



Review on Removal of Drugs from Hospital and Industrial Wastewater using Moving Bed Biofilm Reactor method.

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ABSTRACT

In the todays Census, the major problem regarding the health issues are arising due to the various types of the pollutants in the environment including rivers in which the effluents of the industries and the hospitals are released. Thus to remove such effluents from the hospital and the industrial waste water before releasing it into the water bodies one of the effective method called MBBR is developed .In MBBR, the removal procedure includes the immobilization of the pollutants with the help of the various chips including biochips which immobilizes and degrades the effluents and after the removal of the effluents the water is safe to release in the water bodies. To overcome the ever increasing demand of the water treatment “Moving Bed Biofilm Reactor” is an effective technique. The process was first invented by Professor Hallvard Odegaard at Norwegian University of Science and Technology in the late 1980's. The process takes place in an aeration tank with plastic carriers that a biofilm can grow on. The main objective of using MBBR is being water reuse and nutrient removal or recovery. Aim of the present review is to remove drugs from hospitals and industrial waste water using this method.

KEYWORDS

Pollutants; MBBR; Immobilization; Biochips; Biofilm; Waste water

1. Introduction

A rising worry in the realm of water pollution and the loss of healthy living for marine ecosystems is the presence of numerous dangerous medications in hospital and industrial waste water. Because of the increasing release of drug-containing wastewater into reservoirs as a result of inappropriate handling of such polluted effluents, not only is marine life impacted, but human health is as well. Therefore, it is essential to provide an efficient treatment for the treatment of such undertreated effluents or the release from hospitals or companies. Thus, biofilm techniques in wastewater treatment have earned praise for their efficacy throughout the years in treating wastewater from hospitals and industries ^[1]. Focusing on the Moving Bed Biofilm Process for waste water treatment used in various aspects is the goal of the current effort. The acronym MBBR stands for moving bed biofilm reactor. With the use of unique plastic carriers that offer a surface on which a biofilm can form, the MBBR system comprises of an aeration tank that resembles an active sludge tank. These systems employ an extensive range of plastic carriers. Both the surface area and form of these carriers vary, and they each have unique benefits and drawbacks. The creation of biofilms is greatly influenced by surface area. Therefore, a wide interior surface area is essential for contact with water, air, bacteria, and nutrients. Free-floating carriers allow biofilms to grow on the

surface ^[2]. Good contact between the biomass on the carriers and the substrate in the influent wastewater will result from the aeration system mixing the carriers in the tank ^[3].

2. Principle

Bio-film reactor technology operating in a moving state forms the foundation of the MBBR's primary operating principle ^[4]. According to Rittman (1982), trickling filters, rotating biological reactors, fixed-film reactors, aerated submerged reactors, and membrane bioreactors were the standard wastewater treatment methods used before the invention of moving bed biofilm reactors. Many drawbacks of these systems include the need for a sizable amount of space, the possibility of mechanical failure and maintenance in the case of a rotating biological reactor, the high initial and ongoing costs, and the issue of malodor in trickling filters. Hydraulic instability is a common problem with submerged reactors, while imbalanced biofilm distribution and biofilm growth medium blockage are issues with fixed film reactors ^[1]. Because of its apertures, the MBBR Biochip X30 offers the ideal environment for microorganisms, with its surface and pore structure uniformly spread throughout a diameter of 30mm (1 1/4"). To prevent possible damage, abrasion, or cuts to the pore structure, the MBBR Biochip X30 features a homogenous outer ring that acts as a buffer zone. It also has a low kinetic energy because of its low net weight, which prevents any mechanical wear ⁽⁵⁾.

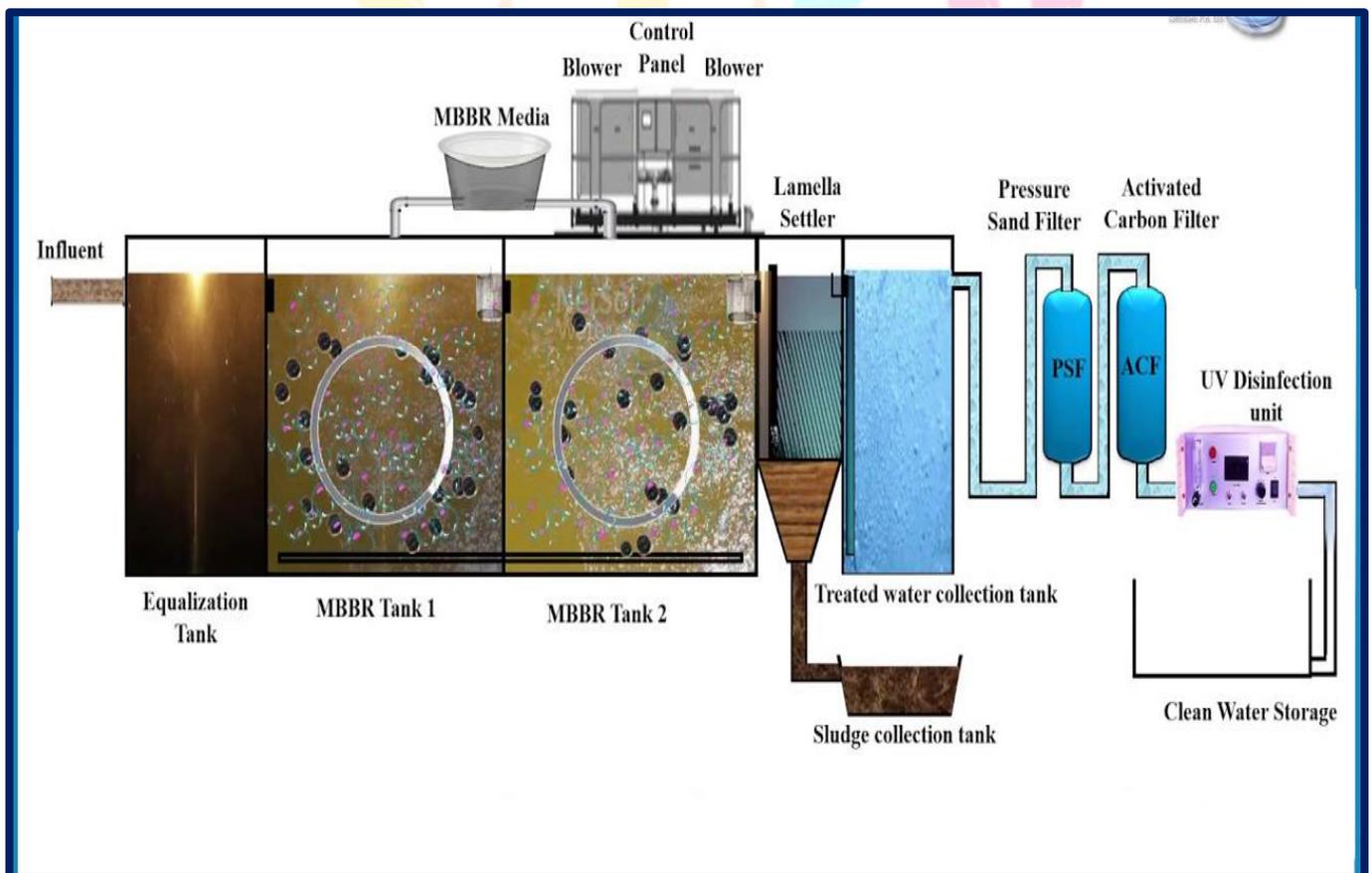


fig. 1 moving bed biofilm reactor

3. Instrumentation

3.1 Influent tank: The reactor, also known as the aeration tank, is where the influent enters at the beginning of the MBBR process. The influent flow to the aeration tank is the first step in the WWTP design process ^[6]. Small microorganisms will break down the sediments in the water in this open-topped tank ^[7].

3.2 Equalization tank: In wastewater treatment, the equalization tank receives wastewater from the collection tank. The primary role is to serve as a buffer to gather the incoming raw sewage, which arrives at greatly varying rates, and distribute it evenly throughout the wastewater treatment facility ^[8].

- Filtered sewage from the Bar Screen Chamber is transported via the intake pipe.
- The tank holds the sewage collection. Because the outgoing rate is constant and the receiving rate varies greatly, the level varies throughout the day.
- To transfer the sewage to the aeration tank, use the raw sewage lift pumps.

- d. The sewage is transported to the aeration tank by the delivery pipe.
- e. The short tubes with regular-spaced pores are the coarse bubble diffusers. In addition to regularly stirring the mixture, they provide big bubbles into the tank to gently aerate the sewage. To ensure that the assembly is securely fixed in one location, the picture displays a set of eight diffusers that are strapped to cement blocks. It is also possible to utilize diffusers alone or in different pairs.
- f. This air supply pipeline is used to supply compressed air. This could be a flexible hose or a stiff pipe. There is just one array of eight diffusers in the figure. Nonetheless, using distinct diffuser pairs, each with its own air line (flexible hose), is more practical ^[9].

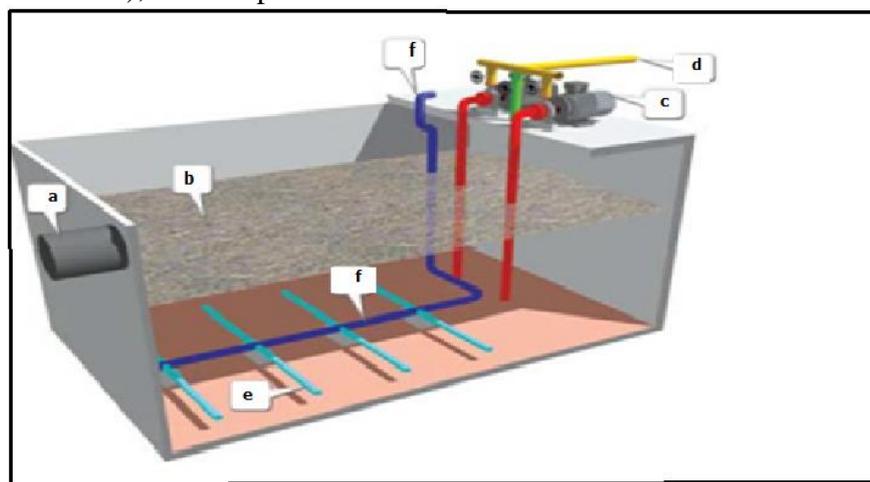


fig. 2 equalization tank

3.3 MBBR media: Microorganisms form as biofilm on suspended carriers in the moving bed biofilm reactor (MBBR), a biological wastewater treatment method. This monitors pH, BOD, COD, and a host of other factors that could impact wastewater quality ^[10]. Utilizing different plastic materials such as Poly Propylene (PP), High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), and other appropriate plastic materials has been the exclusive focus of MBBR media development since the creation of MBBR technology. Plastic MBBR medium are typically round or cylindrical in shape, offering different amounts of surface area for the growth of biofilms. This invention is predicated mostly on the idea that increased surface area yields more biofilms, which in turn leads to increased reduction efficiency and process economy. However, it has been shown that with these plastic MBBR medium, biofilms develop on the inner void surface while, for a variety of reasons, the biomass from the media's outside surface area sloughs off. The effectiveness of MBBR media based on plastic material is widely estimated using specific surface area (SSA) and protected surface area (PSA) per m³ volume of the media delivered in order to account for this occurrence. Currently, SSA of 500–4000 m²/m³ is being offered by several plastic MBBR media with varying sizes and shapes. Residential, commercial, and industrial wastewaters have all been treated extensively using this biofilm method ^[11]. Nevertheless, for MBBR media to be more efficient, total surface area or shielded surface area by itself cannot be used as the only indicator of media efficiency. In addition to surface area, other significant characteristics include the media's surface material, texture, porosity, geometry, and orientation. The design and efficiency of the MBBR process are significantly impacted by these qualities ^[12]. The MBBR method makes use of floating plastic carriers inside the aeration tank to increase the amount of microorganisms that can treat the wastewater. By eating organic waste, this microbe expands the aeration tank's surface area, which promotes the growth of biological bacteria. At the base of the aeration tank, the oxygen-adding aeration system will continually suspend the media from it. Following treatment, the last treated wastewater will be released outside ^[13].

3.4 Blower: A sophisticated treatment system includes blowers for the aeration of wastewater. The way that people want air is a dynamic process. It is doubtful if a single blower with a single flow rate and discharge pressure can satisfy the demands of the system. The energy consumption of the aeration blower system in a typical biological wastewater treatment facility might reach 70% ^[14].

3.4.1 Blower functions

There are multiple uses for the air that the blowers supply to the aeration basin. The first is to provide the oxygen required for the wastewater's organic constituents to be metabolized. The 5-day test performed to determine the concentration of these organic compounds is known as "BOD5" (biochemical oxygen demand), which is the term used to refer to the organic compounds. For the bacteria to use the oxygen in the wastewater, it must dissolve. The diffusers effectively dissolve oxygen into the wastewater by using microscopic air bubbles.

To avoid physical harm, most diffusers have an upper limit on the air flow rate. The diffuser design affects the maximum flow^[15].

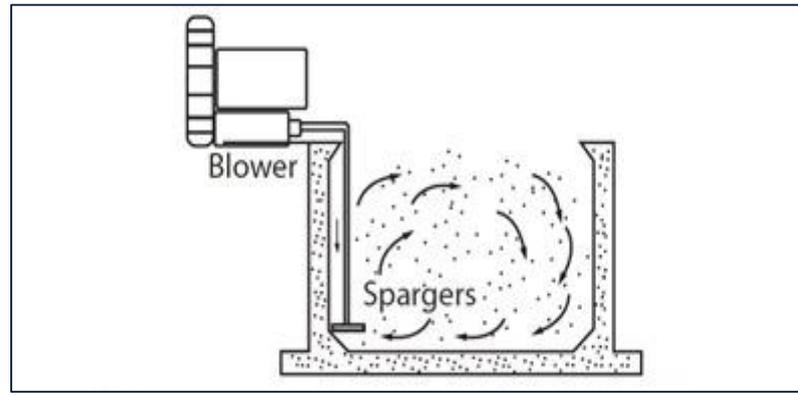


fig. 3 blower

3.5 Lamella settler: The primary goal was to ascertain the removal efficiency for related contaminants and total suspended solids^[16].

3.5.1 Features and benefits:

- Enhanced separation through plate design; improved settling outcomes on the same footprint; higher flow capacity on a smaller footprint than traditional sedimentation. Distributing flow evenly across the Lamella plates is ensured by excellent hydraulic design.
- Inlet apertures for continuous settling; a special and tried-and-true flow control mechanism that allows the liquid to enter the plates through the sides and guarantee that each plate receives the same flow rate; no disturbance occurs when settled material falls off the plate.
- Well-established sustainable design. Lamella separators are engineered to suit a variety of site requirements, including corrosive situations. They also efficiently separate solids with almost no energy consumption. Reliability and extended economic life cycle are provided by either none or few moving components. A variety of materials, such as FRP, stainless steel, or mild steel painted.
- Lamella plate automatic cleaning with Clean-out significant water and energy savings; enhanced water outlet quality as a result of routine cleaning; and increased worker safety.

How the Lamella settler works

By way of the feed pipe, the feed is introduced. Solids settle on the incline plates and slide into the sludge hopper at the bottom of the unit while the liquid flows upward between the plates. The hopper is used to thicken the sludge before it is released. The plate's top apertures allow the clarified liquid to exit, and it is then released into collection channels that lead to the water outflow. For optimal performance at maximum capacity, the flow is distributed evenly to every plate. The settled solids cannot be taken away by the fluid coming from the side entry.

3.5.2 Applications

In a wide range of water treatment applications, including pre-water treatment, backwash water treatment, primary and secondary settling, and tertiary treatment, lamella settlers offer exceptional separation and clarifying performance.

- Thickened sludge
- Water used in industrial processes
- Pulp and paper industry;
- Iron and steel industry;
- Chemical industry: purification and thickening;
- Mill scale removal
- Metal hydroxide wastewater;
- Metal finishing (treatment of metal surfaces);
- Clarification of pressure/vacuum filtrate
- Water treatment in power plant dust scrubbers;
- Water recirculation in the potato and vegetable industries;
- Purification in biological cleaning processes^[17].



fig. 4 lamella settler

3.6 Pressure sand filter

A predetermined percentage of coarse and fine media is mixed together to create a depth filter called the Pressure Sand Filter/Multigame Sand Filter. A filter bed with sufficient pore sizes to hold both large and small suspended particles is created by this configuration. The particular flow rate at which this filter operates is significantly higher than that of traditional filters. To treat water with 50–25 ppm suspended particles, respectively, and create a filtrate with less than 5 ppm, specific flow rates of 15–30 M/Hr have been effectively achieved. Up to 25 NTU of turbidity can be handled by the Multigame sand filter in feed water, and less than 2 NTU will be present in the treated water produced by these filters. Two of the most popular types of rapid sand filters (RSF) are rapid gravity and rapid pressure^[18].

3.6.1 Working principle

Using sand, screen, and disc, or hydrocyclone filters, filtration can eliminate suspended solids particles. Depending on the property's water quality and the type of irrigation system being utilized, filters may be installed alone or in groups. Since pressurized sand filters can hold particles up to 20 mm within the sand bed, they maximize the retention efficiency and perform exceptionally well at retaining organic particles and algae. For these reasons, they are frequently employed in irrigation^[19]. Water passes through multiple layers of filter material, including layers of gravel, pebbles, and graded sand, in a pressure sand filter. The water's impurities are collected in the media bed, and the filtered water enters the discharge manifold located at the base of the tanks. Backwashing, the final and final stage, successfully removes the pollutants that have been captured from the media bed. Following back-washing, the filter is rinsed with raw water and reinstalled once the necessary water quality is attained.

3.6.2 Features & advantages

- i. Greater specific flow rate compared to traditional down flow filters, saving money and space.
- ii. Extremely low maintenance needs
- iii. Reduced water requirement for backwashing
- iv. Generally speaking, backwashing can be done with raw water.
- v. Plastic pipes are resistant to corrosion and don't need to be maintained.
- vi. It is simple to use and intuitive to operate thanks to the single lever controlled multiport valve.
- vii. Options for Manual and Automatic Operation
- viii. Personalized dimensions and arrangements
- ix. Perfect as a pre-treatment
- x. An increased specific velocity

3.6.3 Applications

- i. It is widely utilized in the side stream filtering process for the treatment of potable water.
- ii. It is perfect for filtering water that has been clarified.
- iii. Furthermore, it is utilized in the filtering of chemical solutions and seawater. There are rubber-lined and epoxy-painted filters available for these kinds of filtering.
- iv. Preparation of the Reverse Osmosis System
- v. Pretreatment of drinking water at hotels, commercial centers, and housing societies
- vi. Swimming Pool Filtration in Hotels & Housing Societies
- vii. Pretreatment of boiler feed and cooling towers^[20].

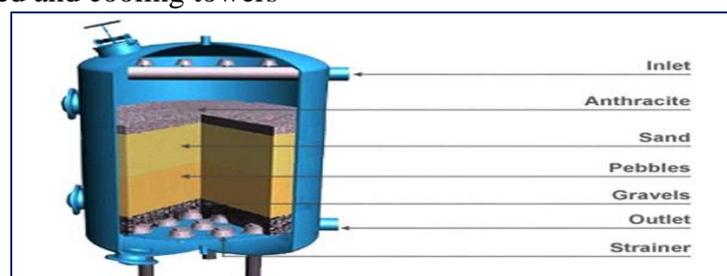


Fig. 5 Pressure Sand Filter

3.7 Activated carbon filter

The method of activated carbon filtering essentially removes undesirable impurities from wastewater. Oxygen is first applied to activated carbon. This aids in the charcoal's millions of microscopic pores opening. The absorption of pollutants from water is a very efficient use of activated carbon. Activated carbon is a part of the filtering process that removes leftover pollutants from sewage discharge. Carbon takes up micro-pollutants including methane, chlorine, organic chemicals, and even the flavor and odor of water. Microbial concentration of water filtered using activated carbon. Under laboratory conditions,

research was conducted with both filtered and unfiltered water to investigate the impact of filtration on the microbiological content of the water^[21].

By employing the absorption process, the activated carbon filter method eliminates impurities from water. It is a rather inexpensive procedure that effectively rids waste water of undesirable impurities. The process' greatest feature is its ease of production anywhere in the world; its sole disadvantage is that the filter quickly wears down and needs to be replaced on a regular basis^[22]. Carbonized materials like cellulose, polyacrylonitrile, or phenolic resin fiber are used to create activated carbon filters, which are then activated^[23].

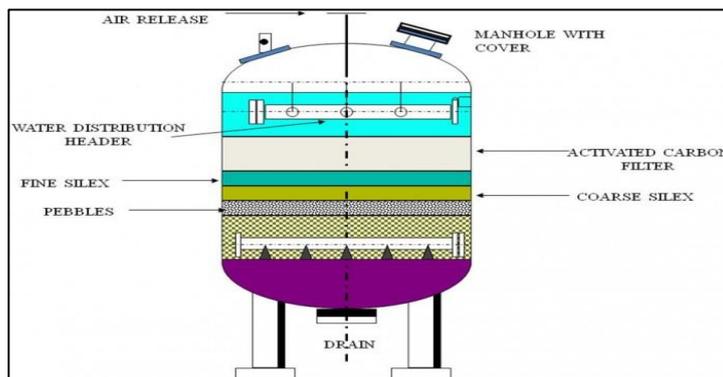


fig. 6 activated carbon filter

3.8 UV disinfection unit

The use of UV radiation for wastewater disinfection is regarded as a reliable substitute for chemical disinfection due to the lack of harmful byproducts that are typically produced and detected during chemical disinfection^[24].

UV light penetrates microbes and destroys their DNA to disinfect water with this technology. Destroying DNA stops an organism from being active and from reproducing because DNA is essential to an organism's activities and ability to reproduce. Naturally occurring in extremely small amounts in sunshine is also this UV energy (wavelength: 240–280 nm). Ultraviolet lamps, also referred to as high mercury discharge lamps, assist produce the same energy at stronger intensities.

3.8.1 Benefits of UV disinfection system

- i. Natural: Water purification by UV therapy is a natural process.
- ii. Environmentally Friendly – During the UV disinfection process, no toxic byproducts are produced.
- iii. Effective – Every known microbe is photosensitive to UV light.
- iv. Economical – Out of all the disinfection systems, lowest operating cost.
- v. Safe and Chemical-Free – Absence of chemical addition means there is no risk of overdose.
- VI. Fast – Instant because it is in-contact purification^[25].

table 1 comparison of uv disinfection system, chlorination and ozonation

	Ultra Violet	Chlorination	Ozonation
Capital Cost	Low	Lowest	High
Operating Cost	Lowest	Low	High
Ease of Installation	Excellent	Good	Complex
Ease of Maintenance	Excellent	Good	Poor
Contact Time Required	<10 seconds	20-30 minutes	10-20 minutes

[25]

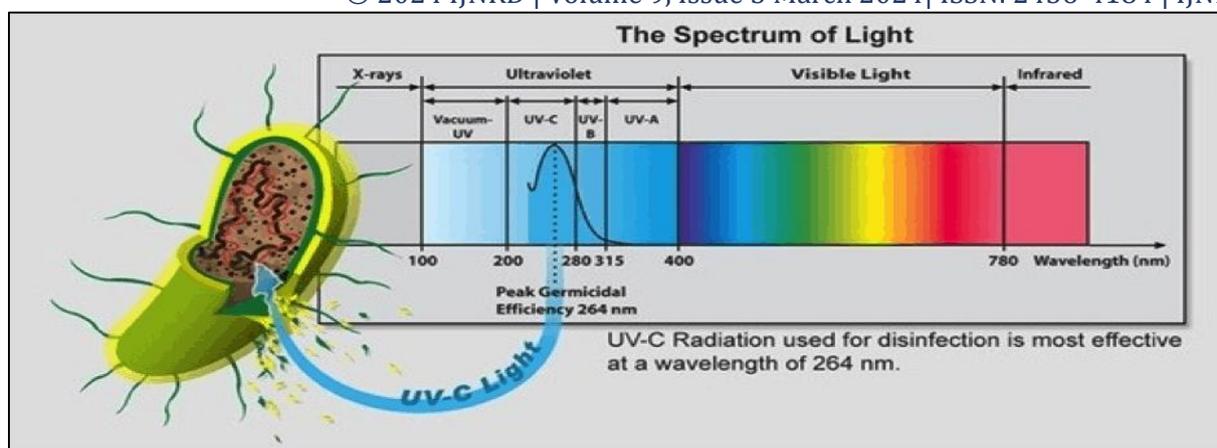


fig. 7 the spectrum of light

4. Experimental Methodology

- i. Inlet water is coming to screen chamber for preliminary treatment for removal of the waste such as racks, plastic, cans, sticks, breaks which could damage downstream equipment's or block pipes
- ii. After screen chambers, the sewage is pumped to the equalization tank. Equalization tank is used to maintain the desired flow rate at constant or uniform flow rate as well as for making mixture homogeneous, to avoid shock loading in MBBR technique. The aeration in equalization tank will reduce the BOD of wastewater by 10 -20% and provide mixing to make a homogeneous solution for the treatment. Blowers are provided for supplying the air in equalization tank and MBBR tanks.
- iii. After equalization tank the homogeneous raw sewage is send to MBBR tank. MBBR is the part of secondary or biological treatment process. MBBR consist of an aeration tank like activity sludge tank with a special plastic media that provide a surface where microorganisms as a film can grow this carrier media is dumped in an aeration system. Aeration is provided to continuously circulate the plastic media and to maintain the dissolved oxygen level in the MBBR tanks. Proper aeration leads good contact between the BOD or organic material and biomass or microorganisms or carrier media to prevent the plastic carrier from escaping the aeration tank it is necessary to have on the outlet of the tank.
- iv. After MBBR tank 1 , water is send to MBBR tank 2 . The process of MBBR tank 2 is almost the same as MBBR tank 1 .At the outlet of MBBR tank 1 and 2 , media retention screens or perforated plates are provided to keep biofilm carriers inside the tank.
- v. After MBBR tank 2, a mixture of digested sludge & treated water, is send to lamella settler or tubes settler, where the sludge is collected separately in sludge collection tank through the bottom hopper of clarifier & clean water is collected in treated water collection tank, through the launder at the top of the clarifier.
- vi. The important thing is, this is just a treated water, but it might have pathogen therefore we can either provide chlorination at the outlet of the treated water tank or alternatively for further purification this treated water is passed through PSF (Pressure Sand Filter) for radiation of total suspended solid & biochemical O₂ demand.
- vii. Next after, passed through ACF (Activated Carbon Filter) for removal of smell, odor and color.
- viii. After ACF, this water is passed through UV disinfection unit for killing out all types of pathogens present in water.
- ix. UV disinfected water is considered as clear water, which is further stored in clean water storage tank^[26].

5. Advantages

5.1 High Treatment Efficiency: High treatment efficiency is provided by MBBR wastewater treatment. The process's biofilm carriers offer a lot of surface area for microbial development, which causes the reactor's microbe concentration to be quite high. This ultimately results in high rates of organic matter breakdown and effective wastewater treatment^[27].

5.2 Low Space Requirement: An efficient method of treating wastewater in places with limited space is MBBR wastewater treatment. When considering other technologies for treating wastewater, including activated sludge systems, the process takes up less area. For small and medium-sized wastewater treatment facilities, MBBR systems are a good choice since they are simple to set up and manage in limited areas^[28].

5.3 Reduced Sludge Production: Compared to alternative wastewater treatment technologies, MBBR wastewater treatment produces less sludge, which is one of its main benefits. Sludge recycling is not

necessary because the biofilm carriers employed in the process are self-cleaning. Reduced disposal expenses and simpler treatment system maintenance result from this^[29].

5.4 Flexibility: The MBBR wastewater treatment method is a versatile procedure that may be readily modified to accommodate evolving wastewater properties. The method may be tailored to handle various kinds of wastewater, which makes it a good choice for treating wastewater in a variety of commercial and public settings^[30].

5.5 Energy Efficiency: Wastewater treatment with MBBR technology uses less energy. In comparison to other wastewater treatment technologies, such as activated sludge systems, the procedure uses less energy for aeration. As a result, the wastewater treatment plant uses less energy and pays less to operate^[31].

5.6 Robust Process: The MBBR wastewater treatment method is a resilient process that can adapt to changes in the organic load and influent flow. The technique is less sensitive to variations in the properties of wastewater because the biofilm carriers it uses offer a stable habitat for microbial development. As a result, the process of treating wastewater becomes more steady and dependable^[32].

5.7 Low Operating Costs: One affordable option for treating wastewater is MBBR wastewater treatment. Lower running expenses for the treatment plant are the outcome of the energy-efficient process and reduced sludge production. The MBBR system is a cost-effective solution for wastewater treatment because of its small size, which also results in lower infrastructure expenditures^[33].

5.8 Environmental Benefits: Numerous environmental advantages come with MBBR wastewater treatment. Hazardous pollutants are kept out of the environment by reducing the organic content of wastewater using this method. The treatment plant generates less waste as a result of the reduced sludge generation. A more sustainable future is also facilitated by the energy-efficient procedure, which lowers the treatment plant's carbon impact^[34].

5.9 Works Quickly With a Low Hydraulic Retention Time: The length of time it takes a water treatment system to efficiently treat the influent is known as the hydraulic retention time, or HRT. In certain cases, this can take a lengthy period, meaning that the procedure proceeds slowly. In a particular period of time, less wastewater can be treated the slower the procedure is. The design of MBBR systems enables them to operate rapidly and with a comparatively low HRT. The HRT for MBBR systems is typically a few hours or less. This low HRT is made feasible by the fast-moving media and the high biofilm concentration. An MBBR system allows a facility to process twice as much wastewater in a day as another type of system with the same capacity because of how quickly they operate. Going back to the point regarding the reduced footprint of an MBBR, this implies that a smaller system can treat more water faster than an equal system. For this reason, MBBR systems are a very effective option^[35].

6. Disadvantages

As with any possible solution, MBBR also involves some disadvantages. The disadvantages of an MBBR system include:

6.1 Manual monitoring: One drawback of MBBR systems is also present in biological water treatment methods generally. With a biological system like an MBBR tank, an operator must periodically take samples and study them to make sure the bacteria on the carriers are still thriving. This is in contrast to other types of water treatment, which can employ sensors to monitor the system's development^[36].

6.2 Skilled experts: This brings up another drawback of biological systems: their operators need to be highly qualified professionals with specialized knowledge in biological water treatment. This is required in order for them to fully examine the media and make sure that it is still breaking down the waste in the tank. Naturally, as we've seen, using the tank is a straightforward, primarily hands-off task^[37].

6.3 Insects: An additional drawback of working with biofilms is the attraction of some insects, such as red worms, mosquitoes, and sewer flies. This could suggest that portion of the biofilm on the carriers is lost to insects, which would reduce the system's efficacy. By utilizing tanks made to keep these insects out, treatment plants can guard against this issue^[38].

6.4 Escaping carriers: Despite the strainers designed to keep the insects in, some users have claimed that over time, even in the absence of insects, the carriers may wash out of the system. This may possibly be due to a potential defect in the tank's design. Using an MBBR system has considerably more benefits than drawbacks when it is configured correctly^[39].

7. Applications

7.1 Manufacturing of chemicals

A large amount of wastewater with organic pollutants is produced during the chemical production process. This wastewater needs to be treated before it can be recycled or released into natural waterways. Chemical manufacturing companies ought to give MBBR serious consideration for their ETP ^[40].

7.2 Use in Sewage treatment plants

Moving bed biofilm reactor technology (STP-MBBR) is also used in sewage treatment facilities. It is built using an active sludge aeration system. The sludge is collected in the plastic containers because of their large internal surface area. The surface area of the carriers optimizes their interaction with air, water, and microorganisms, facilitating the denitrification process and subsequent volume reduction of organic waste ^[41].

7.3 Food & beverage industry

Most beverages contain water as a primary ingredient, but water is also utilized for cleaning and chilling during the beverage-making process. It is necessary to treat the wastewater generated by these processes. MBBR is especially well-equipped to handle the high volume demand for water treatment in the industry ^[42].

7.4 Processing of dairy products

In addition to other wastes, the processing of dairy products such as milk, cheese, and yoghurt generates a large amount of effluent, which contains biochemical oxygen demand (BOD). The dairy industry finds MBBR to be a significant wastewater treatment option because of its excellent efficacy ^[43].

7.5 Manufacturing of pulp and paper

There are significant water usage requirements in the pulp and paper industry. Paper makers produce a large amount of contaminated effluent that requires on-site treatment, with process water accounting for around 85% of this. The effectiveness of MBBR in treating this wastewater has been established ^[44].

8. Following are the some drugs which had been effectively removed with the help of MBBR Technique

Sulfamethoxazole
Azithromycin
Antiretroviral agents
Ofloxacin
Ibuprofen
Metronidazole
Ethyl glycol
Antidepressants
Analgesics
B-Blockers

9. Conclusion

This study aimed to describe a simple, cost effective and reliable method for the removal of the Drugs from the Industrial and the Hospital Wastewater. The moving bed biofilm process is robust, compact and self-driven established technology in the area of advanced wastewater treatment. There is successful implementation of MBBRs in treatment of sewage as well as the wastewater released from Industries and Hospitals. The advantages of MBBR over other biofilm systems include its flexibility with respect to reactor shape and choice of carrier filling with minimum specific surface area. This method is useful over the conventional method because the high efficiency of the MBBR process over the other methods. In this review we had discussed about the two drugs – Sulfamethoxazole and azithromycin. These drugs are removed by the treatment of the Industrial and Hospital effluents with the help of the MBBR media.

10. Abbreviations

ACF: Activated Carbon Filter
BOD: Biological Oxygen Demand
COD: Chemical Oxygen Demand
DNA: Deoxyribonucleic Acid
ETP: Effluent Treatment Plant
FRP: Fiber Reinforced Plastic
HRT: Hydraulic Retention Time

MBBR: Moving Bed Biofilm Reactor

NTU: Nephelometric Turbidity Unit

O₂: Oxygen

PSF: Pressure Sand Filter

SCFM: Standard Cubic Feet Per Minute

SSA: Specific Surface Area

STP-MBBR: Sewage Treatment Plant- Moving Bed Biofilm Reactor

TOC: Total Organic Carbon

UV: Ultraviolet

WWTP: Waste Water Treatment Plant

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