Performance Evaluation of Moving Bed Biofilm Reactor and It's Modification

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Abstract— In recent years, an increasing interest in biofilm processes for the treatment of municipal and industrial wastewaters has been observed. One of the growing biofilm technologies is the Moving-bed Biofilm Reactor (MBBR), which has been successfully established in the market. A great number of large-scale wastewater treatment plants along with many other smaller treatment installations around the world make use of the MBBR concept. The development of the MBBR process was based on the central idea of obtaining, in a single system, the best characteristics of the activated sludge and biofilm processes. With the biomass immobilized on a free-support media, solids retention in the biological reactor is enhanced. This chapter covers the principle of the MBBR operation, the biofilm carriers employed in such systems, the key operational aspects and a broad range of applications of this technology.

Key words: Moving-bed Biofilm Reactor (MBBR)

I. Introduction

Wastewater is nothing but used water. Domestic wastewater is the water used from houses and apartments. Wastewater from baths, sinks, washing machines, and other kitchen appliances is called as grey water and wastewater from toilets is called as black water. Industrial wastewater is used water from manufacturing or chemical processes.

Only 3 % of all the water on earth is fresh water and more than 97 % is saltwater. Out of this 3 % of fresh water, more than two-thirds (68.9 %) is frozen as snow and ice, and more than one-third is stored below ground as ground water. This means that only 0.3 % of all fresh water on the planet is readily available as surface water in lake, rivers and streams (Cassardo and Jones, 2011). Because of this reason instead of disposing wastewater directly and polluting the environment, we can treat it and reuse for various purposes such as irrigation, washing, gardening, road cleaning etc.

A wastewater treatment system is the combination of unit operation and unit processes designed to reduce certain constituents of wastewater to an acceptable level. Wastewater treatment systems are often divided into primary, secondary and tertiary subsystems. The purpose of primary treatment is to remove organic and inorganic suspended solids from the incoming wastewater. Secondary system usually consists of biological conversion of dissolved and colloidal organics into biomass and simple end products. In most cases, secondary treatment of municipal

wastewater is sufficient to meet effluent discharge standards. In some instance, additional treatment may be required. Tertiary treatment most often involved further removal of dissolved solids, colour and odour.

If wastewater treatment plant constructed for whole city, village or definite part of city is called as centralized wastewater treatment plant. Generally, activated sludge process, sequential batch reactor, aerate lagoon, oxidation pond etc. technologies are used as centralized wastewater systems. Today, obtaining large piece of open land is strenuous for the treatment of municipal wastewater. Therefore, wastewater treatment plant requiring comparatively smaller footprint such as for individual household, clusters of homes, isolated co adopted, termed as decentralized wastewater treatment. Different decentralized wastewater treatment systems are available such as septic tank, constructed wetland, trickling filter, upflow anaerobic sludge blanket, RBC, anaerobic bio-filter etc. (Guidelines, 2012). Moving bed biofilm reactor is a recent treatment system for decentralized wastewater management.

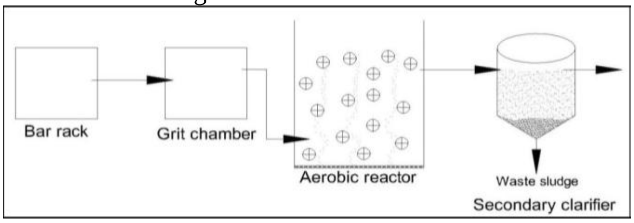
Moving bed biofilm reactor is one of the best secondary wastewater treatment system. In this system growth of microorganism is in suspension and adhered biomass (biofilm). Therefore, it is possible to maintain a higher amount of biomass in the same biological reactor and thus allowing larger amount of substrate for biodegradation. In reactor, for biomass to adhere 50–70 % media is introduced, in which 67 % is optimal (Odegaard, 1999). In MBBR biofilm gets developed on the media. The biofilm adds weight of the particle, the weight of media increases with biofilm thickness. So, increasing mixing or aeration is required to keep the media in suspension

II. Moving Bed Biofilm Reactor

Two technologies are commonly used for biological treatment of sewage which are activated sludge and trickling filters, a MBBR is a compilation of these two technologies. The biomass in the MBBR exists in two forms suspended flocks and a biofilm attached to media. The MBBR was developed in Norway at the Norwegian University of Science and Technology in co-operation with a Norwegian company Kaldnes Miljǿteknologi (now AnoxKaldnes AS). The first MBBR was installed in 1989 (Borkar et al., 2013).

MBBR has become popular in the field of wastewater treatment because it maximizes the capacity and efficiency of the treatment plant by minimizing the footprints. It has the capacity to retrofit the old treatment plants, higher nutrient removal ability, produce less sludge as a result of high biomass retention time, easy maintenance, economical and so on. The key element of the MBBR is the use of small plastic biofilm support media to allow a high concentration of protected biofilm growth in a well-mixed reactor. The reactors can be operated under aerobic conditions for carbonaceous and nitrogenous organic matter removal and under anoxic conditions for denitrification (Ahmadi et al., 2011). In an aerobic reactor, circulation of media is facilitated through the action of air bubbles injected into the tank by a diffused aeration system. In an anoxic reactor, a submerged mechanical mixer is typically supplied.

Before treating wastewater in MBBR, it passes through bar rack. Bar racks have the openings ranging from 40 to 150 mm and are used to remove the big floating objects from entering the plant. This water passes through grit chamber where the grit (dense material such as sand, dirt, or broken glass) is removed. After preliminary treatment this water is fed to aerobic reactor for removing organic matter for the designed retention time. After biological treatment, effluent is passes through the secondary clarifier where biomass is separated as sludge from the treated wastewater. The sludge is removed from the bottom of the clarifier and supernatant is separated from upper side of clarifier. Figure 2.1 shows flow diagram of wastewater treatment in MBBR.



Flow sheet for MBBR treatment

Components of MBBR are explained as follow

A. Aeration

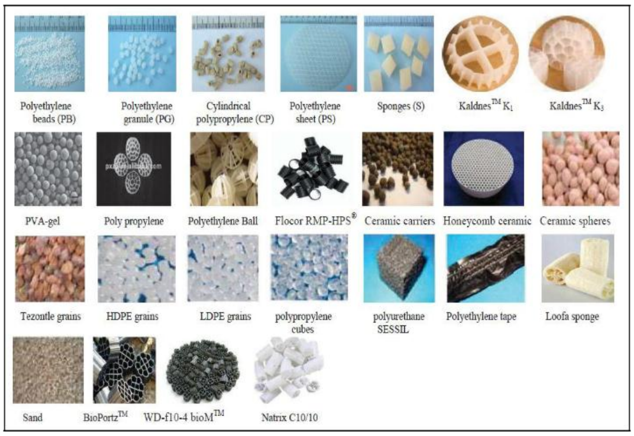
Aeration is important part of MBBR for providing oxygen to microorganisms and keeping media in suspension by distributing it homogenously. So, a network of lateral and longitudinal pipes connected to aerators with 1–2 mm orifices is used at the bottom of reactor. Air moves upwards from orifices in the form of bubbles. Size of bubble depends on the diameter of orifice provided.

B. Media

Media is the important component of MBBR system. Media provides surface area to the microorganisms for growth as biofilm. These media move freely into the wastewater and increase contact between substrate available in wastewater and microorganisms present on the media. Generally this media is made by polyethylene and specific gravity of media is between the ranges of 0.90-0.98 g/cm^3. There are different types of media which can be used as a space for the microbial growth. Characteristics of media are given in Table and physical appearance of these media

C. Characteristics of the media

Material	Polyethylene
Density of Media (g/m^3)	0.97
Length (mm)	9
Diameter (mm)	25
No. of media/ m^3	1,72,000
Specific surface area (m^2/m^3)	610

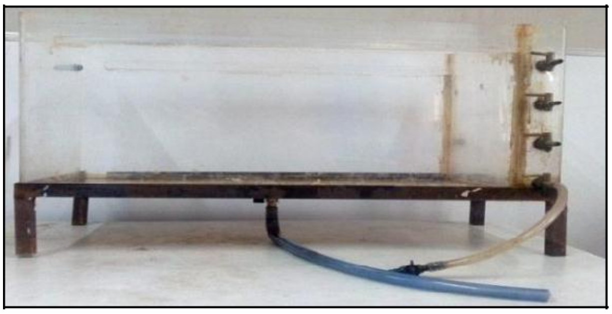


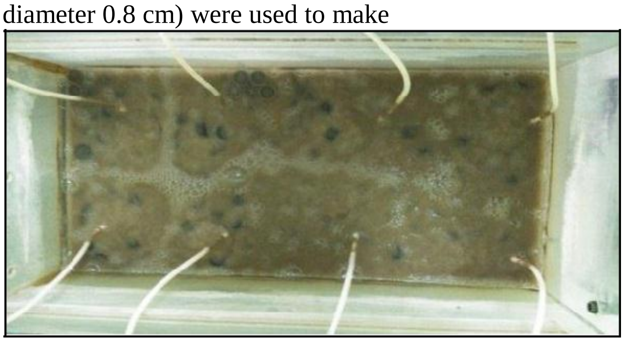
The physical appearance of the media used in attached growth processes

III. EXPERIMENTAL SETUP

Figure shows the photographic view of the reactor used for experiment. Reactor was fabricated by our group. Laboratory scale setup was used having volumetric capacity 20 L. 4 diffused aerators were kept at bottom side of the reactor for providing required aeration. All diffused aerators were kept at equal distance. Figure shows the photographic view of location of aerators in the reactor. Specifications of the reactor have been given in the table. Valve is provided at the bottom side of reactor for removing excess sludge. At both side of reactor rails were provided where baffle frame were put.

Partitions in the reactor. Objective of providing holes to baffles were allowing flow of water from one compartment to other compartment with restricting movement of media from one compartment to other. Figure shows the photographic view of baffle.Baffles (with holes having diameter 0.8 cm) were used to make





Locations of diffused aerators

Material	Glass
Total depth (cm)	35
Effective depth (cm)	25
Width (cm)	30
length (cm)	60

Total volume (liter)	20
Diffused aerators (Nos.)	4
Capacity of each diffused aerator (L/min)	1

IV. METHODOLOGY

A. Development of an activated sludge for MBBR

Active biomass is very important for developing biofilm on media. Cow dung is rich with microorganisms therefore it was used for sludge development. Jaggery is the best source of nutrients so slurry of jaggery was used for providing nutrients to the microorganisms. Following steps were adopted to develop an activated sludge.

1) Initially, around 5 % of reactor was filled with cow dung slurry.
2) Then, about 2 % jaggery slurry was added in the reactor.
3) Remaining volume of the reactor was filled with the fresh domestic wastewater and sufficient aeration was provided.
4) Aeration was switched off after decided time interval and sludge was allowed to settle completely. Then around 50 % of wastewater (supernatant of settled wastewater) was replaced with the fresh domestic wastewater. Wastewater was replaced thrice a day.
5) Phosphate buffer, magnesium sulfate, calcium chloride and ferric chloride were added as nutrients each time after replacement of wastewater.
6) After development of sufficient quantity of active sludge, it was filled in the MBBR to get desired MLSS.

B. Development of biomass on the media

Biofilm development is first step in the MBBR. At the time of biofilm development sludge gets penetrate in the media. This accumulated sludge adheres to the surface of media. Then this adhered biomass starts to grow on the media. This adhered biomass is called as biofilm. Following steps were adopted to development of biofilm on the media.

1) Initially, 25 % volume of reactor was filled by the active sludge.
2) Then, around 40 % of reactor was filled by media.
3) Remaining volume of the reactor was added with the fresh domestic wastewater.
4) Aeration was switched off after decided interval and sludge was allowed to settle completely. Then around 50 % of wastewater (supernatant of settled wastewater) was replaced with the fresh domestic wastewater. Wastewater was replaced thrice a day.
5) This process was continued for first 15 days. After that loading was increased and around 70 % of wastewater was replaced with the fresh domestic wastewater.
6) Biofilm was visually observed on the media after around 45 days. Then biofilm development procedure was stopped. For biofilm development around 30 to 45 days are required. Figure 3.5 shows photographic view of adhered biomass.

Media with adhered biomass

Quantifying the adhered biomass is very essential. To quantify adhered biomass around 4–5 media were collected from reactor and immersed in 100 ml of distilled water in a beaker which was shaken vigorously till the biomass got detached from media. Media were removed and suspended solids remaining in the beaker were measured. Then adhered biomass was expressed in the form of mg biomass/media (Oliveira et al.,2014).

V. MODIFICATIONS MADE IN MBBR

In this experiment MBBR was initially operated conventionally. Then, modifications were made in the MBBR to keep media in suspension. Arrangement of conventional and modified MBBR is discussed below.

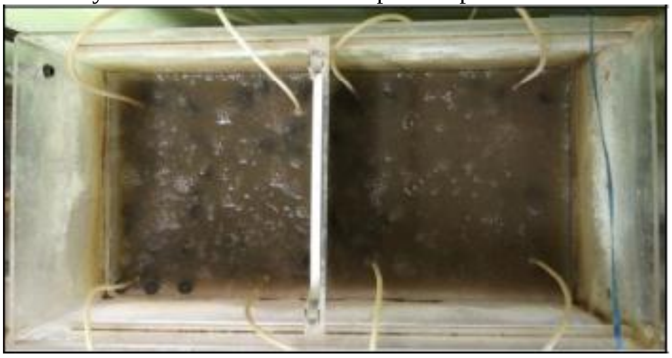
1) Conventional:

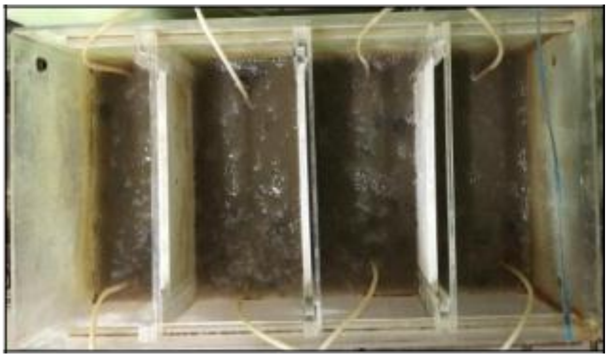
Wastewater was treated in the MBBR for decided OLR with 40 % media. 8 diffused aerators were used in the reactor for providing oxygen and keeping media in suspension. Aeration rate of each diffuser was 2 L/min. Conventional MBBR is denoted by C.

2) Modification 1- Dividing the total volume of the reactor

This was achieved by introducing the equidistant intermediate baffles. Due to less available circulation space to media, contact between air and media might get increased. This also facilitates effective substrate diffusion because of the increased contact between adhered biomass and the substrate. 40 % media was added in the reactor for adhered growth.

i. Reactor was divided in 2 equal compartments by adding a baffle intermediately. 4 diffusers were provided in each compartment. Aeration rate of each diffuser was 2 L/min. Figure shows the photographic view of this modification. This configuration of MBBR is denoted by M1.





VI. Scope of Work

1) A clarifier with sludge scraping mechanism will be provided for settling of fully aerated sewage from the aeration tank. The clarifier will be provided with adequate volume and surface area to ensure proper settling of sludge from the MBBR tank.
2) As the suspended growth system is common now a days but it has certain limitations & disadvantages, so attached growth system is the better option for the treatment of waste water. Attached growth system is found more beneficial over suspended growth system.

VII. Conclusion

The study was conducted to enhance movement of media using different configurations of MBBR. Performance evaluation of all configurations of MBBR is carried out by varying parameters such as OLR, HRT and F/M. based on the studies carried out following are conclusions drawn.

Reactor with most effective distribution of aeration gives better organic matter removal efficiency than reactor divided in small compartments for any OLR.

Reactor with 40 % media has increased adhered biomass by around 13 % which given around 12 % extra COD removal efficiency than reactor without media.

The quality of effluent from MBBR system is within the permissible limits for discharging effluent in the water resource as well as for land disposal (CPCB, 2015).

References and Bibliography

[1] Ahmadi, M., Izanloo, H., Alian, A. M., Amiri, H., and Sepehr, M. N., (2011), "Upgrading of Kish Island Markazi wastewater treatment plant by MBBR." Journal of Water Reuse and Desalination, 1(4), 243–249.
[2] American Public Health Association, (2005): "Standard Methods for the Examination of Water and Wastewater." 21st Edition.
[3] Borkar, R. P, Gulhane, M. L., and Kotangale, A. J., (2013), "Moving bed biofilm reactor – A new perspective in wastewater treatment." Journal of Environmental Science, Toxicology and Food Technology, 6(6), 15–21.
[4] Cassardo, C., and Jones, J. A., (2011), "Managing water in a changing world." Water 2011, 3, 618–628.
[5] CPCB notification file number - 19014/43/06-MON, (2015), Central Pollution Control Board, Ministry of Environment and Forests, India
[6] Guidelines for decentralized wastewater management, (2012), Ministry of Urban Development, India.
[7] Gulhane, M. L., and Kotangale, A. J, (2013), "Moving bed biofilm reactor – New innovation in the field of conventional biological wastewater treatment." International Journal of Scientific Research, 2(12), 167–170.