

## Moving Bed Biofilm Reactor – New Innovation in the Field of Conventional Biological Wastewater Treatment



### Engineering

**KEYWORDS :** Waste water, Moving Bed, Biofilm, Bioreactor, Biofilm carriers, nutrient removal

**Gulhane M. L**

Associate Professor, Department of Civil Engineering, Government College of Engineering, Amravati, Maharashtra, India

**Kotangale A. J**

PG Student, Department of Civil Engineering, Government College of Engineering, Amravati, Maharashtra, India

### ABSTRACT

*A new advanced biological reactor called Moving Bed Biofilm Reactor (MBBR) for wastewater treatment is discussed. General description of expected setup of reactor is given. The Moving Bed Biofilm Reactor (MBBR) technology is an attached growth biological treatment process based on a continuously operating, non-clogging biofilm reactor with low head loss, a high specific Biofilm surface area, and no requirement for backwashing. MBBR is often designed as aerobic system. Moving Bed technology presents several operational advantages, compared to other conventional biological treatments. Different applications of this technology for small plants are studied, considering main investment and operating costs. Processes will take account of Moving Bed Biological Reactors (MBBR) with some sort of modifications. Conditions studied include COD removal, or COD and nutrients removal, with different primary treatments. Smaller biological reactor volumes and smaller secondary settling surface are needed. The results can indicate that MBBR with polyethylene media as Biofilm carrier may possess great potential to be used for OMs removal from water and wastewater. This study can be helpful to check possibility that the moving bed Biofilm process may be used as an ideal and efficient option for the total nutrient removal from municipal wastewater.*

### Introduction

Due to the rapid urbanization, wastewater has been continuously and excessively released into the environment, causing significant impacts on human and wild life. Many organic compounds in municipal wastewater are detected in different types of wastewater, affecting water quality, human health and biodiversity in the ecosystems. These compounds have significant impacts on receiving water bodies so as finding an appropriate treatment technology to effectively remove organic matters (OMs) in wastewater is very essential.

Limited water resources and increasing urbanization require a more advanced technology to preserve water quality. One of the important factors affecting water quality is the enrichment of nutrients in water bodies. Wastewater with high levels of organic matter (COD) Phosphorus (P) and Nitrogen (N) cause several problems, such as eutrophication, oxygen consumption and toxicity, when discharged to the environment. It is, therefore, necessary to remove these substances from wastewaters for reducing their harm to environments. Biological processes are a cost-effective and environmentally sound alternative to the chemical treatment of wastewater.

Biological treatment processes are systems that use microorganisms to degrade organic contaminants from wastewater. In wastewater treatment, natural biodegradation processes have been contained and accelerated in systems to remove organic material and nutrients. Excess microbial growth is removed from the treated wastewater by physical processes. In biological processes, a mixture of wastewater and microorganisms (biomass) is agitated and aerated. Certain microbes, mainly bacteria of specific kind, have the capability to oxidize the dissolved organic matter in the waste water. Microbial growth is accelerated and controlled in the process. Thus, reduction or removal of organic matter in waste is brought about by microorganisms by oxidation. After oxidation, the sludge is separated from wastewater. The microorganisms metabolize nutrients, colloids, and dissolved organic matter, resulting in treated wastewater. These, microbial induced processes are further classified as Aerobic and Anaerobic.

There are already many different Biofilm systems in use, such as trickling filters, Rotating Biological Contactors (RBCs), fixed media submerged bio-filters, granular media bio-filters, fluidized bed reactors, etc. They all have advantages and disadvantages. Two technologies are commonly used for biological treatment of sewage: activated sludge and trickling filters. A moving bed biological reactor (MBBR) is a compilation of these two technologies. The biomass in the MBBR exists in two forms: suspended

flocks and a biofilm attached to carriers. It can be operated at high organic loads and it is less sensitive to hydraulic overloading.

The Moving Bed Biofilm Reactor (MBBR) technology is a leading-edge biological solution for wastewater treatment based on the aerobic biofilm principle which you all of the advantages of activated sludge systems (SBR) and none of the problems. At the core of the technology are specially designed polyethylene carriers that provide a large protected surface area for the microorganisms (that eat the waste) to grow and multiply. This allows a higher concentration of active biomass to be maintained in the reactor for biological treatment without increasing the reactor size. The result is more treatment capacity in a smaller area which saves you valuable space, money and allows you to install in tighter spaces. Besides offering an overall footprint reduction compared to an equivalent SBR system, the MBBR process also offers a buffer against shock loads. In an SBR system the microorganisms are floating freely within the reactor and have no protection against shock loadings or spikes in pH. With MBBR technology, the biofilm that is created around each carrier element protects the bacteria cultures. This makes it much more stable under load variations and less sensitive to temperature or pH variations than conventional systems. To comply with the Clean Water Act, the discharge levels must not exceed the allowable limits. The bio carriers are made of light weight polyethylene with a density just less than water. The fill fraction of carriers in the reactor is about 70%.

Researchers have proven that MBBR possesses have many excellent traits such as high biomass, high COD loading, strong tolerance to loading impact, relatively smaller reactor and no sludge bulking problem. There are presently more than 400 large-scale wastewater treatment plants based on this process in operation in 22 different countries all over the world. During the past decade it has been successfully used for the treatment of many industrial effluents including pulp and paper industry waste, poultry processing wastewater, cheese factory wastes, refinery and slaughter house waste, phenolic wastewater, dairy wastewater and municipal wastewater.

Recently, Moving Bed Biofilm Reactor (MBBR) has brought increasing research interest in practice for removal of biodegradable organic matter and its application has undergone various degrees of modification and development. Moreover, as the carrier using in the MBBR is playing a crucial role in system performance, choosing the most efficient carrier could enhance the MBBR performance. Hence, scientists have been looking for an appropriate carrier which is not costly and has a suitable sur-

face for microbial growth.

### Advantage of Moving Bed Biofilm Processes

The MBBR combines the advantage of fixed film and suspended growth processes, this advantage include

- Compact units with small size.
- Increased treatment capacity.
- Complete solids removal.
- Improved settling characteristics.
- Operation at higher suspended biomass
- Enhanced process stability.
- Low head loss.

### Review Of The Related Literature

The Moving Bed Bio film Reactor (MBBR) represents a different spectrum in advanced wastewater treatment. Odegaard, (2006) operated MBBRs similarly to the activated sludge process with the addition of freely moving carrier media.

In the late 1900s, Moving Bed Bio film Reactor (MBBR) was introduced for biological treatment of different types of wastewater. Odegaard et al. (1994) stated that the Moving Bed Bio film Reactor (MBBR) process was developed in Norway during the late 1980 and early 1990. He concluded that the Moving Bed Bio film Reactor (MBBR) represented a different spectrum in advanced wastewater treatment. MBBRs were operated similarly to the activated sludge process with the addition of freely moving carrier media.

According to **Odegaard et al. (2000)**, the fundamental characteristic of the MBBR was the specially designed Biofilm carriers, for which the geometry, sizing and materials of construction had been considered carefully to maximize performance. This was a key difference from the activated sludge process where treatment performance was more directly tied to reactor volume. In the MBBR, surface area could be increased by designing carriers with a higher specific surface area or by adding a greater quantity of carriers to a reactor volume. This offered flexibility for future treatment capacity upgrades without requiring the construction of additional reactors.

Bengoa Gorka Zalakain showed several advantages of Moving Bed Biofilm reactor from the operational point of view for small community compared to other conventional biological treatments. Processes studied had taken into account of Moving Bed Biological Reactors (MBBRTM) and hybrid processes (HybasTM).

Ødegaard and Rusten (1995) gathered data from various small full-scale wastewater treatment plants and the Moving Bed Biofilm Reactor systems started to develop. However, later, organic matter removal MBBR treatment systems were developed. Currently, MBBR systems are used as stand-alone treatment solutions and in tandem with other treatment processes including AS and membrane bioreactors for high strength organic wastewaters MBBR processes.

Brinkley John investigated processes that would treat variable high strength wastewater in a small footprint and provided provisions for future expansion. He selected the MBBR process due to the success the process had for treating high strength wastewater for comparable pharmaceutical applications. The 0.5 million gallon per day (mgd) MBBR process consisted of two reactors operated in series designed to treat an influent and effluent Biochemical Oxygen Demand (BOD5) of 3,197 mg/L and less than 75 mg/L, respectively.

Åhl et al., (2006) explained that the aeration system also supplied sufficient oxygen so that at least the outer layers of the bio films were aerobic and thus were capable of proving relatively rapid biodegradation. The bio films grew and partially eventually detached from the carrier and the detached segments were carried by the liquid into the secondary clarifier for separation. The biologically-produced solid production by this system was 10 times less than that of the AS systems.

Kermani M., et al (2008) conducted the study to evaluate the organics, phosphorus and nutrients removal from synthetic wastewater by a laboratory scale moving bed biofilm process. For nutrients removal, moving bed biofilm process had been applied in series with anaerobic, anoxic and aerobic units in four separate reactors. Moving bed biofilm reactors were operated continuously at different loading rates of nitrogen and Phosphorus.

Sombatsompop et al., (2011) aimed to comparatively study the efficiency of piggery wastewater treatment by the moving-bed sequencing batch reactor (moving-bed SBR) system with held medium, and the conventional sequencing batch reactor (SBR) system, by varying the organic load from 0.59 to 2.36 kg COD/m<sup>3</sup>.d. The COD treatment efficiency of the SBR and moving-bed SBR was higher than 60% at an organic load of 0.59 kg COD/m<sup>3</sup>.d and higher than 80% at the organic loads of 1.18-2.36 kg COD/m<sup>3</sup>.d. When the organic load was increased, the moving-bed SBR system yielded better treatment efficiency than that of the SBR system.

**Yang Qiqi, et al, (2012)** proved Moving Bed Biofilm Reactor (MBBR) technology as an alternative and successful method to treat different kinds of effluents under different conditions. Because there was a need to investigate how the bio solids dynamics were influenced by process changes relevant to applied wastewater treatment systems and suggested new routes to reactor design and optimization, the biofilm growth, detachment and modeling of MBBR were continue to draw significant research attention.

Mahmoudkhani Rouhallah et al, (2012) made the study which aimed at treatment of waters around Tehran Refinery contaminated with petroleum compounds. During study period a laboratory scale with a total liquid volume of 550 L was used. The reactor was filled with 85% Polyurethane elements, occupying 3% of the reactor's liquid volume. Pilot conditions were as follows, Temperature= 15 to 25 ° C, pH= 6.7 to 7.5, dissolved oxygen = 4 to 5 mg/lit, MLSS= 1400 to 1700 mg/L Hydraulic Retention Time (HRT) = 240 minutes and unlimited Solid Retention Time (SRT), after suspended oil removal by oil separation system, COD, NO<sub>3</sub>-N and PO<sub>4</sub>-P removal efficiencies for the MBBR, filtration and activated carbon was 99, 94 and 58%, respectively. The results of the average effluent from each reactor showed that denitrification process in the preceding the aerobic MBBR, filtration and activated carbon occurred and in pre-denitrification system in filtration, consumed most of the biodegradable organic matter. In case of formaldehyde, phenol and total petroleum hydrocarbon (TPH) parameters, they were removed in the pilot up to 96, 79 and 94%, respectively.

**Javid, A.H., et al, (2013)** investigated feasibility of upgrading and retrofitting municipal wastewater treatment plants at laboratory scale using Moving Bed Biofilm Reactor (MBBR) process. For this purpose, an aerobic pilot was operated for nearly one year in different conditions, in which a moving bed carrier with a specific biofilm surface area of 500 m<sup>2</sup> / m<sup>3</sup> and a filling rate of 60% was utilized. System efficiency in removal of BOD5 and COD was examined at different hydraulic retention times (HRTs) of 1, 1.5, 2, 2.5, 3 and 4 h. The obtained results indicated high ability of the system to tolerate organic loading and to remain stable at a high food to microorganism (F/M) ratio. The system produced effluents with good quality at low HRTs and led to an average BOD5 removal efficiency of nearly 88% during the operational period. The Organic Loading Rate (OLR) applied to the system had a range of 0.73-3.48 kgBOD5/m<sup>3</sup>.day and 2.43-11.6 gBOD5/m<sup>2</sup>.day, at which the reactor showed a good performance and stability.

After thorough evaluation of the related literature, it can be revealed that most of the work on Moving Bed biofilm reactors was carried out by using specially made Biomedica carriers. Certain experiments are done on Moving Bed Biofilm Reactors by taking nanofibres, diatomous earth, Biochips, porous material as media. It has also shown some positive results. But very rare work has been done by taking the stone bed in aeration tank.

Literatures regarding the use of Stone bed as a media during the treatment processes are available in very less amount. Also very less information is available about the study carried out to access the performance of reactors fitted with different categories of aerators in combination, effect of change of flow regime on process performance, effect of air/ oxygen introduction in the system though different aerators. Hence the study is required to be undertaken to analyze the overall performance of Moving Bed Biofilm Reactors under such variable conditions by taking different combinations, trials and errors.

**Materials And Methods**

**Experimental set-up:**

The Moving Bed Biofilm Reactor (MBBR) technology is an attached growth biological treatment process based on a continuously operating, non-clogging biofilm reactor with low head loss, a high specific Biofilm surface area, and no requirement for backwashing. MBBR is often designed as aerobic system. Samples are collected from low income and high income society and its parameters are evaluated prior to treatment. The Moving Bed Bioreactor (MBBR) setup proposed for this study is made up of glass containing three to 5 compartments. The inlet arrangement for influent pre-treated raw domestic waste water is given at the top of tank. The Outlet is provided at same level to that of inlet. The media is continuously agitated by bubbles from the aeration system that adds oxygen at the bottom of the first compartment of the aeration tank. The middle compartment contains channel of stones. The bottom portion of channel contains large sized stones and upper channel is of small sized stones. The wastewater is filtered through stone bed to some extent. After filtering, it will enter to last compartment through the openings provided in the setup. In last portion of tank where the bio carriers are filled, turbulence is provided to waste water with the help of rotors. After treatment, final treated effluent is taken outside through outlet. The proposed experimental set-up for Moving Bed Biofilm Reactor can be made as shown in Fig.1



**Fig 1- Moving Bed Biofilm Reactor experimental setup**

An MBBR may be a single reactor or several reactors in a series. Typically, each MBBR has a length-to-width ratio (L: W) in the range of 0.5:1 to 1.5:1. Plans with an L: W greater than 1.5:1 can result in non-uniform distribution of free-moving plastic biofilm carriers. The MBBRs contain a plastic biofilm carrier volume ranging from 25 to 67% of the liquid volume. This parameter is referred to as the carrier fill. Sieves typically are installed with one MBBR wall and allow treated effluent to flow through to the next treatment step while retaining the free moving plastic biofilm carriers. Carbon-oxidation, nitrification, or combined carbon-oxidation and nitrification MBBRs use a diffused aeration system to uniformly distribute plastic biofilm carriers and meet process oxygen requirements. Plastic biofilm carriers in denitrification MBBRs are homogenized by mechanical mixers. Each component is submerged. Plastic biofilm carriers must be removed before draining and servicing or repairing air diffusers. The bio-carriers are shown in fig 2.



**Fig 2 Types of bio-carriers**

**Table 1: Characteristics of the bio- carriers**

Material	Polypropylene, plastic, ceramic, porous
Shape	Corrugated cylinder, chips, hollow, curved
Density	0.90 to 0.95 g cm <sup>-3</sup>
Dimensions	10×15 mm
Specific surface	260 – 500 m <sup>2</sup> m <sup>-3</sup>

**Operating Principle**

The MBBR is a complete mix, continuous flow through process which is based on the Biofilm principle that combines the benefits of both the activated sludge process and conventional fixed film systems without their disadvantages. The basic principal of the moving bed process is the growth of the biomass on plastic supports that move in the biological reactor via agitation generated by aeration systems (aerobic reactors) or by mechanical systems (in anoxic or anaerobic reactors).

The moving bed processes come from the current trend in wastewater treatment, from the use of systems that offer an increased specific surface in the reactor for the growth of the biomass, achieving significant reductions in the biological reactor volume. Reactor can be operated at very high load and the process is insensitive to load variations and other disturbances.

**Expected Result**

Today the need for clean water is rapidly increasing. So MBBR is technology becoming increasingly popular and widely used in the world to treating different kinds of effluents under different conditions because the idea of the MBBR is to combine the two different processes (attached and suspended biomass). This study may be helpful to check possibility that the moving bed biofilm process can used as an ideal and efficient option for the total nutrient removal from municipal wastewater. The mode of change of aeration provided during the experimental work may affect the efficiency of waste water treatment to good extent.

The Moving Bed technology may help to check the feasibility of waste water treatment by using both attached growth system

and suspended growth system. This technology may be conducted to get low concentration of solids leaving the biological reactors, the absence of filamentous bulking and good settling characteristics of the sludge. The change in the type of media carriers during the experimental work may help to get the expected results in a very beneficial manner.

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