Hunan Daxue Xuebao/Journal of Hunan University Natural Sciences
ISSN : 1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.12684722
Vol: 61 | Issue: 07 | 2024

ENHANCEMENT OF BLACKWATER TREATMENT EFFICIENCY USING MODIFIED SEQUENCING BATCH REACTOR (MSBR) TECHNIQUE

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Abstract

Recently, modifying of Sequencing Batch Reactor (MSBR) treatment technology have been researched and improved widely to enhance and upgrade performance. This study on modified version of conventional SBR was Anoxic phase application in Sequencing Batch Biofilm Reactor (ASBBR). This system was applied for blackwater (BW) to remove a great part of pollutants especially, nutrient removal to achieve the consents and get the discharge standard. The study experiments were carried out through a laboratory-scale, which operated in three different modes for‒medium strength biochemical oxygen demand (COD) 300 mg/L and total suspended solids (TSS) 250 mg/L, as well as strong ammonia-(NH_3-N) 70 mg/L, and total nitrogen (TN) 90 mg/L. The results revealed that the removal efficiencies of the system in the best mode of TSS, COD, NH_3-N, and TN were 95%, 97%, 96% and 92%, respectively. When HRT was 36hrs for organic load 200, 50 and 60 g/m3. d for COD, NH_3-N, and TN respectively. The effluent quality was meet discharge standards after comparison. WWTPs are facing to remove nutrients especially, nitrogen removal which is a major challenge. Also, it is the source of significant pollution problems in ground water for Erbil city. ASBBR was proposed to apply due to their advantages such as efficient in treatment, effective cost and flexibility in operation for various conditions.

Keywords: *MSBR, Upgrading, Enhance, BW, ASBBR, Performance.*

1.0 INTRODUCTION

1.1 General

The disposal of blackwater (BW) into environment without treatment is source of significant pollution problems threatening the communities, public health and environment. Erbil city is oldest city in north of Iraq. Recently, it has been largely developed and many large and small residential projects constructed. Still there is no centralized wastewater treatment plant (WWTP) in the city so far. Currently, in Erbil city the sewage system is only for rain water as a storm drain system, while is used for greywater sewage. But, BW is collected in septic tanks and cesspools then drained by tanker to the permitted locations by local governments of Erbil without any treatment. For this purposes Kurdistan Region Government (KRG) set new regulation, guidance and plan.

Recently, methods of enhancing of conventional SBR treatment technology have been researched and developed. Several modified versions of SBR are Sequencing Batch Biofilm Reactor (SBBR) (Gururaj and Kumar 2015; Abdelaziz et al., 2020; Al-Rekabi et al., 2021; Elhawary et ai., 2021; Al-Khafaji, et al., 2023), Intermittent Cycle Extended Aeration System (ICEAS) (Mahvi et al.,2004; Al-Rekabi et al., 2017), Powdered Activated Carbon SBR (PAC-SBR) (Aziz et al.,2011), SBR retrofit with integrated fixed film

DOI: 10.5281/zenodo.12684722
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activated sludge (SBR-IFAS) (Veolia - AnoxKaldnes Hybas, 2023), Multiple reactors that operate through a series of stages (Aqua MSBR) (Aqua- Aerobic System Inc., 2022) etc. owadays, modified sequencing batch reactor (MSBR) plants have become more popular due to their advantages after improvement and upgrading. There are many different scale WWTPs around the world which based on MSBR treatment process ranging from large-full scale size to small scale size (package plant). One of the recent MSBR is Anoxic Sequencing Batch Biofilm Reactor (ASBBR) treatment technology. It is an effective system and has good and flexible operational stability.

WWTPs are facing to remove nutrients especially, nitrogen removal which is a major challenge. In the recent years, due to their relative low cost biological treatment systems are widely used in wastewater treatment processes (Hibiya et al., 2000). Generally, biological nitrogen removal (BNR) is used often in wastewater treatment because is more cost effective compared with to alternatives such as ion exchange, break point chlorination, ammonia stripping, (Metacalf and Eddy, 2014). BNR involves both nitrification and denitrification. Nitrogen removal, is necessary for WW when there are concerns from Nitrate (NO_3-N) and Nitrite (NO_2-N), where ground water must be protected against high of NO_3-N when wastewater is used for recharge or and other reclaimed water application (Metacalf and Eddy, 2014).

ASBBR was an innovative application technology, enhance performance to increase the removal of efficiency. Especially, nitrogen removal. In this study ASBBR was applied as a MSBR treatment technology for BW treatment as an effective system to achieve the discharge standard within high removal of efficiency and flexible operation for Erbil city.

1.2 Anoxic Sequencing Batch Biofilm Reactor (ASBBR)

Firstly, a conventional sequencing batch reactor (SBR) was upgraded using fixed biofilm carriers (attached growth) with a specific surface area. Adding biofilm carriers (moving bed biomedia) such as shown in fig 1.

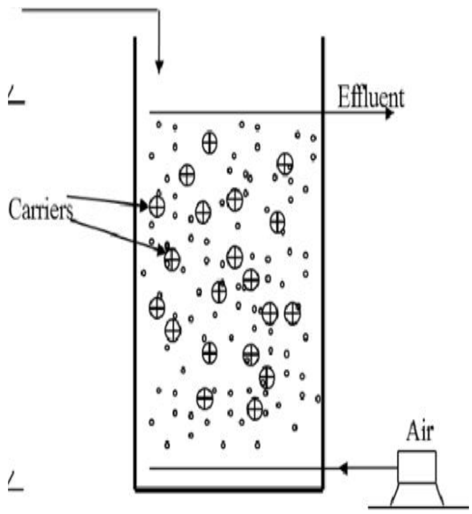

Figure 1: Sequencing Batch Biofilm Reactor (SBBR)

Secondly, Application of anoxic phase in SBBR reactor by adding a separating board (baffle) in the reactor, which was divided into two parts. On the board is aerobic zone, the behind is anoxia and anaerobic zone, with recirculation. Added the anoxic phase into operated cycle to enhance performance of ammonia – nitrogen removal in wastewater. As shown in fig. 2.

ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.12684722
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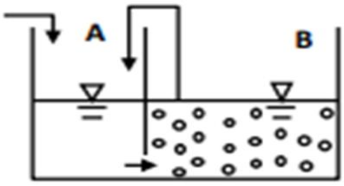

Figure 2: Anoxic Sequencing Batch Biofilm Reactor Reactor (ASBBR)

ASBBR process is modified SBR, by adding both moving bed biomedia and a separating board (baffle) in the reactor, which was divided into two parts. On the board is aerobic zone, the behind is anoxia zone as shown in fig. 2.

2.0 MATERIALS AND METHODS

2.1 Study Area

The real BW was collected from Erbil city disposal area - Qatawy Valley and septic tanks of residential buildings (new Eskan towers). The geographical coordinate is 36°06'50.5"N 43°55'58.6"E and 36° 09' 56" N and 44° 01' 17" Figure 1a respectively. The sewage system of Erbil city is only for rain water as a storm drain system, while is used for greywater sewage. But, BW is collected in both septic tanks and cesspools. Tanker Trucks collect blackwater from households, residential, and commercial buildings then transport it to the permitted locations by local governments of Erbil (disposal area – Qatawy Valley) to discharge to environment directly without any treatment. Nowadays, according to the Erbil Water Directorate (EWD) amount of Nitrite -N and Nitrate-N were very high in ground water which led to close/shutdown some of water boreholes (wells) which were used as one of the main sources of water supply in the city.

Figure 1a: Photos and satellite image of study area

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Figure 1b: Photo of study area

2.2 WW Sampling and Analysis

Real BW collected from study area in Erbil city. The wastewater (WW) quality analysis was done for the pollutant parameters COD, TSS, TN and NH_3-N as well as pH, Temperature, Electrical Conductivity and Total Alkalinity. Collection of samples and analysis were done according to (American Public Health Association APHA, 2005). All the experiments were carried out in the Erbil Directorate of Environment and laboratory of Civil Engineering Department, Salahaddin University-Erbil. The analytical methods which used in this study were followed Standard Methods for the Examination of Water and Wastewater (APHA, 2005). The instruments used during the experimental work are; Lovibond MD 600, APEL PD-303UV and DR3900 HACH spectrophotometers, EUTECH pH700 and HANNA HI97715.

Figure 2: Blackwater sewage samples for the study

2.3 Lab scale ASBBR system configuration

In this study, the laboratory-scale SBBR vessel of total volume is 126 L with rectangular geometric shape length (L) 70 cm, width (W) 45 cm which L=1.55W, a height (H) of 40 cm, depth (D) of wastewater 36 cm and a volume of working is 90 L. Air blower (Type: MiT, B1TT-102, 0.25 Kw, 220-240 V, 50 Hz, Turkey) was used for supplying the air to the reactor. The airflow rate used was ≈100 L /min discharged through the disc diffuser (Aquaflex Disc Diffuser, ADD80-3”, EPDM diffuser membrane) network arrangement located at a height of 5 cm from the reactor bottom. The disc

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diffuser in 3-inch dimeter with air flow capacity about (3000 L/hr). Control electrical board on/off manual and auto, with timer. Also, using barometer gauge mm bar Aterma type small scale, with gate valve control valve, flow meter, electrical pump, mixer, UPVC pipes and fittings etc.

Feeding, withdrawing, and sludge wasting were accomplished by both pumping and gravitational force. Dissolved Oxygen (DO) concentration is kept always ≥ 3.0 mg/L within the aerobic process. Using/adding fixed biofilm (attached growth) carriers with a specific surface 650 m^2/m^3 as detailed in table 1.

Without increasing in area (tank) all process will be in the same tank. Amount of %38 of working volume was selected and used for this specific type of moving bed media as shown in figure 4 which, give approximately 22.23 m^2 of surface area inside the SBBR reactor (nearly 4332 NO.)

Figure 3: Anoxic Sequencing Batch Biofilm Reactor (ASBBR) Lab Scale Plant

Table 1: Biomedia plastic carrier (moving bed biomedia) description

Bio Media Plastic Carrier Description	
Diameter	26 mm
Width	10 mm
Effective Surface Area	5133 mm^2
Surface Area of	650 m^2/m^3
Approximate dia. and No. of inner departments	4-5 mm and 19 mm
Specific Gravity	< 1
Density	(bulk density) 0.92-0.96 g/cm^3
Material , colour and Structure type (shape)	PE Virgin, White and Cylindric Type
Max operation temp	5-60 °C
Number per m^3	100000 (approximately)
Efficiency of Nitrification	400-1200 (gNH4-N/m^3.d)
COD (oxidation efficiency)	2000-15000 (gCOD/m^3.d)
% of Media fill range rate	%30-50 Fill of Volume

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Figure 4: Bio Media Plastic carrier (moving bed biomedia)

2.4 Start-up and Operation

During the start-up phase, ASBBR was operated at 3 cycle times during day (8hrs per each cycle) that was composed (fill 0.5 hr., react time 6.0 hr., settle 1.0 hr., and discharge 0.5 hr.). After 28 days (4 weeks) the biofilm was grown in the reactor. Then the test period started run for approximately 1 week to get the results for different system operations after ensure that the biological treatment systems were mature and that the start-up requirements were reached. DO concentration is kept more than 3.0 mg/L within the aerobic process. Hydraulic retention time (HRT) was calculated as the ratio of cycle time to volumetric exchange rate applied. The organic loading rate (OLR) was determined by the following equation:

OLR = S*Q/V, where S was the influent concentration, Q was the wastewater flow per day and V was the working volume of the reactor.

The operational conditions were used HRT of 18 - 36hrs, aeration time varied from 4 to 9hrs, operated cycle of 2 to 4 cycles per day. Influent concentration prepared of COD, TSS, TN and NH_3-N were about 300, 250, 90 and 70 mg/l respectively. In addition, monitoring of pH and temperature were around 7.8 and 25 C°. DO controlled by DO meter to maintain within the range for experiment.

Table 2: Operation of ASBBR in different cycle mode

System	Cycle Mode	Time (Hour) 12hrs	Cycle time	Operated Cycle/Day	Flow L/Cycle	H.R.T Hrs
ASBBR	A	F, R, S, D	6	4	30	18
	B	F, R, S, D	8	3	30	24
	C	F, R, S, D	12	2	30	36

Cycle		Cycle Mode A	Cycle Mode B	Cycle Mode C
F	**Fill**	0.5hr	0.5hr	0.5hr
R	**React**	4.0hrs	6.0hrs	9.0hrs
S	**Settle**	1.0hr	1.0hr	2.0hrs
D	**Decant**	0.5hr	0.5hr	0.5hr

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ISSN : 1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.12684722
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3.0 RESULTS AND DISCUSSIONS

3.1. BW Characteristics

The wastewater quality analysis was done for the pollutant parameters such as COD, TSS, TN and NH_3-N as well as pH, Temperature, Electrical Conductivity and Total Alkalinity. The results were shown and summarized in Table 3.

Table 3: Characteristics of BW samples

No	Parameter	Unit	May	Jun.	Jul.	Aug.	Sep.	Oct.	Min.	Max.	Avg.	*Effluent (mg\L) Iraqi Standard
1	TEMP.	C^0	25.8	25.1	28.0	26.4	24.9	28.5	24.9	28.5	26.5	35^0 >
2	pH	-	7.95	7.54	7.81	7.91	7.70	8.05	7.7	8	7.85	6.4-8.5
3	COD	mg/l	245	310	261	285	450	367	245	450	320	100
4	NH_3-N	mg/l	70	65	89	56	95	70	56	95	74	5
5	TN	mg/l	95	88	98	69	110	92	69	110	92	15 *
6	TSS	mg/l	289	248	263	250	311	320	248	345	280	40

* WHO standard (Al-Rekabi et al., 2017)

Generally, pH has slightly alkaline maximum was 7.84 and minimum was 7.7 of the samples which were within the Iraqi standard. The pH is a critical parameter that needs to be measured because of bacterial growth and culture of microorganisms. Regarding temperature, biological and chemical reaction are affected by temperature. TSS, COD and NH_3-N were slight fluctuations during the period, see table 3.

When the used BW characteristics were compared to the untreated domestic wastewater typical characteristics of, TSS (250 mg/L), COD (300 mg/L), were considered to be in the medium strength range, while NH_3-N (70 mg/L) and TN (90 mg/L) was found to be in the strong range as shown in Table 4.

Table 4: Comparison BW with raw domestic sewage, (Metcalf and Eddy, 2014)

Pollutants (mg\L)	Mean Values of raw wastewater (mg\L)	The Concentration of International Domestic Sewage (Metcalf and Eddy, 2014)		
		Low	Medium	High
COD	300	250	430	800
NH_3-N	75	12	25	45
TN	90	20	40	70
TSS	250	120	210	400

3.2. Performance of ASBBR

ASBBR system operated and monitored in three cycle modes A, B and C as explained in table 2. Aerobic zone was 60% and pre anoxic zone 40% of the reactor. Temp. Was about 25 C^0 and PH was around 7.8, DO and PH controlled by DO and PH meter to maintain within range for experiment.

In mode A the filling is 30 min, the reacting is 4hrs, the settling is 60 min, and the drawing (decant) is 30 min. So, total cycle 6hrs was run/operated 4 times per day. The hydraulic retention time HRT was 18hrs the removal rates of TSS, COD, NH_3-N/ TN and TP reached 87%, 90% 74%, and 67%, respectively table 5 and figure 4.

Secondly, in mode B the filling is 30 min, the reacting is 6hrs, the settling is 60 min, the drawing is 30 min, so, total cycle 6hrs were run/operated 4 times per day. The hydraulic retention time HRT was 24hrs the removal rates of TSS, COD, NH_3-N and TN reached 91%,95%, 89 % and 78%, respectively details was shown in table 5 and figure 4

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In last cycle mode C, the filling is 30 min, the reacting is 9hrs, the settling is 2hrs, the drawing is 30 min, so, total cycle 12hrs was run/operated 2 times per day. The hydraulic retention time HRT was 36hrs the removal rates of TSS, COD, NH_3-N/ and TN reached 95%,98%,96% and 87%, respectively details was shown in table 5 and figure 4

Table 5: Average % Removal of BW samples during the study

System	Mode	TSS		COD		NH_3-N		TN	
		%Removal	Effluent	%Removal	Effluent	%Removal	Effluent	%Removal	Effluent
ASBBR	A	87	32.5	90	30	74	18.2	67	29.7
	B	91	22.5	95	15	89	7.7	78	19.8
	C	95	12.5	97	9	96	2.8	92	7.2

Removal of Efficiency in (%) = (C1 – C2)/C1 × 100

Where C2 and C1 were the effluent and influent concentrations of the parameters.

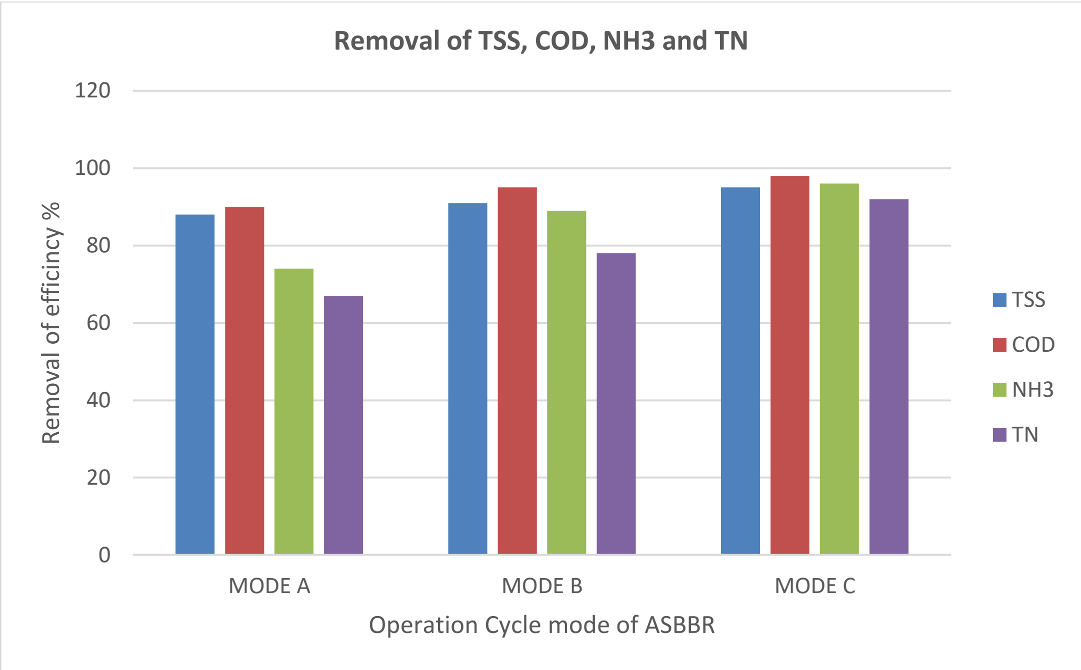

Figure 5: Blackwater sewage samples for the study (Effluent from septic tank)

The results of experiment show that, the efficiency of NH3- N removal in the reactor in the range 74 – 96%. Was increased due to more aeration. Can reach the maximum in mode C**.** Moreover, the removal rates of COD were increased due to more aeration and maximum was in mode C (97%). Time of settling was increased in mode C therefore TSS removal of efficiency was maximum and reach to (95%).

In mode C more NH_3-N was converted to NO_2-N and particularly NO_3-N. TN reached 92%, there are anoxic/anaerobic phase inside the reactor support TN removal by sufficient denitrification process.

When comparing the ASBBR effluent value to the WHO, and Iraqi discharge standards, it was observed that the COD and TSS met these standards. While, NH_3-N and TN met the standards only in mode C.

Over all, Last mode C was the best one among them considering the best operational condition.

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Table 6: The comparison of ASBBR Effluent with standards of effluent discharge

Parameter	ASBBR Effluent(mg\L)			International Standards of Effluent Sewage (mg\L)	
	Mode A	Mode B	Mode C	Iraqi Standard	*WHO [WHO, 2006]
COD	30	15	9	100	100
NH_3-N	18.2	7.7	2.8	5	6
TN	29.7	19.8	7.2	-	15
TSS	32.5	22.5	12.5	40	-

* (Al-Rekabi et al., 2021)

In general, both COD and NH_3-N removal were benefitting from Bio-media. Adding moving bed biomedia (biofilms) inside bioreactor. Active biomass grows in biofilms on the surfaces of plastic carrier elements which enhance performance, increase capacity and cost effective.

Modified Ludzak-Ettinger (MLE) process, which is Preanoxic denitrification, the most common process used for biological nitrogen removal. (Metacalf and Eddy, 2014), without adding any source of carbon for denitrification, especially total nitrogen removal which lead to decrease in OPEX. But in post anoxic denitrification OPEX increased due to adding carbon source for denitrification. Insufficient carbon for complete denitrification; thus, it requires an external carbon source for efficient performance of the bioreactor.

3.3 Operation Conditions

ASBBR system was a single vessel (tank) reactor with activated sludge system. It operates in time rather than in space as a batch reactor for wastewater treatment. All processes were still in the same tank. It was an innovative application technology as a modified version of SBR (MSBR). Enhance performance to increase the removal of efficiencies, especially, nitrogen (NH3-N/TN) removal then carbon removal (COD/BOD) as well as other parameters such as TSS.

Both COD and NH_3-N removal were benefitting from Bio-media. Adding moving bed biomedia (biofilms) inside the reactor. Active biomass grows in biofilms on the surfaces of plastic carrier elements which enhance performance, increase capacity and cost effective. Generally, WWTPs are facing to remove nutrients especially, nitrogen removal which is a major challenge. Application of anoxic phase in the reactor by adding a separating board (baffle) in the reactor, which was divided into two parts. On the board is aerobic zone, the behind is anoxia / anaerobic zone, with recirculation.

Adding the anoxic phase into operated cycle to enhance performance of total nitrogen removal. On the other side, without adding any source of carbon (external source) for denitrification (convert nitrite and nitrate to nitrogen) for nitrogen removal especially, which decrease operation cost (OPEX).

Generally, biological nitrogen removal is used often in wastewater treatment because is more cost effective compared with to alternatives such as ion exchange, break point chlorination, ammonia stripping, (Metacalf and Eddy, 2014). Biological nitrogen removal, which involves both nitrification and denitrification.

The effects of aeration time on the efficiency of the ASBBR were also studied in terms of removals. Aeration is the main parameter that affects the operational cost, so that decreasing aeration time is very important to achieve cost- efficient operation. According to the obtained removal efficiencies of mode C were higher than mode A and B. So, the removal efficiencies of ASBBR were increased by increasing the aeration. Increasing of aeration to remove high strength pollutant is necessary to get the effluent targets (consent). Nitrogen (NH_3-N) removal need more aeration O2 than COD. However, time of aeration is one of the main parameters that affects the operational cost which lead to high

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ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.12684722
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OPEX in WWTPs. Theoretically, the O2 required to complete oxidation of ammonia is about 4.57 g O2/g N. (Metacalf and Eddy, 2014).

In addition, ASBBR can be operated for different operating conditions in very simple as shown in figure 6 for nitrogen (NH_3-N and TN) removal.

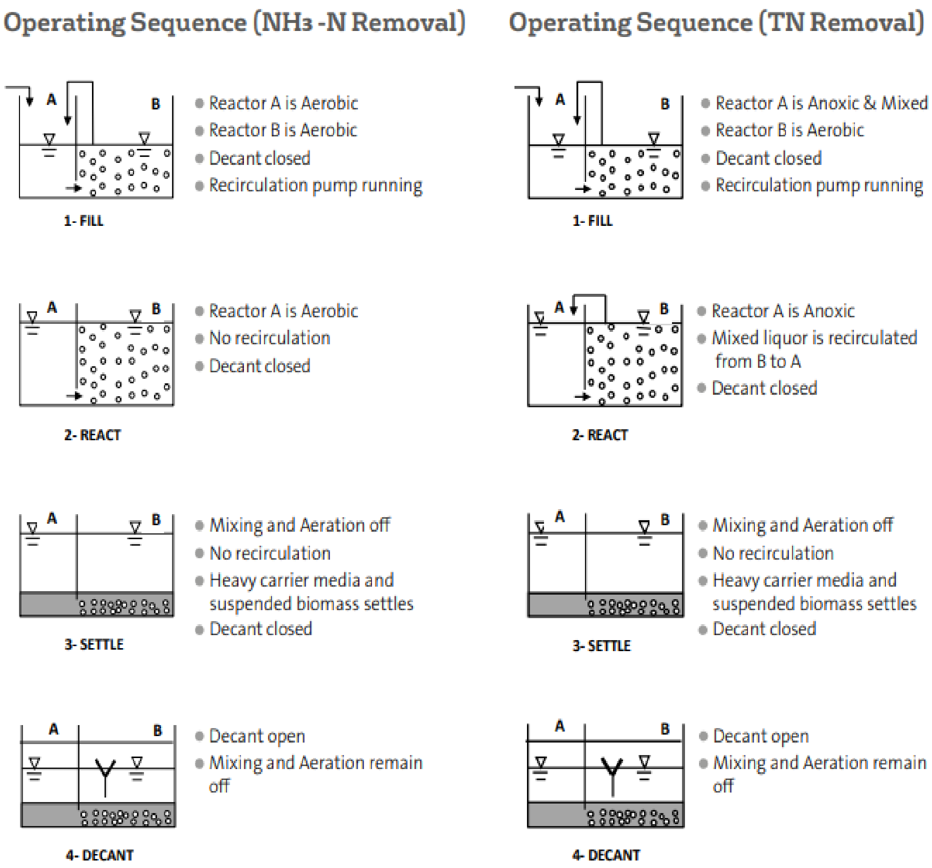

Figure 6: Operation of ASBBR in different way for various condition

Nowadays, automation by programmed logic controller (PLC), and supervisory control and data acquisition (SCADA) make it more easy and very simple in operation for various conditions and allows to adjust the work parameters to the various conditions. In the past, WWTP that based on SBR known as complex in operation due to more complicated process which need skill operators (Water Environment Federation,1996) and suffering from supporting by technologies in operation. But currently, well known as highly flexible, modular wastewater treatment system. Easy installation. Simple, intuitive operation, due to developments and improvements in technologies in recent years that related to operation of WWTPs. Therefore, around the world MSBR plants have become more popular over the last years. According to Ding et al. (2011), to optimize the operation of traditional SBBR and reduce the aeration phase, a newly developed intelligent controlling system was adopted to control the SBBR. Lab-scale ASBBR operation condition was compared to common full-scale range in treatment processes based on SBR, Table 7.

Because of existing moving bed biomedia (biofilm). ASBBR was robustness in the process and resisting loading rate (shock load) due to Biofilm (Wilderer et al., 1993). As well as, start-up period was slightly faster. In the end, ASBBR is found as flexible technology which can be atomized in treating BW which allows to adjust parameters and operation to the various conditions.

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ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.12684722
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Table 7: Operation of ASBBR in Lab and common Full-scale range

System SBBR	Cycle Time hr	Fill Time hr	React Time hr	Settle Time hr	Decant Time hr	Operated Cyc/Day	DO mg /l	pH	T C°	H.R.T Hrs	SRT day	Media % vol. SBBR	OLR COD Kg/m3.d	Control	V treated
Full scale (WWTP)	6-12	0.5-2	4-8	1-2	0.5-2	4-2	>2	6 -8.5	40>	6-36	14-30	25 -50%	0.15-9	PLC	0.3-0.5 Vt
Lab scale	12	0.5	9	2	0.5	2	≈3	≈7.5	25^0	36	28	38%	0.4	A/M	0.44 Vt

A=Auto, M=Manual, PLC= programmed logic controller

4.0 CONCLUSIONS

ASBBR was able to treat BW for high (strong) range NH_3-N (70 mg/l) and TN (90 mg/l). The removal efficiencies were 95%, 97%, 96% and 92% for TSS, COD, NH_3-N and TN respectively. It was achieved the required effluent quality of TSS, COD, NH_3-N and TN were 12.5, 9.0, 2.8 and 7.2 mg/l respectively.

NH3-N and COD removal consequently OPEX were benefitting from biofilms inside the reactor as well as robustness and faster startup of the system. Good COD (9 mg/l) affluent quality produced due to long time of aeration, biomedia (biofilm) and source of carbon (internal carbon source) for efficient denitrification. On the other side, carbon nitrogen (C/N) ratio requires for efficient performance of the bioreactor.

The removal efficiencies of ASBBR were increased by increasing the aeration. Increasing of aeration to remove high strength pollutant was necessary to get the effluent targets (consents), especially nitrogen (NH_3-N) removal which need more aeration O2 (4.57 g O2/g N) than carbon removal (COD). However, time of aeration is one of the main parameters that affects the CAPEX. On the other hand, without adding any source of carbon (external carbon source) for efficient denitrification for total nitrogen TN removal, reduce OPEX.

When ground water was source of water supply then must be protected against pollution. BW which usually contain quite amount of nitrogen. There were concerns from NO_2-N and particularly NO_3-N on ground water such as in Erbil city. Application of ASBBR system/technology for WWTP in Erbil city will help EWD and all water associations.

Over all, ASBBR was an effective treatment technology which has quite good performance and high removal efficiencies. It was achieved the required effluent quality (consents) when comparing to the discharge standards. Also, robustness in the process, flexibility in operation for various conditions and cost effective.

References

1) Abdelaziz, H. A., Moharram Fouad, Mohamed Mossad (2021), "Upgrading sequencing batch reactor using attached biofilm", Water Environment Federation, Water Environment Research, pp1700–1713.

2) Abdelaziz, H. A., Fouad, M., Mossad, M., (2020)," Effect of increasing organic loading rate on the performance of conventional and modified sequencing batch reactors ", Mansoura Engineering Journal, (Mej), Vol. 45, Issue 4.

3) Al-Khafaji, S. A., Al-Rekabi, W.S., Al-Saad, Z. A., Al-Shmailawi, A. H., (2023), "Sequencing Batch Biofilm reactor (SBBR) Performace in Domestic Sewage Treatment: Mini Review", Eurasian Journal of Engineering and Technology, vol 15, pp96-105.

DOI: 10.5281/zenodo.12684722
Vol: 61 | Issue: 07 | 2024

4) Al-Rekabi, W.S., Abbas, A. A., Abbas, S. A. (2017), "Municipal Wastewater Treatment of Basrah City Using Intermittent Cycle Extended Aeration System (ICEAS)", Journal of Engineering and Sustainable Development Vol. 21, No. 02, March 2017, ISSN 2520-0917.

5) Al-Rekabi, W.S., Al-Khafaji, S. A., Hassan, A. H., Janna H., (2021), "Effectiveness of Sequencing Batch Biofilm Reactor Technology to Treat Domestic Wastewater in Basrah City", Journal of Ecological Engineering 2021, 22(8), pp 234–242.

6) APHA, (American Public Health Association), (2005)," Standard Methods for the Examination of Water and Wastewater, 21st ed., American public health association", Washington DC.

7) Aziz S. Q., Ali S. M. (2018), Characteristics and Potential Treatment Technologies for Different, Kinds of Wastewaters, Zanco Journal of Pure and Applied Science, 30(s1), pp 122- 134.

8) Aziz, S. Q., and Fakhrey, E. S., (2017), "Optimization of Aeration Style and Cycle Time for Treatment of Oil Refinery Wastewater Using Powdered Activated Carbon and Sequential Batch Reactor", ZANCO Journal of Pure and Applied Sciences, Salahaddin University-Erbil ZJPAS (2017), 29 (1); pp 140-153. (http://dx.doi.org/10.21271/ZJPAS.29.4.15).

9) Aziz, S.Q., Aziz, H.A., Mojiri, A., Bashir, M.J. and Abu Amr, S. (2013), "Landfill leachate treatment using sequencing batch reactor (SBR) process: Limitation of operational parameters and performance", Int. J. Sci. Res. Knowl., 1(3), pp 34-43.

10) Aziz SQ, Aziz HA, Yusoff MS, Bashir MJK (2011). Landfill leachate treatment using powdered activated carbon augmented sequencing batch reactor (SBR) process: Optimization by response surface methodology. J. Hazard. Mater., 189: pp 404–413.

11) Aziz SQ (2011). Landfill Leachate Treatment Using Powdered Activated Carbon Augmented Sequencing Batch Reactor (SBR). Process Unpublished, PhD thesis, School of Civil Engineering, University Sains Malaysia.

12) Aziz S. Q., Omar I. A., Bashir M. J. K., Mojiri A. (2020), Stage by stage design for primary, conventional activated sludge, SBR and MBBR units for residential wastewater treatment and reusing, Advances in Environmental Research, 9, pp233-249.

13) Boon, A. G, (2003). "Sequencing batch reactors: a review". Water and Environment Journal, vol.17, no. (2), PP 68-73.

14) Cho, B.-C.; Chang, C.-N.; Liaw, S.-L.; Huang, P.-T., (2001) "The feasible sequential control strategy of treating high strength organic nitrogen wastewater with sequencing batch biofilm reactor". Water Sci Tech 2001, 43, p115-122.

15) Ding, D., Feng, C., Jin, Y., Hao, C., Zhao, Y., Suemura, T., (2011). "Domestic sewage treatment in a sequencing batch biofilm reactor (SBBR) with an intelligent controlling system". Desalination 276 (1–3), pp260–265. https://doi.org/10.1016/j. desal.2011.03.059

16) EPA, U.S. (1986), "Summary report Sequencing Batch Reactor" United States Environmental Protection Agency EPA/625/8-86/011. Washington D.C., Summary report Sequencing Batch Reactor.

17) EPA, U.S. (1992). "Sequencing Batch Reactors for Nitrification and Nutrient Removal". US Environmental Protection Agency, EPA 832 R-92-002, Washington D.C., pp: 1-5 to 1-7.

18) Elhawary A.S., Rozaik E.H., Zaher K., (2019)," Effect of Biofilm Filling Rates, Various Cycles Duration and Organic Loading Rates On Organic and Nutrients Removal In Sequencing Batch Biofilm Reactor (SBBR)", International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 02, www.irjet.net

19) Gururaj A, Kumar BM, (2015), "Comparison of Performance Sequencing Batch Biofilm Reactor (SBBR) For the Treatment OF DOMESTIC. International Journal of Current Research. Vol. 7, Issue, 07, pp.18147-18150.

DOI: 10.5281/zenodo.12684722
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20) Hibiya, K., Tsuneda, S. and Hirata, A. (2000), "Formation and characteristics of nitrifying biofilm on a membrane modified with positively-charged polymer chains", Colloids and Surfaces B: Biointerfaces, vol. 18, no. 2, pp. 105-112.

21) KOIKA and K-water. (2007), “The Erbil water supply and sewerage system improvement project”, Final report, Erbil-KRG.

22) Machat H, Boudokhane C, Roche N, Dhaouadi H, (2019), “Effects of C/N Ratio and DO concentration on Carbon and Nitrogen removals in a Hybrid Biological Reactor”, Biochemical Engineering Journal (2019), https://doi.org/10.1016/j.bej.2019.107313

23) Mahvi, A. H. (2008). “Sequencing Batch Reactor: A promising technology in waste water”, Iranian Journal of Environmental Health and Science Engineering, 5(2), pp79- 90.

24) Mahvi, A.H., Mesdaghinia, A.R. and Karakani, F. (2004). “Feasibility of continuous flow sequencing batch reactor in domestic wastewater treatment”, American Journal of Applied Sciences, 1 (4), pp 348-353.

25) Metcalf & Eddy (revised by Tchobanoglous, G., Burton, F.L. & Stensel, H.D. (2003), (2014). "Wastewater Engineering, Treatment and Reuse". 4th edition, McGrawHill, New York.

26) Modified Sequencing Batch Reactor, Aqua MSBR, (2022) “Aqua MSBR®”, available at: Aqua MSBR® - Aqua-Aerobic Systems | Activated Sludge System https://www.aqua-aerobic.com/downloads/MSBR-Brochure-2012_web.pdf, (accessed 1st Sept. 2023).

27) MOHE, (2012), The Iraqi National Environment Wastewater Standards for Agricultural Irrigation Quality standard for water sources according to regulations issued by Iraqi government. Iraqi government

28) Simon Judd. (2013), “Watermaths” process fundamentals for the design and operation of water and wastewater treatment technologies, text book, Second Edition.

29) Singh, M., and Srivastava, R. K. (2011). Sequencing batch reactor technology for biological wastewater treatment: a review. Asia-pacific journal of chemical engineering, vol. 6 no. (1), pp 3-13.

30) Veolia, AnoxKaldnes Hybas™, (2023), “Krüger Kaldnes Technology:, Introduction” available at: https://www.krugerkaldnes.no/en/technologies/anoxkaldnes-hybas (accessed 1st July 2023).

31) Water Environment Federation, (1996). “Operation of Municipal Wastewater Treatment Plants.” (Manual of Practice—MOP 11. 5th ed. Volume 2. Alexandria, Virginia: Water Environment Federation, 1996.)

32) Wilderer, P. A., Röske, I., Ueberschär, A., & Davids, L., (1993), “Continuous flow and sequenced batch operation of biofilm reactors: a comparative study of shock loading responses”, Biofouling, 6 (4), pp295–304.

33) WHO, (2006). "A compendium of standards for wastewater reuse in the Eastern Mediterranean Region". World Health Organization Regional Office for the Eastern Mediterranean Regional Centre for Environmental Health Activities CEHA 2006 (WHO-EM/CEH/142/E)