shaped like small cylinders about (18 mm in diameter, 20 mm long) as shown in fig (2) and table (1).

Table -1 Characteristics of the media used

Parameter	Value
Dimension (mm)	Length: 20 mm Diameter:18 mm
Filling ratio (%)	50%
Surface area (m^2/m^3)	100 m^2/m^3
Density (g/cm^3)	0.95 g/cm^3
Color	Gray
Shape	Cylindrical Wave

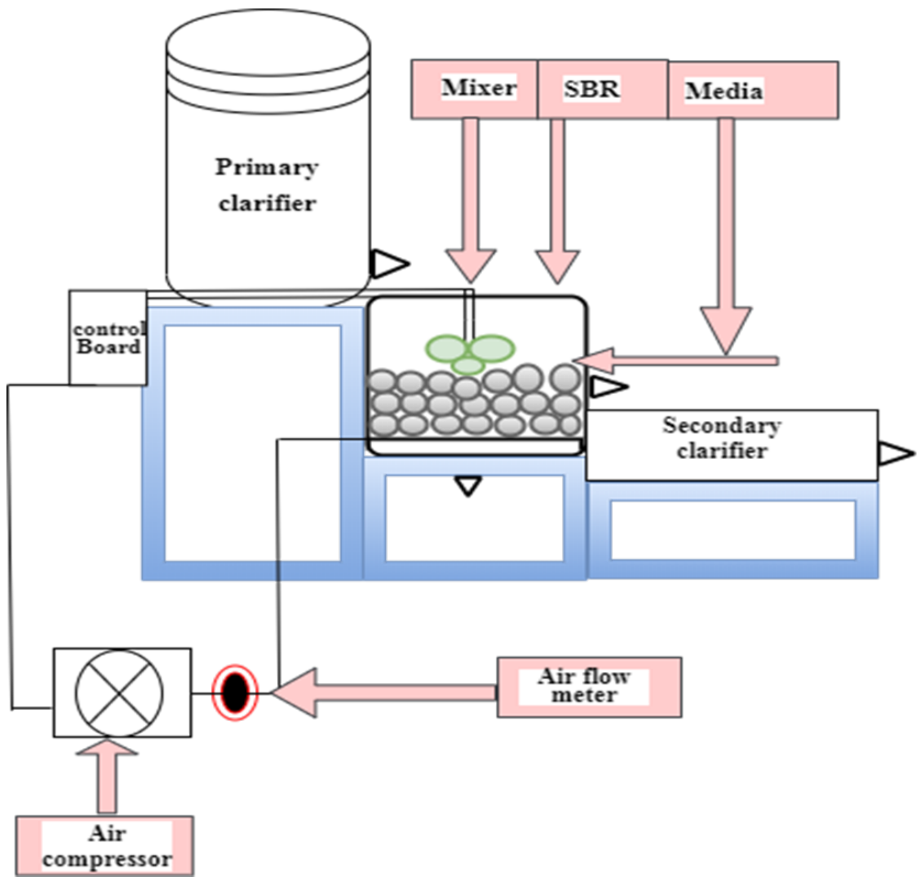

Figure 1. Schematic Diagram of the SBMBBR unit

Figure 2. Kaldnes carriers

B. Operation procedure –

The study was conducted using raw domestic wastewater supplied from the preliminary treatment portion at Al Samawa Water Treatment Plant in Al Samawa city in mid-Iraq and collecting sludge seeds from Al Samawa City (Al Samawa Sewage Treatment Plant) main sewage treatment plant. The sludge collected was screened with a sieve no (0.4 mm) to remove coarse and inorganic sludge particles, then the sludge was aerated at room temperature for two days. The sludge was combined with wastewater for the first clarifier at a ratio of (2/3 of the effective volume 80 L). and for the reactor (1/3 of effective volume 80 L). After that, we connect MBB carriers to the reactor where the tank volume is used to produce biomass, so we don't need to recycle the sludge; this is achieved by increasing biomass on carriers that move freely in the water. The SBMBBR will thus be prepared to batch operation mode for 6 weeks. To start generating biofilm growth on conveyor components by running a batch transfer sequence reactor bed biofilm reactor (SBMBBR), a batch process was used. Manually setting the necessary periods for each stage by using the control board (filling, aeration, anoxic, settle, and discharge). Automatically, the raw wastewater transports until the total volume of the SBR tank material_(80 L) from the primary clarifier to the SBR reactor. The temperature was regulated to maintain the temperature of the reactor. We used the heater to verify this by setting the temperature from 22.5°C to 27.5°C during winter. To observe the temperature of the reactor, a thermometer was used. The SBR is filled with wastewater at the filling point, with wastewater which is mixed together with sludge. The reaction phase begins automatically when the filling phase ends. It may be anoxic or aerobic according to the available conditions (anoxic with only mixer operating with speed (80 rpm) for anoxic or aerobic with both mixers with speed (40 rpm) and aerator operating). The 10 minutes before the aeration phase, 10 minutes before the completion of aeration) the samples are taken from the reactor for PH, DO. At the aeration phase, the samples were taken for MLSS (total).

C. Analytical methods –

We are studying parameters that were Chemical Oxygen Demand (COD) by DR5000 according to the standard process [8]. Ammonium (NH_4^+ -N) method (LCK 303) by DR 1900 [9], Total Nitrogen (TN) It was measured according to this method (LCK 338) by DR 1900 [10], and Total Phosphor (TP) It was measured according to this method (LCK 348 Phosphorus total) by DR 1900 [11].

III. RESULTS AND DISCUSSION

The biofilm appeared on carrier components after the start-up stage ended. The SBMBBR was operated at batch operation mode. The samples were obtained from the influent and effluents, in SBMBBR, Measurements were made for (Temp, DO, and PH). The total mixed liquor suspended solids concentration (MLSS Total) was tested and the samples of COD, (NH_4^+-N), (TN), and (TP) were analyzed. We studied the effects of gas/water ratio on the removal of (COD), (NH_4^+-N), (TN), and (TP) from the domestic wastewater at eight different ratios ranging from (3/1 to 10/1) it is (3/1, 4/1, 5/1, 6/1, 7/1, 8/1, 9/1, and 10/1) at HRT 24hour, (fill=1 hr, eartion=14 hr, anoxic=7 hr, settle=1 hr, drainge=1 hr). The Discharge 50% during these percentages, we find the better percentage that gives the best removal efficiency. The optimum value of the ratio of gas/water given the highest removal efficiency.

A. Removal of COD at different gas/water ratios –

In this part, we will discuss COD removal at different gas/water ratio modes in the SBMBBR, the COD concentration variance with Various gas/water ratio. the average performances of the SBMBBR in COD removal are shown in fig (3). As gas/water ratio was rose from 3/1 to 5/1, the average effluent COD concentrations Diminished from 21.65 mg/L (SD=1.48) to 11.95 mg/L (SD= 2.47), while the average removal efficiency increased from 94.85% (SD= 0.54) to 96.14% (SD= 0.29). As gas/water ratio was rose from (6/1 to 10/1), the average effluent COD concentrations Diminished from 14.5 mg/L (SD= 1.13) to 3.55 mg/L (SD= 1.202), while the average removal efficiency increased from 96.56% (SD= 0.36) to 99.21% (SD=0.3). Comparison of the effluent quality of SBMBBR with discharge standards concluded that that COD at gas over water ratio (3/1,4/1,5/1,6/1,7/1,8/1,9/1,10/1) could be consistent with the Iraqi and European standards as shown in table (2).

B. Removal of NH_4^+-N at different gas/water ratios –

Since the priority of COD removal and ammonium removal begins after that the process of ammonium degradation is affected by COD concentration. The concentration of COD is high one hour before aeration and the high rate of heterotrophic bacteria is rapidly introduced, so that the degradation of COD is rapid, inhibiting the self-supporting form of nitrifying bacteria, so that the rate of denitrification is sluggish, reducing the rate of concentration of ammonium [12].

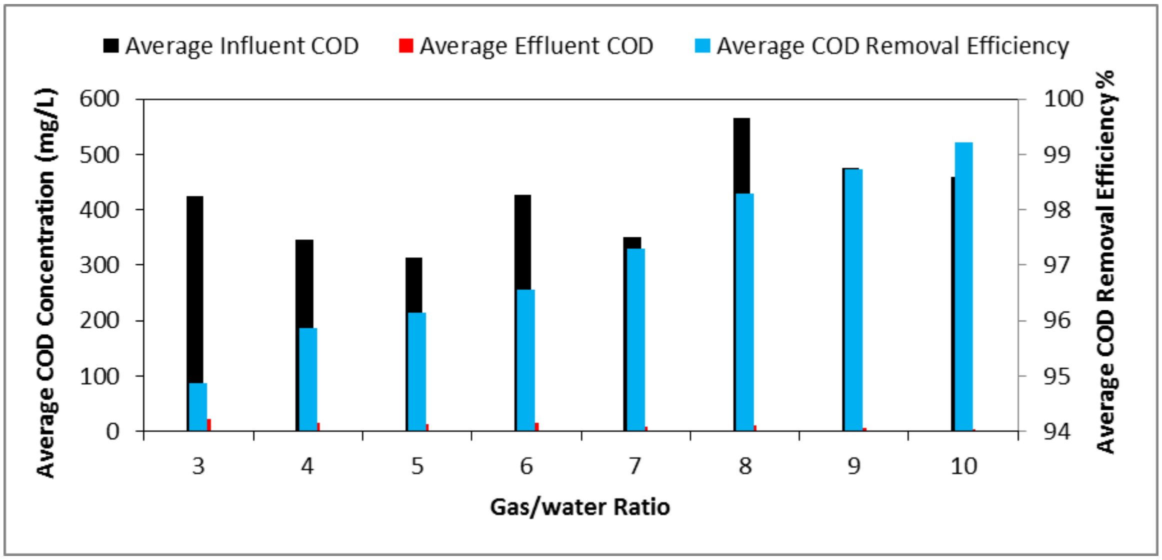

Figure 3. Profile of average COD concentration and average removal efficiency at different Gas/water ratio.

In this part, we will discuss the removal of ammonium at different Gas/Water ratio in the SBMBBR. The average performance of the SBMBBR in NH4+-N removal is shown in fig (4). The effluent NH4+-N concentrations decreased to the range (2.74 mg/L to 2.9 mg/L) at gas/water ratio of 3/1, while at gas/water ratio 4/1 the effluent NH4+-N concentrations Diminished to the range (1.94 mg/L - 2.2 mg/L) at gas/water ratio of 4/1. at a gas/water ratio of 5/1the effluent NH4+-N concentration (1.84 mg/L-1.76 mg/L), at gas/water ratio of 6/1 (1.47 mg/L– 1.57 mg/L), at gas/water ratio of 7/1 the effluent NH4+-N concentrations decreased to the range 1.2 mg/L to 0.98 mg/L. at gas/water ratio of 8/1 (0.48 mg/L-0.61 mg/L). the (0.33 mg/L-0.24 mg/L) at gas/water ratio of 9/1.and (0.15 mg/L-0.22mg/L) at gas/water ratio of 10/1. The average NH4+-N effluent concentration reduced from 2.82 mg/L (SD= 0.11) to 1.09 mg/L (SD= 0.15) as the gas/water ratio rose from (3/1 to 7/1), while the average efficiency of removal increased from 93.84 % (SD=0.33) to 97.64% (SD=0.37) .

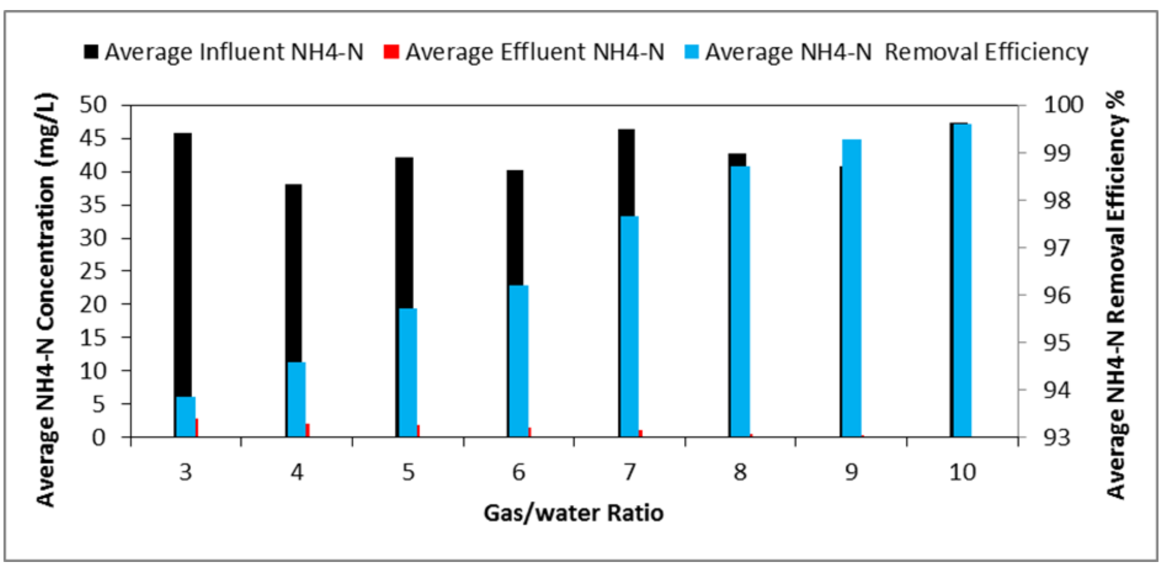

Figure 4. Profile of average NH4+-N concentration and average removal efficiency at different Gas/water ratio.

When the gas/water ratio was rose from (8/1 to 10/1), the average NH4+-N effluent concentration decreased from the 0.54 mg/L (SD=0.09) to 0.18 mg/L (SD=0.04), while the average removal efficiency increases from 98.72% (SD=0.25) to 99.60% (SD=0.11). Comparison of the effluent quality of SBMBBR with discharge standards concluded that NH4+-N at gas/water ratio (3/1,4/1,5/1,6/1) could only comply with the Iraqi standard. The gas/water ratio (7/1, 8/1, 9/1, 10/1) complies with all specifications as shown in table (2).

C. Removal of TN at different gas/water ratios –

The total nitrogen (TN) in domestic wastewater contains 60% to 70% from Ammonium (NH4+-N) resulting from rapidly breaking down urea [13]. Domestic wastewater treatment plants (WWTP) also For biological nitrogen elimination, use nitrification/denitrification. Caution To prevent nitrification failure, it is important to take because of the slow growth and susceptibility of nitrifying bacteria to environmental circumstances. The temperature often greatly affects the growth and operation of nitrifiers [14].

The average performance of the SBMBBR in TN removal is shown in fig (5). The efficiency of TN removal is greatly affected by the gas/water ratio in the 3/1 to 10/1 range. The ratio of gas to water was increased from 3/1 to 7/1, the average effluent TN concentrations Diminished from 54.87 mg/L (SD= 0.219) to 23.95 mg/L (SD=0.212), while the average removal efficiency increased from 37.67 % (SD= 0.9) to 64.92% (SD=0.68). As the gas/water ratio was rose from (8/1 to 10/1), the average effluent TN concentrations increased from 28.1mg/L (SD=0.283) to 33.54 mg/L (SD=3.847), while the average removal efficiency decreased from 56.47% (SD=1.85) to 34.14% (SD=4.37). Comparison the effluent quality of SBMBBR with discharge standards concluded that TN concentrations at gas/water ratio (3/1, 4/1, 5/1, 6/1, 7/1 ,8/1, 9/1, and 10/1) was (54.87 mg/L, 34.81 mg/L, 34.75 mg/L, 28.37 mg/L, 23.95 mg/L, 28.1 mg/L, 37.45 mg/L, and 33.54 mg/L) respectively these values not meet to all standards as shown in table (2).

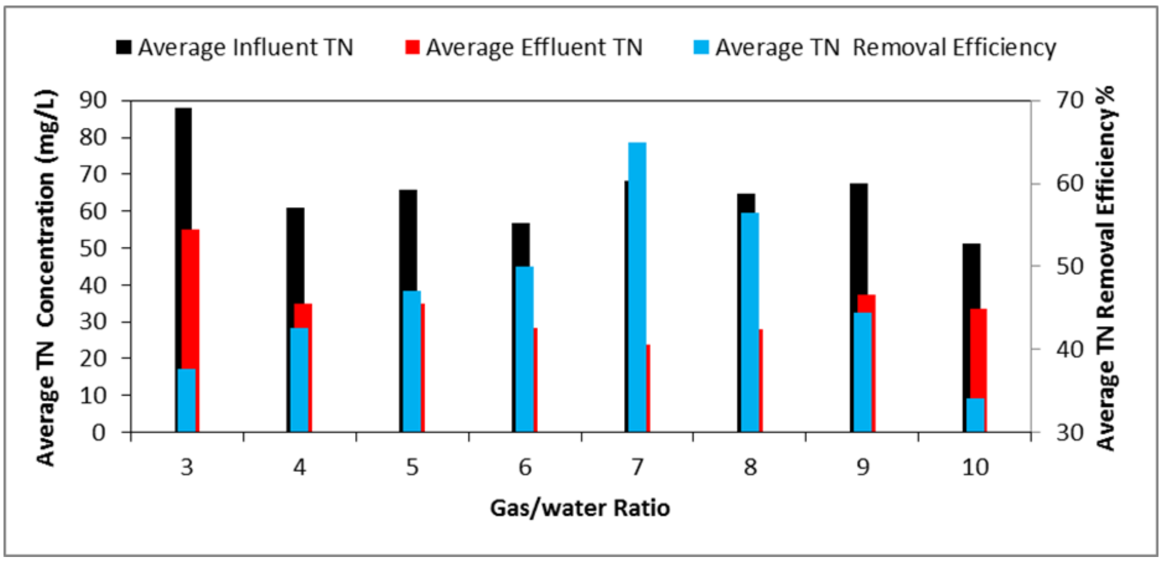

Figure 5. Profile of average TN concentration and average removal efficiency at different Gas/water ratio.

D. Removal of TP at different gas/water ratios –

In this part, we will discuss total phosphorus removal at different gas/water ratio modes in the SBMBBR. the average performance of the SBMBBR in TP removal is shown in figure (6). The gas/water ratio in the 3/1 to 10/1 range greatly affects the efficiency of TP removal. As gas/water ratio was rose from 3/1 to 7/1, the average effluent TP concentrations Diminished from 1.62 mg/L (SD=0.49) to 0.81 mg/L (SD= 0.09), while the average removal efficiency increased from 44.68 % (SD= 2.76) to 80.70% (SD=1.78). As the gas over water ratio was rose from 8/1 to 10/1,the average effluent TN concentrations increased from 1.19 mg/L (SD=0.09) to 2.03 mg/L (SD=0.13), while the average removal efficiency decreased from 65.62 % (SD=4.58) to 46.02% (SD=5.07.

Comparison of the effluent quality of SBMBBR with discharge standards concluded that the TP at gas/water ratio (3/1, 4/1, 5/1, 6/1, 8/1, 9/1, and 10/1) at (1.62 mg/L, 1.44 mg/L, 1.04 mg/L, 1.2 mg/L, 1.19 mg/L, 1.5 mg/L, and 2.03 mg/L) was meet to the standards Iraqi just, while, the gas/water ratio (7/1) which equal (0.81 mg/L) meet to all the standards (IRAQI, European) as shown in table (2).

E. Gas/water ratio of optimal value –

Overall, the results showed that the Gas over water ratio ranged from 3/1 to 10/1 did not substantially affect the efficiencies of COD and NH4+-N removal, while CHINA Standards, European Wastewater Standards, could not meet the average effluent of TN concentrations. But the lowest value we got in these ratios is at a ratio of 7/1 (23.95

mg/L). On the other hand, the average TP effluent concentration did not meet the gas/water ratio of Iraqi standard and European standard (3/1, 4/1, 5/1, 6/1, 8/1, 9/1, and 10/1) while it could meet the gas/water ratio of Iraqi standard and European standard (0.81 mg/L) at 7/1. Finally, we can conclude that the 7/1 gas/water ratio is optimal for the elimination of organic substances and nutrients at the same time.

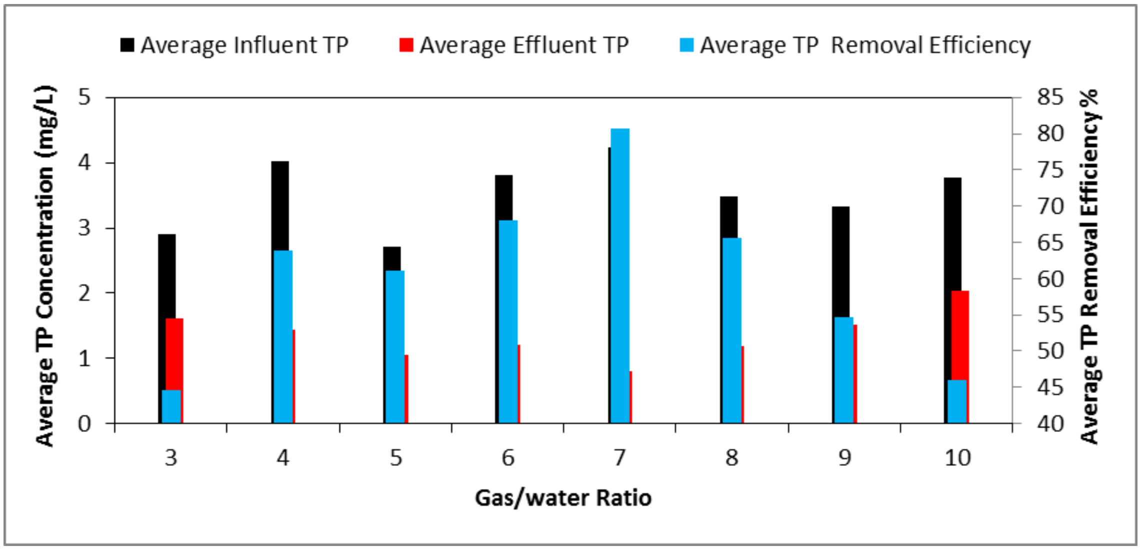

Figure 6. Profile of average TP concentration and average removal efficiency at different Gas/water ratio.

Table-2 Standards for Discharge of Effluent

Pollutant	**IRAQ** [15]	**CHINA** [16]		**European Wastewater Standards** [17]
		Grade A	**Grade B**	
COD mg/L	<100	20	30	125
NH_4-N mg/L	10	1	1.5	-
TN mg/L	--	10	15	10
TP mg/L	3	0.2	0.3	1
PH	6-9.5	6-9	6-9	-

IV.CONCLUSION

The next conclusions can be shown according to the findings of the experiment:

• The (SBMBBR) has been able to sustain a considerable quantity of biomass attached to it that would provide good production and achieve adequate nutrient removal.

• The system of (SBMBBR) in the laboratory is very effective of domestic wastewater at AL Samawa City in terms of high removal rates for pollutants which at Gas over water ratio of 7/1 and HRT 24 hour and the Discharge 50% .whereas the average effluent results for the (COD=9.15 mg/L) with average removal efficiency 97.29%, (NH4+-N=1.09 mg/L) with an average removal efficiency of 97.64%. (TN=23.95 mg/L) with an average removal efficiency of 64.92%, and (TP=0.81 mg/L) with an average removal efficiency of 80.70%.

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