Global Scientific JOURNALS

GSJ: Volume 11, Issue 2, February 2023, Online: ISSN 2320-9186
www.globalscientificjournal.com

Fabrication and laboratory testing of an intelligent sequencing batch reactor

Wisam Abdulla Najim Alhalfi* and Dr. Wisam S. Al-Rekabi*

*University of Basrah

P A P E R   I N F O

Keywords:
Sequencing Batch Reactor (SBR), Wastewater Treatment (WWT), Domestic and Hamdan Sewage Treatment Plant in Basrah City.

A B S T R A C T

Basrah city in particular, and southern Iraq in general, is exposed to water scarcity and as well as to a severe saline tongue. That is why we must treat the wastewater before it is discharged into nature, leading to surface water and groundwater pollution and endangering human resources and fish wealth.

And from here, the idea of sewage treatment in Basrah city before being dumped in the Shatt al-Arab by sequencing batch reactor (SBR) instead of the conventional activated sludge process.

This research aimed to manufacture a sequencing batch reactor (SBR) system that operates in one tank for all the necessary removal processes instead of the conventional activated sludge processes (ASP) that works to accomplish the removal operations by separate tanks for each function.

The tests were carried out for the influent and effluent from the manufactured wastewater treatment system through varying hydraulic retention times for seven different cycles and controlled by the Arduino board, where the removal efficiency was 95, 95, 92 and 95 for COD, NH4, TN and PO4, respectively.

1. INTRODUCTION

Due to its high-efficiency level, the activated sludge system is currently the most widely used method for treating wastewater. Pollutant reduction occurs during the activated sludge process thanks to suspended biomass. Nitrogen, phosphorus, and organic waste are reduced using activated sludge reactors. Numerous varieties, such as the sequencing batch reactor, have been created (SBR). The biological and chemical reactions that happen in the reactor are described by differential equations called "activated sludge models." Essential elements of the process examined by the models include control, design, and simulation of activated sludge reactors. [1 and 2]

A sequencing batch reactor (SBR) is a single-tank, time-controlled sludge system that uses the fill, react, settle, draw, and idle process steps. The SBR is made up of a single vessel with a pipe for wastewater inflow, air diffusers with a compressor and pipes for aeration, sludge drawing equipment for draining sludge, decant equipment for drawing supernatant effluent, a stirrer (mixer) for inducing aeration, and a control system for operation control with regard to time and sequence. [3, 4 and 17]

Sequencing batch reactor technologies have been developed recently because wastewater treatment requires strict regulations to obtain treated water with appropriate characteristics and low environmental pollution. SBR is a single unit combining aerobic and anaerobic stages. It saves 25% of the aeration processes associated with low sludge production and nitrogen and phosphorous removal by adjusting the actual operation cycle. [5, 6, 7 and 8]

The sequencing batch reactor technology is the most suitable and best for the activated sludge process (ASP). Due to its flexibility and ability to obtain the best standards for the effluent to be discharged, the conventional biological treatment process for wastewater has become more stringent and faces significant challenges. The SBR process achieves high-quality nutrient removal in a short amount of time while saving more than 60% of the operational costs needed for a conventional ASP; as a result, the SBR process has recently experienced tremendous popularity. [9 and 10]

The biological process was developed using a series batch reactor with five tanks (anaerobic - oxic /anoxic) to fluctuate the concentrations of organic substances and nutrients in the reactor. Where the operational cycle was divided into two parts, and each piece was divided into eight periods, which were as follows: (90,60,60,30,90,60,60 and 30) minutes in the Hydraulic retention time for 16 hours, the air/water ratio is 35%, and solids retention time is 21 days under a temperature of (19-23) oC. [11]

Industrial effluent was treated using the sequencing batch reactor. Because it is simple to use and keeps a high biomass concentration, it has been proven efficient in treating this effluent from various industries. [12 and 16]

At various particular nutrient input rates, nutrient removal from synthetic wastewater by sequencing batch operation was examined (SNLR). Anaerobic (An), anoxic (Ax), oxic (Ox), anoxic (An), and oxic (Ox) phases with hydraulic residence times (HRT) of 2/1/4.5/1.5/1.5 h, respectively, made up the five steps of nutrient removal in a sequencing batch reactor (SBR). All studies employed a 45-minute settling phase to wrap up the process. [17]

The initial purpose of sequencing batch reactors (SBR) was to remove phosphate and COD from wastewater. SBR systems have been adapted to achieve nitrification and denitrification, coupled with COD and phosphate removal, in response to current laws on nutrient discharge limitations. The fill, react, settle, decant, and idle processes are all included in the sequencing process used by SBR treatment systems. The stages in the reaction cycle are changed to give anaerobic, anoxic, and aerobic phases in a certain number and order when biological nutrient removal is needed. [17, 18, 19 and 20]

2. Manufacture of Sequencing Batch Reactor (SBR):

In this study, a sequencing batch reactor was built in the laboratory with a volume of (55 litres) and dimensions (46 * 30 * 40) centimetres. Two tanks were added, one for feeding the reactor with a volume of (60 litres) and the other for discharging the reactor with a volume of (60 litres) from both sides. Pumps were added to fill the reactor and create a mixer to mix wastewater and complete chemical reactions. Finally, a system of copper tubes was made and placed inside the reactor. Precise orifices were made in these tubes to prepare air for aeration operations through a pump that blower air. [13]

In the reactor, a hole was made to discharge (effluent) with an automatic valve to empty the wastewater into the second tank. The Arduino control panel was used to control the sequencing batch reactor times from the time of aeration, mix, settling and discharge by programming this electronic painting, as shown in Figure (1) and figure (2).

In figure (1), the schematic model of the reactor represents, and as mentioned earlier, the system consists of three tanks for feed, react and decant, where the first tank is filled. Then the pump works to serve the second tank for the mixing and aeration operations to begin through the mixer and ventilation tubes in the second tank until the allotted time is completed For these operations and then opens the automatic valve for the purpose of draining the wastewater to the third tank, which will be discharged for settle and according to the specific impact of this process.

Figure (2) represents the tangible form of the system that was made in the laboratory, which consists of glass tanks, plastic and copper tubes, water pumps, and a blower shown in Figure (3), which pumps air at a rate of 2000 litres/sec and operates at a power of 20 watts and 220 volts.

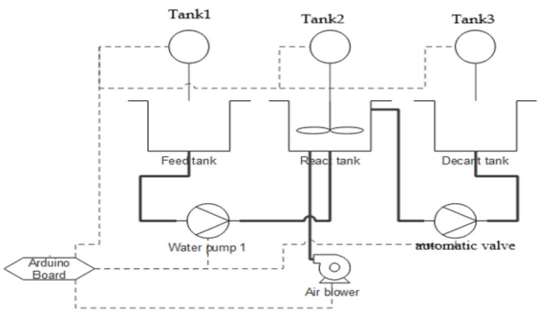

Figure 1. Schematic of the SBR.

Figure 2. Sequencing Batch Reactor System (SBR)

Figure 3. Blower motor

3. The Programmable Control Panel (PCP):

In this project, an Arduino panel was used that connects to all pumps and valves in the reactor system. Figure (4) represents the Arduino control panel, which is a programmable board that was programmed in (Arduino C) language to provide the required time sequence for the operation of the sequencing batch reactor system and to work 24 hours and during five stages (fill, react, decant, settle and idle) and with different time periods to achieve the purpose for which it The system was designed. Note that pumps need a current 220 V and cannot connect directly to the Arduino panel. Thus pumps and valves are connected to the Arduino board through an eight-relay module Arduino panel to get data from computer communication. [13, 14, 15 and 16]

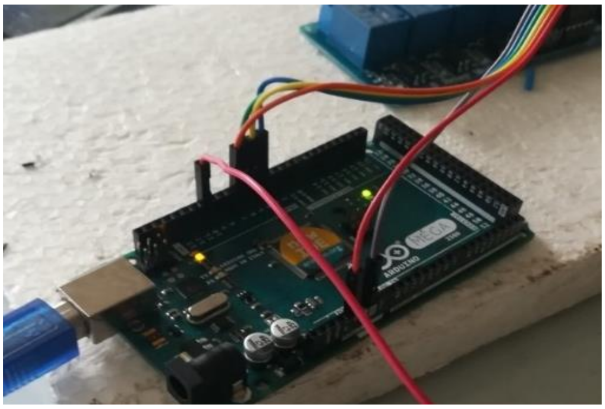

Figure 4. Arduino Panel

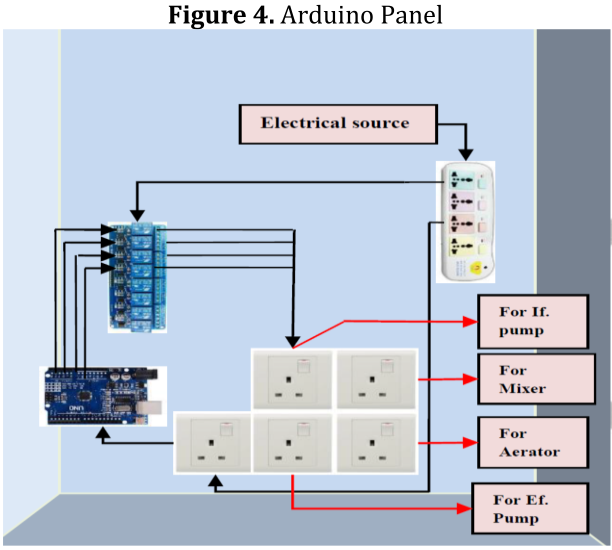

Figure 5. Programmable Control Panel (PCP) and electric connections

Figure 6. The code of the PCP photo

3. Sequencing batch reactor (SBR) performance:

The target of this paper is to assess the ability of the SBR system, which was installed in the laboratory, to remove COD, N-NH4, TN and P-PO4 from sewage that was brought up from the Hamdan Sewage Treatment Plant in Basrah City and reuse the treated water to maintain the environmental sustainability. Particularly given that Basrah City is currently experiencing water scarcity and is affected by salinity.

The table below shows the concentrations of the substances investigated for removal.

Table 1. Raw wastewater characteristics (influent)

Parameter	Unit	Range	Value
COD	mg/l	200 – 540	370
TN	mg/l	32 – 88	60
N – NH4	mg/l	11.2 – 37.12	24.16
P – PO4	mg/l	4 – 7.7	5.85
PH	———	6.87 – 8.80	7.30
Temperature	ºC	40 – 46	43

Sequencing batch reactor operations are divided into five stages: (fill, react, decant, settle and idle). [3, 13, 14, 15 and 16]

After that, tests were conducted on the reactor's performance for domestic sewage water in seven cycles and by changing the hydraulic retention time (HRT), where the process of filling the tank with (5) minutes, and then aeration and mixing operations, because the raw water was suffering from a decrease in oxygen, then settle all of this amounted to about (125) minutes. The amount of change in each cycle was (30) minutes, as shown in table (2), and in each cycle, laboratory tests were carried out using the standard methods applicable. [13]

Table 2. Design operation

Cycle	Filling time (min.)	Aeration time (min.)	Settling time (min.)	Decanting time (min.)	HRT (min.)
1	5	25	60	35	125
2	5	55	60	35	155
3	5	85	60	35	185
4	5	115	60	35	215
5	5	145	60	35	245
6	5	175	60	35	275
7	5	205	60	35	305

4. Results and Discussion:

This part targets to analyze and study the treatment of domestic wastewater for the city of Basra by the activated sludge system using the sequencing batch reactor that was manufactured in the laboratory and the efficiency of removal for this manufactured device by presenting and discussing the practical results that were made in the laboratory.

Figures 7, 8, 10, 11, 13, 14, 16 and 17 Indicate concentrations of the parameters (chemical oxygen demand (COD), the ammonia – N (NH4 – N), the total nitrogen (TN) and the total phosphorus (TP)) of wastewater entering (influent) and leaving (effluent) in this reactor respectively with time.

Figure 9, 12, 15 and 18 Indicates the removal rates (overall conversion efficiency). It was found that levels of the removal rates of the parameters (chemical oxygen demand (COD), the ammonia – N (NH4 – N), the total nitrogen (TN) and the total phosphorus (TP)) increase with time.

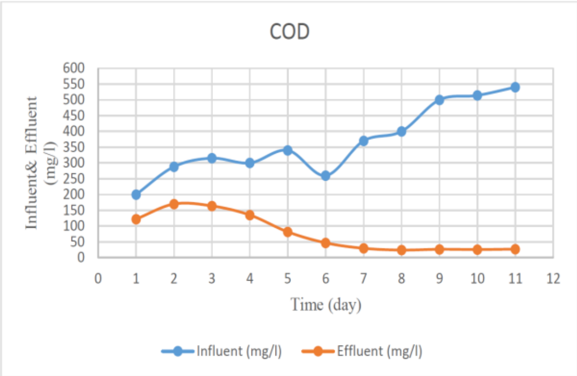

Figure 7. Relationship between wastewater's chemical oxygen demand (COD) concentrations and time.

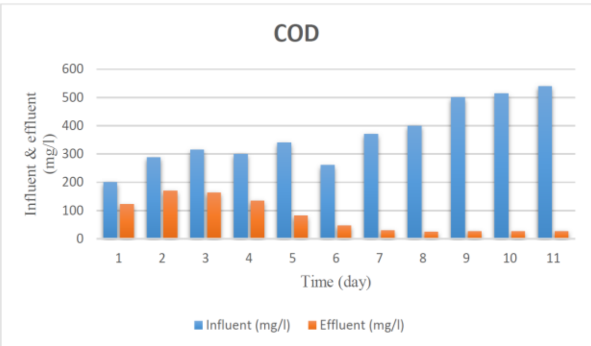

Figure 8. Relationship between wastewater's chemical oxygen demand (COD) concentrations and time.

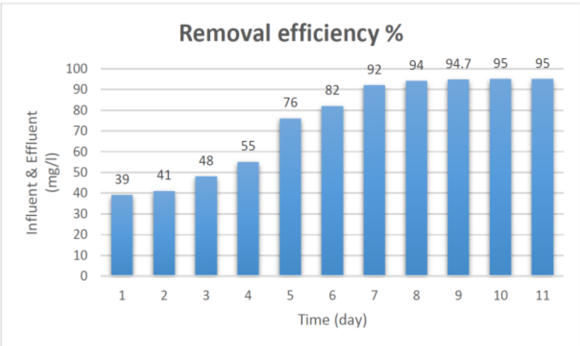

Figure 9. Relationship between COD removal rates (overall conversion efficiency) and time.

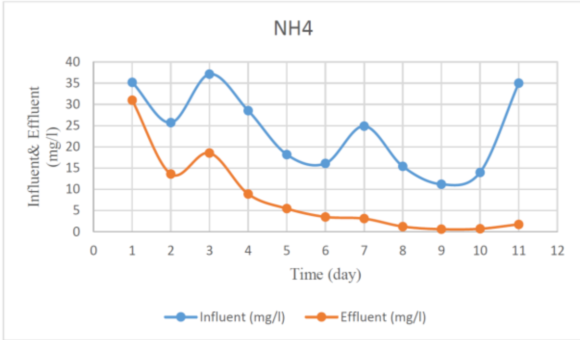

Figure 10. Relationship between wastewater's ammonia – N (NH4 – N) concentrations and time.

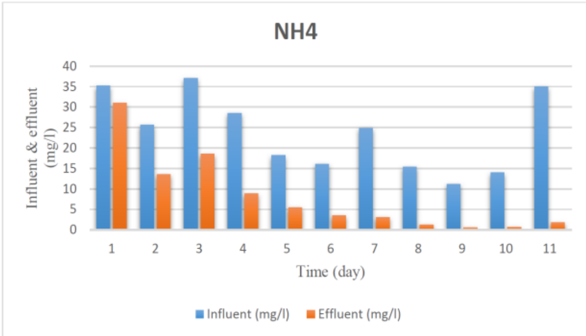

Figure 11. Relationship between wastewater's ammonia – N (NH4 – N) concentrations and time.

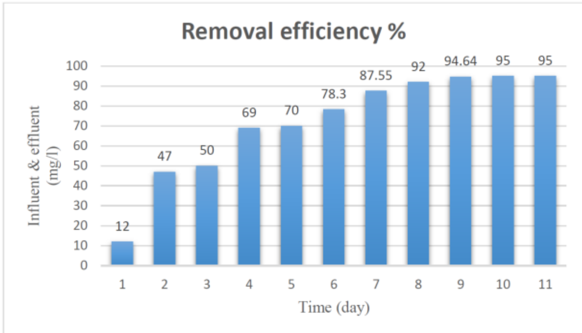

Figure 12. Relationship between (NH4 – N) removal rates (overall conversion efficiency) and time.

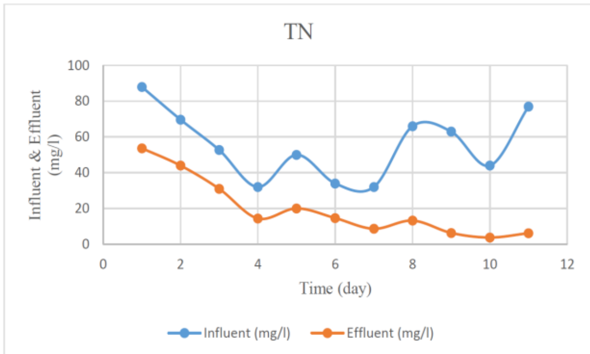

Figure 13. Relationship between wastewater's total nitrogen (TN) concentrations and time.

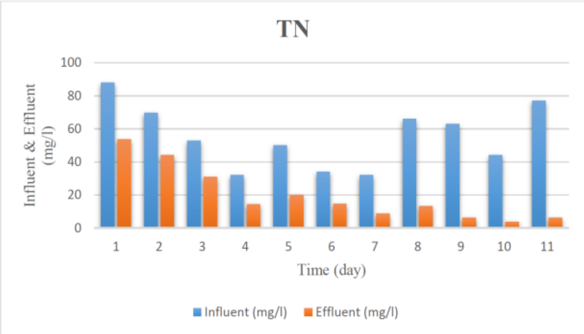

Figure 14. Relationship between wastewater's total nitrogen (TN) concentrations and time.

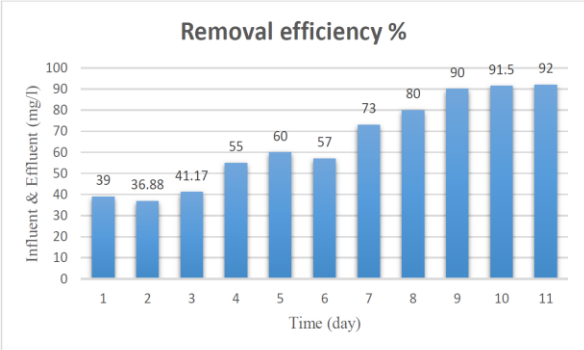

Figure 15. Relationship between TN removal rates (overall conversion efficiency) and time.

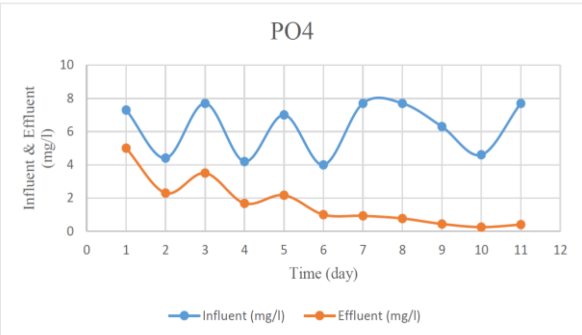

Figure 16. Relationship between wastewater's total phosphorus (TP) concentrations and time.

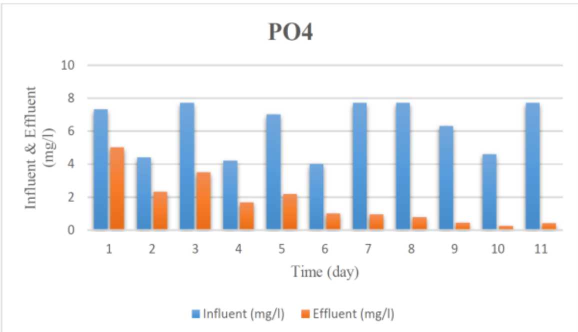

Figure 17. Relationship between wastewater's total phosphorus (TP) concentrations and time.

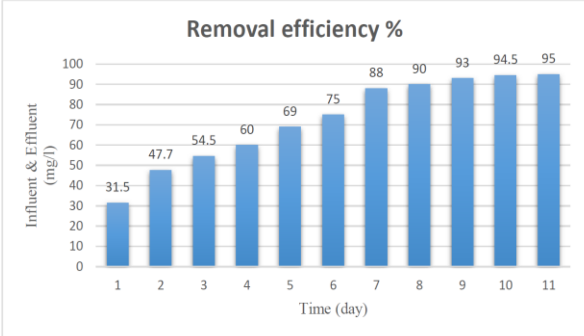

Figure 18. Relationship between TP removal rates (overall conversion efficiency) and time.

Figure 19 Indicates the removal rates (overall conversion efficiency), and it was found that the removal rates of parameter (COD, NH4, TN and TP)levels increase with time.

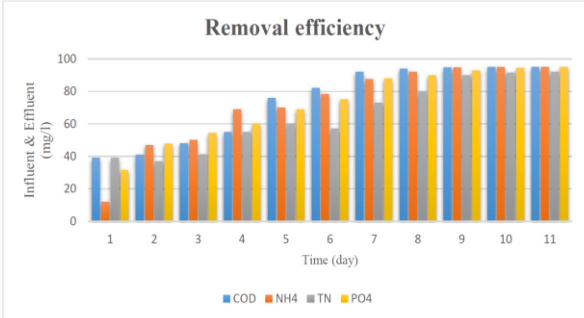

Figure 19. Relationship between the removal rates (overall conversion efficiency) of the parameters (COD, NH4, TN and TP) with time.

4. Conclusions:

- The SBR system that was manufactured in the laboratory was able to achieve the requirement through the removal of activated sludge for a period of 31 days and a concentration of dissolved oxygen of (2 mg/L and more) and at a temperature of (40-46) degrees Celsius and it was (95%), (90%), (92%) and (95%) for COD, NH4, TN and TP respectively so that the removal efficiency for parameters that were examined continued to increase from day to day, due to the adaptation and acclimation between microorganisms with time and as well as achieving high – quality effluent in a very – short aeration time.
- The SBR system gives results, requirements and economic feasibility much better than the conventional activated sludge process for wastewater treatment in Basrah city because the SBR system is inside one tank (small area), so it saves more than 60% of the cost of the conventional ASP, which It covers large areas, up to tens of acres With multiple tanks, these tanks require complex design considerations for each stage.

6. REFERENCES:

1. M. C. Oselame, H. Fernandes and R. H., "Simulation and Calibration of a Full-Scale Sequencing Batch Reactor for Wastewater Treatment", **Brazilian Journal of Chemical Engineering**, Vol. 31, pp. 649 - 658, July - September, (2014), dx.doi.org/10.1590/0104-6632.20140313s00002541.
2. Krist V. Gernaey, Mark C.M. van Loosdrecht, Mogens Henze, Morten Lind, Sten B. Jørgensen, "Activated Sludge Wastewater Treatment Plant Modelling and Simulation: State of the Art", **Environmental Modelling & Software (Elsevier)**, Vol. 19, (2004), pp. 763–783. DOI:10.1016/j.envsoft.
3. Shahryar Jafarinejad, "Recent Developments in the Application of Sequencing Batch Reactor (SBR) Technology for the Petroleum Industry Wastewater Treatment", **International Scientific Organization, Chemistry International**, Vol. 3(3), (2017), pp. 342–350. ISSN: 2410-9649. http://bosaljournals.com/chemint/.
4. Sunil S. Mane, G.R.Munavalli, "Sequential Batch Reactor Application to Wastewater – A Review", International Conference SWRDM, (2012), http://www.unishivaji.ac.in/uploads/journal/Journal_42/29.pdf.
5. Mohini Singh and R. K. Srivastava, "Sequencing Batch Reactor Technology for Biological Wastewater Treatment: A Review", **Asia-Pacific Journal of Chemical Engineering**, Vol. 6,(2010), pp. 3–13. DOI:10.1002/apj.490.
6. W. J. NGI, T. S. SIM, S. L. ONG, K. Y. NG, M. RAMASAMY and K. N. TAN, "Efficiency of Sequencing Batch Reactor (SBR) in the Removal of Selected Microorganisms from Domestic Sewage", **Environmental Modelling & Software (Elsevier)**, Vol. 27, (1993), No. 10, pp. 1591-1600, 1993. https://doi.org/10.1016/0043-1354(93)90105-Q.
7. S. Venkata Mohan, N. Chandrashekara Rao, K. Krishna Prasad, B.T.V. Madhavi, P.N. Sharma, "Treatment of Complex Chemical Wastewater in a Sequencing Batch Reactor (SBR) with An Aerobic Suspended Growth Configuration", **Environmental Modelling & Software (Elsevier)**, Vol. 40,(2005), pp. 1501–1508. DOI: 10.1016/j.procbio.2003.02.001.
8. Metcalf & Eddy. In Wastewater Engineering: Treatment, Disposal and Reuse, 3rd edn, (Eds.: G. Tchobanoglous, F.L.. Burton) McGraw Hill: New York, 1991.
9. Aparna Dutta and Sudipta Sarkar, "Sequencing Batch Reactor for Wastewater Treatment: Recent Advances", **Springer International Publishing**, Vol. 1, (2015), pp. 177–190. DOI 10.1007/s40726-015-0016-y.
10. M. Casellas, C. Dagot and M. Baudu, "Set up and Assessment of a Control Strategy in a SBR in Order to Enhance Nitrogen and Phosphorus Removal", **Environmental Modelling & Software (Elsevier)**, Vol. 41, (2006), pp. 1994–2001. DOI:10.1016/j.procbio.2006.04.012.
11. Saad Abualhail, Rusul Naseer and Lu Xiwu, "Biological Nutrient Removal Using a Novel Five-Step Continuous Flow Activated Sludge Process Technology", **Environment Protection Engineering**, Vol. 39, (2013), pp. 1994–2001. DOI: 10.5277/epe130312.
12. A.H. mahavi, "Sequencing Batch Reactor a Promising Technology in Wastewater Treatment", **Iranian Journal of Environmental Health Science & Engineering**, Vol. 5, (2008), pp. 79–90. DOI: 30929960/https://www.sid.ir/paper/558356/en.
13. S.P.I.D. Sathkumara, C.S. Kalpage and Achala Pallegedera, "Developing of Lab Scale Smart Sequencing Batch Reactor", **Journal of Environmental Management**, Vol. 106, (2018), pp. 79–90. https://www.researchgate.net/publication/328127258_Smart_Sequencing_batch_reactor.
14. Wisam S. Al-Rekabi, He Qiang and Wei Wu Qiang, "Review on Sequencing Batch Reactors", **Pakistan Journal of Nutrition**, Vol. 6, (2007), pp. 1680–5194. https://faculty.uobasrah.edu.iq/uploads/publications/1612389243.pdf
15. P. G.Patil, Dr. G. S. Kulkarni, Ph.D., Smt. S. V.Kore, M. Tech. and Shri. V. S.Kore, "Aerobic Sequencing Batch Reactor for wastewater treatment: A review", **International Journal of Engineering Research & Technology**, Vol. 2, (2013), pp. 534–550. DOI : 10.17577/IJERTV2IS100087.
16. Reyad Ranjon Roy and Arpita Aditya, "A Review on Applicability and Design of Sequencing Batch Reactor", **Journal of Applied Sciences and Engineering Research**, Vol. 5, (2016), pp. 245–256.DOI: 10. 6080.ipajaser. 05025.
17. Fikret Kargi and Ahmet Uygur, "Nutrient Loading Rate Effects on Nutrient Removal in a Five-Step Sequencing Batch Reactor", **Environmental Modelling & Software (Elsevier)**, Vol. 39, (2003), pp. 507–512. DOI:10.1016/S0032-9592(03)00135-3.
18. A. Carucci, M. Majone, R. Ramadori and S. Rossetti, "Biological Phosphorus Removal with Different Organic Substrates in An Anaerobic/Aerobic Sequencing Batch Reactor", **Environmental Modelling & Software (Elsevier)**, Vol. 35, (2007), pp. 161–168. DOI:10.1016/s0273-1223(96)00892-x.
19. Jiashun Cao, Oloche James Oleyiblo, Zhaoxia Xue, Y. Martins Otache & Qian Feng Chinese Journal of Oceanology and Limnology, "Achieving Low Effluent NO3-N and TN Concentrations in Low Influent Chemical Oxygen Demand (COD) to Total Kjeldahl Nitrogen (TKN) Ratio Without Using External Carbon Source", **Chinese Journal of Oceanology and Limnology**, Vol. 33, (2015), pp. 11039–1052. DOI:10.1007/s00343-015-4201-z.
20. Adarsh Singha, Ashish Srivastava, Duduku Saidulua and Ashok Kumar Gupta, "Advancements of Sequencing Batch Reactor for Industrial Wastewater Treatment: Major Focus on Modifications, Critical Operational Parameters, and Future Perspectives", **Journal of Environmental Management**, Vol. 317, (2022). DOI:10.1016/j.jenvman.2022.115305.