A Comprehensive Review of Moving Bed Biofilm Reactor for Different Wastewater Treatment and Reuse

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ABSTRACT

This review includes some previous studies applied to MBBR in the treatment of sewage water in general, with a mention of the results reached by the researchers, All studies proved the efficiency of MBBR by removing the tested parameters, including COD, BOD, NH_4, NO_3, NO_2, TN, and TP, as well as for bacteria such as total bacteria, coliform bacteria, and fecal bacteria, whether it was used as a primary or additional treatment unit, so this technology is considered one of the most promising technologies. And the modern one that must be focused on studying.

Keywords: *MBBR, Sewage Treatment, Biological Treatment, Biofilm Reactor*

1. Introduction

Water is a necessary element for maintaining life on Earth as well as the source of human society's ongoing advancement and growth [1]. Hospital facilities, agricultural drainage, industrial wastewater, and sewage water are all included in the wastewater.

Large amounts of organic matter are typically present in sanitary wastewater, which causes the water's natural oxygen reserves to be depleted. The nutrients in the wastewater, such as nitrogen and phosphorus, may also promote excessive algal growth (eutrophication), which reduces the amount of oxygen in the air, causes odor issues, causes toxins to be excreted, etc. In addition to eutrophication, several problems can be caused by untreated or insufficiently treated wastewater, such as oxygen consumption, and toxicity especially when it discharges directly into the environment[2][3].

So we must avoid these negative impacts by conducting treatment for this water containing nitrogen substances like ammonium and nitrate, one of the most suitable solutions to decrease the content of nitrogen in sewage is biological treatment .this treatment combines the two stages of nitrification and denitrification [4]. There are many treatment methods (traditional or modern), and each method has its advantages and disadvantages which trickling filter TF, rotating biological contactors RBC, activated sludge process ASP, membrane bioreactor process MBR and moving bed biological reactor MBBR

In this review, we focused on the MBBR (Moving Bed Biofilm Reactor) in order to treat domestic, industrial, hospital, and dairy plants, etc.

2. Moving Bed Biofilm Reactor (MBBR)

Prof. Hallvard Ødegaard at the Norwegian University of Science and Technology first improved the MBBR (Moving Bed Biofilm Reactor), a kind of wastewater treatment method, between the latter half of the 1980s and the beginning of the 1990s, this MBBR was developed by the Norwegian company and then it was manufactured in several countries within the specifications that guarantee the purpose for which it was manufactured. It's a combination of suspended growth and an attached treatment method. On the other hand combination of the biofilm process and activated sludge process [5]. Usually, MBBR is composed of a tank with a chosen volume. Carriers manufactured according to specific specifications are placed inside the reactors, with good mixing and aeration. The usage of biomass carriers is spreading throughout the world for a variety of purposes, including the refit and improvement of municipal wastewater, industrial wastewater roughing filters, and small low-operational units [6]. The MBBR technique can be used in both aerobic and anoxic/anaerobic conditions. The different design forms are shown in Figure 1. The movement of the carriers occurs as a result of aeration in aerobic systems (Figure 1-a). For this reason, the aerators perform a dual duty, which means they are in charge of oxygenating microorganisms and preserving carriers' motion in the reaction medium. Therefore, more air input is required, which raises operating expenses overall and particularly energy-related ones.

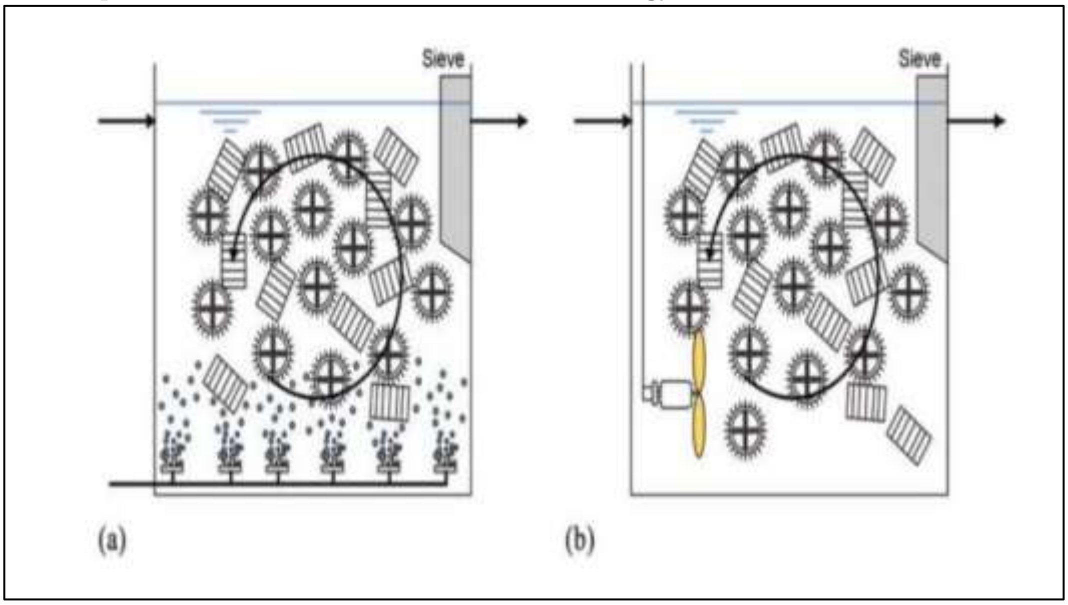

Figure 1: MBBR process types in operation. (a) A reactor that is aerobic, or (aerated). (b) Anaerobic-anoxic reactor.

Also, the requirement for devices offering adequate aerations and motions of moving supports led to an increase in expenses. There must be a mechanical mixing apparatus in the anaerobic/anoxic techniques (Figure 1-b). For aerobic systems, the increase of the MBBR process efficiency depends critically on the design of the appropriate aerators. a machine usually known as the screen, is positioned near the reactor's outflow to retain media inside this reactor cited by Gzar et, al [7]

3. Characteristics of biofilm carriers and filling ratio

It is made of polyethylene with selected specific gravity according to its type of it and the specific surface area below the table of some of these types.

Table 1-Characteristics of Carriers for MBBR Produced by Anoxkaldnes TM Company.

Parameter	AnoxKaldnes type K1	AnoxKaldnes type K3	Natrix type O	Natrix type F3
Shape				
Length (mm)	7	12	50	37
Diameter (mm)	10	25	60	46
Maximum fillinf degree	70%	70%	60%	60%
Effective specific surface (m^2/m^3 carriers)	500	500	300	200

The medium has a cylindrical shape with a defined length and diameter [8]. Complete mixing (whereby mechanical stirrers in anoxic vessels are ensured, while the aeration mechanisms in the aerobic types) of the media must be provided to the kept carrier moving continuously over the reactor's full volume. The biofilm death/regeneration mechanisms are made possible by the continual carrier movement, which also reduces clogging hazards [9]. Also, we must provide air agitation by a diffuser introduced at the bottom of the reactor. The airflow rate must be monitored [10]. As for the filling ratio, it varies from one researcher to another and is between (30-70)% of the empty volume of the reactor. Performance of plant, the plants were continuously fed with a constant flow rate depending on the specified hydraulic residence time (HRT).

4. Advantages of moving bed biofilm reactor (MBBR)

Mbbr presents several operational advantages:

1- We get good sludge-settling properties and a less concentration of solids is being discharged from the biological reactors thanks to this method [5].

2- No need for biomass recycling [10] and in order to keep the amount of sludge constant in the aeration chamber, no loss of sludge during the step of the reaction, and no sludge needs to be collected by the clarifier [11].

3- A smaller footprint than certain conventional systems, including activated sludge [9].

4- There is no demand that two distinct tanks be operated in succession [12]. In the same tank, aeration and settling take place [11].

5-In comparison to other systems, biofilm reactors because of a larger biomass content and better specific removal rates, the reactors' compactness, higher volumetric load, and increased process stability [11].

5- Many studies pointed out that wastewater treatment

Comett et all [11] operated a pilot plant such as a membrane moving bed reactor MBBR with a matrix medium and sequence batch reactor SBR in each condition. The reactor received the influent (generated from dewatering anaerobically treated biowastes) an alternative hydraulic retention time HRT of four days. Both technologies demonstrated effective carbon removal. In MBBR the removal efficiency for chemical oxygen demand COD was 53% and 55% for SBR, which means COD removal efficiency in the SBR system was higher when compared to MBBR .ammonium concentration removal of 99% was obtained in MBBR.

Ferrention et al, [4] compared SBR-MBBR and A/O–MBBR in accordance with COD, TN removal, and sludge generation. COD and TN Removal efficiencies were 88% and 75%, 92% and 72%, 90%, and 47% in the SBR-MBBR system with a filling ratio of 40% (from empty reactor volume) at HRT 24,18 and 12 h .when increase the ratio of filling to 60% with 12h for HRT, the COD and TN removal increased to 93% and 66%. the A/O –MBBR setup accomplished a COD and TN removal efficiency equal to 85% and 72% First, intermittent aeration conditions with a low concentration of dissolved oxygen (DO) during the nitrifying phase were used to operate the SBR-MBBR. Two filling ratios and three distinct volumetric organic loading rates (OLR) were used to test this configuration, then, two separate denitrification reactors were added before the MBBR concentrated. A/O -MBBR is used to denote this setup in the text below. Also, with the A/O-MBBR setup, the overall greater achievement was attained, Throughout the several experimental periods of the SBR-MBBR system, they noticed less sludge generation from suspended biomass predominant denitrification activity, and both systems showed the primary nitrification activity for connected biomass.

Luostarinen, et al [3] evaluated the viability of MBBR for use locally as DPWWe (10°C) post-treatment of anaerobically pre-treated dairy parlor effluent and a mixture of black water and kitchen waste BWKW e (20°C). This study was in MBBR to reduce the nitrogen and COD (chemical oxygen demand), the results were 50-60 % of nitrogen and 40-60 % of total COD. Also showed the effect of aeration, Intermittent aeration was used to remove nitrogen in a single reactor. Similar nitrogen and COD removal were supplied in continuous and sequencing batch operation complete nitrification was finished while Lack of carbon hindered denitrification. When the searcher's mixture of a two-staged UASB–septic tank and intermittent aeration moving bed biofilm reactor (MBBR) decreased over 90% of organic matter, 80% of total phosphor, and 65-70% of total nitrogen.

Trapani et al [9] used hybrid moving bed biofilm reactors with a different falling ratio of carriers in a pilot plant to show the hardly discernible performance difference behavior between these two systems 35% and 66 %, result lead to addressing the falling percentage of preference for the 35%.additional they carried out respirometric analyses to evaluate the effect of various types of biomass used in the removal of carbon and nitrogen in influent the maximum total COD was 632 mg/l with an effluent value equal to 60 mg/l at a filling ratio of 35% while at 66% the effluent was 72% which value beyond HMBBR. It is clear the removal efficiency for 35% is better than 66% and the reason may be was the greater concentration of suspended growth, more advanced enzymatic hydrolysis, and bio flocculation. While in pure MBBR they found when increasing the filling ratio the removal efficiency increase too. The reactors displayed extremely high efficiency both concerning ammonium and organic matter reactors the same total suspended solids TSS has to be carried out. Finally, both reactors showed the excellent result in nitrification ability, hybrid reactor with a 66% filling ratio has a slight advantage of up to 99%, which may be because there is a significant amount of connected biomass, It results in a greater concentration of slow-growing species, like nitrifying bacteria.

Shore et al [13] utilized MBBR as the last stage of ammonia treatment at high temperatures (35, 40, 45)°C. bench-scale reactors were able to effectively remove up to 19 mg/l NH_3-N of the influent ammonia in industrial and synthetic wastes. At 45°C there was no evidence of biotreatment but if the temperature dropped to 30 °C effective nitrifications were rapidly recovered. At 35 and 40°C, nitrification was accomplished, but 45°C nitrifications could not be sustained for more than 24h the filling ratio was 50% of empty reactor volume It was assumed that biofilm development on the carrier media would offer some protection for ammonia-oxidizing bacteria (AOB) and nitrite-oxidizing bacteria (NOB) activity at those temperatures of ammonia despite the adverse operating conditions.

Tawfik and Temmink [8] evaluated the composition system of MBBR and (UASB) up-flow anaerobic sludge blanket at a temperature of (22-35)°C at different hydraulic retention times (13.3,10, and 5) h. the laboratory-scale sewage treatment system was fed with domestic wastewater COD inf= 600 mg/l as the HRT increased, the efficiency removal values of the various COD percentages increased and became constant at an HRT of more than 6h, at HRT of 8h the reactor accomplished 66% for COD removal at HRT equal to 13.3 h the overall removal efficiency for total COD was 92 mg/l this was in run one, in run two where HRT was 10 h this result was 86 mg/l while in run 3 HRT=5h the value was 80 mg/l the research also dealt with a valuable account fecal coliform as well as the nitrification rate. At raising the HRT from 10 to 13.3 h an improvement was observed in the removal of FC, the nitrogen removal in the MBBR treating UASB reactor effluent was 26% at an OLR of 4.6 g COD m^{-2} day^{-1} while in OLR of 7.4 and 17.8 g COD m^{-2} day^{-1} the percentage was 16%.

Zinatzadeh and Ghaytooli [10] examined removing nitrogen and organic carbon from municipal wastewater, they selected two numerical independent variables to assess the process performance, HRT and DO a categorical change, and one kind of stacking media. HRT was taken at 4,8 and 12 h and 2,3 and 4 mg/l for DO, to investigate it as a numerical variable the form of a ring and Kaldenes-3 was examined as a categorical variable, they used two parallel reactors maximum removal of COD was found to be (85-88)% at HRT equal to 12h and DO of 4 mg/l with Kaldenes-3 and ring form they indicated that the system with the ring form might increase the effectiveness of total nitrogen TN removal, the optimum denitrification ratio for ring form and Kaldnes-3 were gained 90 and 70 mg N /L. d. at DO =3 mg/l and HRT =8h.at packing rate of 50% (v/v) the removal efficiency of COD was< 85% the result illustrated more durable biofilm in a system process with K_3 could be developed because of its structural characteristic, in the system with ring form TN removal efficiency accomplish more than in another system, demonstrating that ring shape favors anoxic conditions.

Majmudar et al [5] introduced this paper including a comparison between aerobic, and anaerobic treatment, attached and suspended growth moving beds, and fixed bed reactors. They examine several parameters like COD, BOD, TDS, PH, and NH_3-N^+ of the activated sludge process ASP stream. Values of flow rate to get an optimized value between them. Even with a fill rate range of (30-40) %, the result was good. They have achieved a COD reduction of about 52% with MBBR, while in ASP the rate was 6%, hence they concluded that even at optimized retention time one cannot be achieved that efficiency with MBBR in comparison to APS for this specific plant, fall rates were 30,40,50 and 60 % when the rate increase to 60% they got a maximum reduction of 61.3% at HRT=4.6 day but when viability and feasibility come to the best properties will be 50% media fill rate range and HRT of 3.3 days at a flow rate of 1.6 (l/hr).

6. Conclusion

Currently, wastewater is treated with a combination of physical, chemical, and biological processes. MBBR is one of the most commonly used. In order to increase the number of organisms that can be used to treat sewage, the MBBR system makes use of floating plastic carriers (media) inside the aeration tank. In this paper from above, It is obvious that the use of MBBR of various types has increased in recent years to treat various polluted water, whether domestic, industrial, or hospital water, etc. It has proven its efficiency in removing various parameters such as COD, BOD TN, TP NO_2, NO_3, etc. Also, this promising technology has several advantages including it utilizes suspended biomass, similar to identical to traditional activated sludge (CAS).and attached biomass, as a biofilter, sludge production will be less, and the space required is not large, strong enough to resist toxic shock, additional life of it is long about (10-15) years and many other features.

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