



TREATMENT OF SEWAGE USING MOVING BED BIOFILM REACTOR (MBBR)

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ABSTRACT

Contaminants include viruses, bacteria, and protozoa can be found in sewage. The advancement of ecologically sustainable and economically viable wastewater treatment technology is imperative due to the growing worldwide demand for clean water resources. In this project, a state-of-the-art and incredibly successful biofilm-based technology called the Moving Bed Biofilm Reactor (MBBR) is used to purify sewage water. In order to promote the growth of microorganisms and aid in the biodegradation of organic and inorganic contaminants found in sewage water, the MBBR biofilm reactor uses suspended plastic carriers as a growing substrate. The development of biofilms on the carrier surfaces promotes microbial activity, resulting in a vibrant and varied microbial community that can break down a variety of pollutants. Because of its compact and modular design, the reactor may be used for both new wastewater treatment plants and the retrofit of existing ones. It is shown how effective MBBR is at eliminating contaminants such organic matter, nitrogen, and phosphorus, and how it might potentially meet strict discharge regulations. Furthermore, the adaptability of the reactor to changing wastewater conditions is demonstrated by an examination of its capacity to manage varying hydraulic and organic loads. To achieve improved overall treatment performance, the combination of MBBR with other treatment processes—such as activated sludge systems or tertiary treatment—is also discussed. At first, the aeration process took five days and eight hours to complete, with the Trail 1 result. next, the filter media process tank was used for ten days and eight hours of operation. Initially, the following findings were noted: pH = 8.34, TDS = 1138 mg/l, Temperature = 28.5oC, COD = 0, DO = 3.5 mg/l.

Keyword: Moving Bed Biofilm Reactor, Activated Sludge Process, Aerobic Digestion, Biological Treatment, Drains, Dry Weather Flow, wastewater treatment

1. INTRODUCTION

An essential component of environmental management that guarantees the preservation of water resources and public health is the treatment of sewage water[1]. Novel technologies have been created recently to improve wastewater treatment operations' sustainability and efficiency. One such cutting-edge innovation that is becoming more well-known is the Moving Bed Biofilm Reactor (MBBR). MBBR is a biofilm-based treatment strategy that is a strong contender for treating sewage water since it has a number of benefits over conventional techniques[2]. Sewage generation has increased at an unparalleled rate as a result of modern society's growing urbanization and industrialization. Even if they work well, conventional wastewater treatment techniques may have problems with energy usage, space needs, and their capacity to adjust to changing pollutant loads[4]. The investigation of novel technologies such as MBBR has been propelled by the necessity for treatment options that are both sustainable and efficient. Using suspended plastic carriers inside the reactor to promote the growth of biofilm is the fundamental idea behind MBBR[5]. These carriers offer a surface on which microorganisms can adhere and establish a dynamic biofilm, thereby fostering an environment that is favorable for the biological breakdown of pollutants found in sewage water. The carriers' mobility makes it possible for the wastewater to be mixed [6] and in contact with them continuously, which improves the treatment process efficiency.

When it comes to treating sewage water, MBBR is becoming more and more popular because of its many benefits. Because of its small size, treatment plants don't need as much space, which makes it appropriate for both new installations and facility upgrades [7]. A diverse microbial community is encouraged by the biofilm's large surface

area, which allows the reactor to process a variety of organic and inorganic pollutants. Additionally, MBBR offers operational flexibility by demonstrating resilience to variations in hydraulic and organic loads.

By offering a home for microorganisms that can degrade complex pollutants, the biofilm formation on the carriers in MBBR improves treatment efficiency. Stricter water quality standards are met in part because of the reactor's exceptional efficacy in removing phosphorus, nitrogen compounds, and organic matter. Since MBBR uses less energy [8], produces less sludge, and has the ability to recover resources, it complies with sustainability principles. The technology is a desirable choice for businesses and municipalities looking for affordable and environmentally friendly sewage water treatment solutions because of its scalable modular design and long track record of economic success. As the need for effective, flexible, and long-lasting solutions increases, MBBR shows promise as a solution to the problems related to sewage water treatment.

DEVELOPMENT OF MBBR TECHNOLOGY

The Moving Bed Biofilm Reactor concept was first developed in the 1980s in Norway by Professor Hallvard degaard at the Norwegian University of Science and Technology (NTNU). The initial purpose of MBBR was to address the challenges associated with conventional wastewater treatment methods, particularly [9] in handling varying organic loads and providing a compact and efficient system. Following the conceptualization of MBBR, pilot studies were conducted to assess its feasibility and effectiveness in treating different types of wastewater. Positive results from these studies led to the implementation of full-scale MBBR systems in various wastewater treatment plants around the world. The technology gained recognition for its ability to achieve high treatment efficiency while offering operational flexibility. Over the years, advancements and innovations have been made in MBBR technology, including improvements in reactor design, media configurations, and process optimization. These developments have further enhanced the reliability and performance of MBBR systems in treating sewage water.

As the need for sustainable and efficient wastewater treatment solutions grew, MBBR gained popularity globally. Municipalities, industrial facilities, and researchers started recognizing the advantages of MBBR in terms of its compact footprint [10], adaptability to varying conditions, and cost-effectiveness. MBBR is often integrated with existing wastewater treatment systems, such as activated sludge processes, to enhance overall treatment performance. This integration allows for the optimization of treatment processes and the achievement of desired effluent quality standards.

The treatment of sewage using Moving Bed Biofilm Reactor has evolved over the past few decades from a conceptual idea to a widely adopted and established technology[11]. The continuous refinement and global implementation of MBBR highlight its significance in addressing the challenges of sewage water treatment in a sustainable and effective manner.

CHEMICAL CHARACTERISTICS OF SEWAGE

Sewage typically has a high organic matter content. The kinds and state of the sewage, however, determine how much organic matter is there. Sewage may contain suspended or sedimented materials, colloidal matter, dissolved substances, or other forms of organic matter. Humans excrete a significant amount of chloride (8–15 g/day) as NaCl [12]. Hydrogen sulfite, or H₂S, is produced in sewage by anaerobic bacteria during the anaerobic breakdown of organic materials. H₂S gives sewage a foul smell. Sewage typically contains a significant amount of organic matter. However, the kind and state of the sewage determine how much organic matter is present. Sewage contains organic matter in the form of suspended particles, colloidal matter, dissolved substances, and sediments.

Common anaerobic bacteria includes:

- Clostridium sporogens
- Bifidobacterium
- Peptococcus
- Methanogenic bacteria like Methanobacterium, methanosarcina

Common aerobic bacteria includes :

- Zeoglea remigera
- Noacrdia
- Flavobacterium
- Achromobacter
- Nitrosomonas

Zeoglea remigera is the main organism found in trickling filter.

Parameter	High	Medium	Low
COD	1200	750	500
BOD	560	350	230
TKN	100	60	30
NH ₃	75	45	20
TP	25	15	6
TSS	600	400	250
pH	8.0	7.5	7.0
Alkalinity eqv/m ³	7	4	1
COD/BOD	2.5–3.5	2.0–2.5	1.5–2.0
COD/TP	45–60	35–45	20–35

Typical characterization of raw sewage (L Metcalf et al., 2003)

The characterization of wastewater in terms of quantity and quality is principally a function of the wastewater origin i.e. industrial or domestic. The Federal Clean Water Act defines pollutant as meaning “dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water”. Despite this broad, all-encompassing definition, wastewater can typically be characterized as either domestic, industrial, or some combination of both as suggested by Corbitt (1999). According to Environmental Protection Agency the first step in addressing wastewater problems is to develop a source reduction program and selecting an appropriate pre-treatment system, this can only be possible by analyzing the physical and chemical characteristics of the process wastewater stream in question. The measured levels of pollutants are subsequently compared with the discharge regulations limits applicable to each area.

DIFFERENT TREATMENT METHODS FOR SEWAGE

Sewage is treated using a variety of techniques to get rid of impurities and prepare the water for reuse or release into the environment. In order to address different pollutants, the treatment process usually consists of several stages. The following are a few typical sewage treatment techniques:

Screening:

Purpose: Removal of large objects and debris.

Description: The sewage is passed through screens or grates to remove large objects like sticks, leaves, and plastics.

1. Primary Treatment:

Purpose: Removal of suspended solids and organic matter.

Description: Sewage is settled in primary sedimentation tanks, allowing heavy solids to settle at the bottom as sludge, and lighter solids to float as scum. The clarified water is then passed on for further treatment.

2. Secondary Treatment (Biological Treatment):

Purpose: Biological breakdown of organic pollutants.

Description: Activated sludge processes, trickling filters, or sequencing batch reactors are used to encourage the growth of microorganisms that consume and break down organic matter in the sewage.

Tertiary Treatment:

Purpose: Further polishing of treated water to meet specific quality standards.

Description: Tertiary treatment can involve processes like filtration, chemical coagulation, and advanced oxidation to remove remaining impurities, nutrients, and pathogens.

Disinfection:

Purpose: Elimination of pathogenic microorganisms.

Description: Common disinfection methods include chlorination, UV irradiation, and ozonation to kill or inactivate bacteria, viruses, and other harmful microorganisms.

Nutrient Removal (Biological Nutrient Removal - BNR):

Purpose: Reduction of nitrogen and phosphorus to prevent eutrophication.

Description: Additional biological processes, such as denitrification and phosphorus removal, can be incorporated to target specific nutrients in the sewage.

Anaerobic Digestion:

Purpose: Stabilization and reduction of organic sludge.

Description: Sludge produced during treatment can undergo anaerobic digestion, a biological process that produces biogas (methane) and stabilizes the sludge.

Sludge Dewatering:

Purpose: Reduction of sludge volume for easier handling and disposal.

Description: Mechanical methods (e.g., belt presses, centrifuges) are used to remove water from sludge, reducing its volume before further treatment or disposal.

Constructed Wetlands:

Purpose: Natural treatment of sewage through wetland vegetation.

Description: Sewage flows through wetland areas planted with specific vegetation that promotes biological and physical treatment processes, removing pollutants through natural processes.

Membrane Bioreactors (MBR):

Purpose: Combines biological treatment with membrane filtration for solids separation.

Description: MBR systems use membranes to separate solids from treated water, eliminating the need for secondary sedimentation tanks.

Reverse Osmosis (RO) and Ultrafiltration (UF):

Purpose: Advanced removal of dissolved contaminants.

Description: Membrane processes like RO and UF can be used for the removal of dissolved salts, organic molecules, and other small particles from treated sewage.

Ion Exchange:

Purpose: Removal of specific ions from water.

Description: Ion exchange involves exchanging undesirable ions in the sewage with ions on a resin, effectively removing targeted contaminants.

Activated Carbon Adsorption:

Purpose: Removal of organic compounds and residual contaminants.

Description: Activated carbon is used to adsorb organic molecules and other trace contaminants from the treated water.

DETAILED DESCRIPTION OF MBBR SEWAGE TREATMENT

In the field of wastewater treatment, there is a growing demand for advanced technologies that can effectively and efficiently treat sewage. One such technology that has gained a lot of attention is the Moving Bed Biofilm Reactor. The moving bed biofilm reactor is a promising biological wastewater treatment technology that offers several advantages. It is widely used worldwide for its simplicity and potential efficiency in removing organic contaminants and nutrients from wastewater. This technology utilizes small carrier elements that move around in the reactor, creating a biofilm on their surface where the biomass grows (Revilla et al., 2016).

This biofilm allows for both attached and suspended growth systems, increasing the treatment capacity and ensuring a high biomass concentration per unit volume in the reactor. The use of a moving bed biofilm reactor in wastewater treatment offers several benefits compared to conventional treatment processes. These benefits include increased energy efficiency, better recovery from shock loads, and reduced sludge production. The moving bed biofilm reactor achieves high removal efficiencies of organic contaminants, such as COD, as well as nutrients like phosphate (Philipp et al., 2021). Additionally, the MBBR system has high tolerance to water temperature changes and heterogeneity of charges during the treatment process, making it a robust and reliable solution for wastewater treatment (Mazur & Chmielowski, 2020). Furthermore, the choice of carrier media in the moving bed biofilm reactor plays a crucial role in its efficiency. Various types of carrier media can be used in the moving bed biofilm reactor, such as plastic biofilm carriers or submerged fixed-film media. These carriers provide a suitable microenvironment for cell growth, facilitating the formation of a biofilm and reducing washout from the system (Jiang et al., 2016).

Overall, the moving bed biofilm reactor proves to be a highly efficient and versatile technology for the treatment of sewage. It offers increased energy efficiency, better recovery from shock loads, reduced sludge production, and high removal efficiencies of organic contaminants and nutrients. Additionally, the use of carrier media in the reactor allows for the formation of a biofilm, which promotes both attached and suspended growth systems. This biofilm provides a protected surface area for sludge accumulation and biomass immobilization, ensuring a high biomass concentration per unit volume in the reactor. In summary, the moving bed biofilm reactor is a highly efficient and versatile technology used for the treatment of sewage. The efficiency of the moving bed biofilm reactor in treating sewage is attributed to several factors. These include the use of polypropylene carriers with a highly porous structure for biomass immobilization, which provide a protected surface area for sludge accumulation and biomass immobilization. This results in a high biomass concentration per unit volume in the reactor, leading to increased treatment efficiency. In addition, the moving bed biofilm reactor combines the advantages of conventional activated sludge and fixed-film practices. Therefore, it can effectively remove organic pollutants, nutrients, and partially toxic substances from sewage.

LITERATURE REVIEW

Hanwen Zheng et al., 2023 Evaluated the efficiency of recirculating aquaculture systems, nitrification, the process of converting ammonia to nitrite and then to nitrate, is commonly accelerated by introducing nitrifiers or mature bio-carriers. This study compared three strategies for establishing nitrification in a moving bed biofilm reactor (MBBR): the conventional method (Control group A), inoculation with biofloc recovered from a tilapia biofloc culture system (Group B), and addition of extra nitrite (Group C). The biofloc-inoculated group showed significantly faster nitrification (38 days) compared to the control group (56 days) and the nitrite-added group (59 days), indicating that seeding biofloc can greatly enhance the nitrification process in the MBBR of a recirculating aquaculture system (RAS). Ying Cao et al., 2023 has investigated the co-existence of nitrate (NO₃⁻), antibiotics, phosphorus (P), and copper (Cu²⁺) in aquaculture wastewater and the need for simultaneous removal of these pollutants. The study establishes a moving bed biofilm reactor (MBBR) for the simultaneous removal of NO₃⁻, P, antibiotics, and Cu²⁺. The results show high removal efficiencies for these pollutants, and the study also investigates the role of enzymes, reactive oxygen species, and microbial communities in the removal process.

Svendsen . B et al., 2023 studied the efficiency of intermittent feeding with carbon (ethanol) on the degradation of pharmaceuticals in a moving bed biofilm reactor (MBBR). The researchers found that for 17 out of 36 pharmaceuticals, intermittent feeding increased the degradation rate constants (K) by a factor of 3-17, while for six other pharmaceuticals, it decreased K. The study also identified three dependencies related to intermittent loading, where the relationship between K and carbon loading varied for different compounds. These findings suggest that optimizing processes in MBBRs should consider prioritizing specific compounds based on their degradation characteristics.

AERATION PROCESS

Aeration is a critical process in sewage treatment that involves introducing air into sewage or wastewater to facilitate the growth of aerobic microorganisms, which then break down organic matter and pollutants. This process occurs in treatment plants within dedicated tanks or basins called aeration tanks. The primary goal of aeration is to provide oxygen to micro-organisms, particularly aerobic bacteria, that metabolize and biodegrade organic compounds present in the wastewater. These microorganisms require oxygen to thrive and perform their role in breaking down organic matter. It is achieved using mechanical equipment such as diffused air systems, surface aerators or mechanical aerators. These devices introduce air into the wastewater, creating a suitable environment for the microorganisms to grow and multiply. These microorganisms use oxygen to decompose and metabolize organic pollutants, converting them into simpler, less harmful substances such as carbon dioxide, water, and biomass.

TYPES OF AERATION SYSTEMS

Diffused Air Systems: These systems use diffusers, typically made of porous materials, to release fine bubbles of air into the wastewater. The increased surface area of these bubbles enhances the transfer of oxygen to the microorganisms.

Surface Aerators: These devices agitate the wastewater's surface, causing oxygen transfer by creating turbulence and mixing air with the water. This helps in increasing the dissolved oxygen content throughout the wastewater.

Controlled Environment: Aeration tanks are designed to maintain specific environmental conditions suitable for the growth of aerobic bacteria. Factors such as temperature, pH levels and dissolved oxygen levels are carefully monitored and controlled to optimize microbial activity.

Oxygen Transfer: The aeration process effectively increases the dissolved oxygen content in the wastewater, providing the necessary oxygen for the aerobic bacteria to thrive and efficiently degrade organic pollutants.

EFFICIENCY OF AERATION PROCESS

Proper aeration significantly enhances the efficiency of the biological treatment process in sewage treatment plants, ensuring effective removal of organic contaminants and reducing the overall pollutant load in the wastewater.

DETAILED EXPERIMENT PROCESS

- The sewage water is being collected in a tank and then the aeration process is started.
- The aeration process is nothing but give the oxygen to that Ammonia which is already presented in the sewage water.
- This ammonia is used to destroy the some unwanted particle in the sewage water.
- MBBR is a highly effective biological treatment process based on a combination of conventional activated sludge process and biofilm media. The MBBR process utilizes floating High Capacity
- Micro Organism BioChips media within the aeration and anoxic tanks. The microorganisms consume organic material.



Experimental Process of Aeration Tank

FILTER MEDIA PROCESS

Biochip filter media, sometimes referred to as biochip arrays, are cutting-edge instruments used in medical diagnostics and biological research to examine and identify a variety of biological materials, including proteins, DNA, and other compounds. They are composed of a variety of tiny spots or wells arranged onto a solid substrate, typically silicon or glass. Depending on the purpose of the biochip, these patches are functionalized with certain biological components like proteins, enzymes, DNA probes, or antibodies. Biochip filter media represent an advancement in biological filtration technology, optimizing microbial growth and biofilm formation in a smaller footprint. Their efficient design and ability to promote active microbial communities make them valuable components in modern wastewater treatment systems, contributing to improved water quality and environmental sustainability. Biochip filter media are innovative components used in biological filtration systems for water treatment. These biochips, also known as biofilm carriers or biofilm media, are designed to provide a high surface area in a compact form, optimizing the growth of microbial biofilms for effective wastewater treatment.

The biochip design typically consists of small, structured materials, often made from plastic or other suitable polymers, engineered to maximize surface area. These chips provide a habitat for microorganisms to attach and form biofilms, which are essential for biological treatment processes. Despite their small size, biochips offer a large surface area per unit volume, facilitating the growth of a dense and diverse microbial community. This increased surface area allows for more efficient biological degradation of organic pollutants. The structured design of biochips promotes rapid and robust biofilm development. Microorganisms quickly colonize the chips, forming biofilms that actively metabolize organic contaminants present in wastewater. The high microbial activity supported by biochips results in enhanced pollutant removal. The biofilms formed on these media effectively break down organic matter, reducing pollutants to simpler, less harmful compounds.



Picture of the Bio Chips

DESIGN & FUNCTION

The biochip is made up of distinct areas (wells or patches) where various biological molecules or probes are rendered immobile. Based on its functionalization, each spot is tailored to draw particular target molecules. As an example, an area may be functionalized using antibodies that attach to a specific protein or DNA sequence. The final output can help by providing details regarding the kind and number of molecules found. This information might include the presence of particular proteins, DNA mutations, or infections in a clinical sample.

ADVANTAGES

Biochip filter media have a number of benefits, such as high throughput, multiplexing (the capacity to examine several targets at once), and comparatively fast outcomes. Their versatility and specificity in identifying target molecules make them useful in a variety of sectors, including biological research, pharmaceutical research, medical diagnostics, and environmental monitoring. Biochips are compact and space-saving compared to traditional filter media, making them

suitable for systems where space is limited, such as in decentralized wastewater treatment or small-scale applications. These biofilm carriers can be used in various configurations and treatment processes, including moving bed biofilm reactors (MBBRs), fixed-film systems, or trickling filters, offering versatility in wastewater treatment applications.



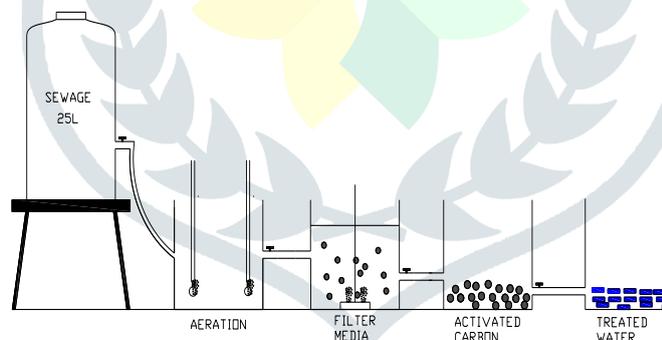
Experimental Process Filter Media

ACTIVATED CARBON

Activated carbon is commonly used in sewage water treatment to remove impurities and contaminants through a process called adsorption. Adsorption is the adhesion of atoms, ions, or molecules from a gas, liquid, or dissolved solid to a surface. Activated carbon has a large surface area and is highly porous, making it an effective material for adsorbing a wide range of pollutants from water.

OVERALL METHODS INVOLVED IN THE FILTRATION PROCESS

- Sewage water from the aeration process is collected in a tank for this filter process.
- The aeration process treats waste water in the first tank. Water is permitted to enter the second tank following the procedure.
- After being treated by biochips and bio balls in the second tank, the water is permitted to proceed to the third tank, which houses the activated carbon filter.
- Activated carbon: This material absorbs any harmful molecules by acting as a strong magnet.
- The treated water will be tested to see how much the process has purified it after it is all finished.



Methods Involved In Sewage Water Treatment Using (MBBR) Moving Bed Biofilm Reactor

RESULT & DISCUSSION

CHARACTERIZATION OF TREATED EFFLUENT TRAIL 1

The pH value is being reduced at minimum in the process of trail 1 and in the trail 2 pH value is being reduced at maximum.

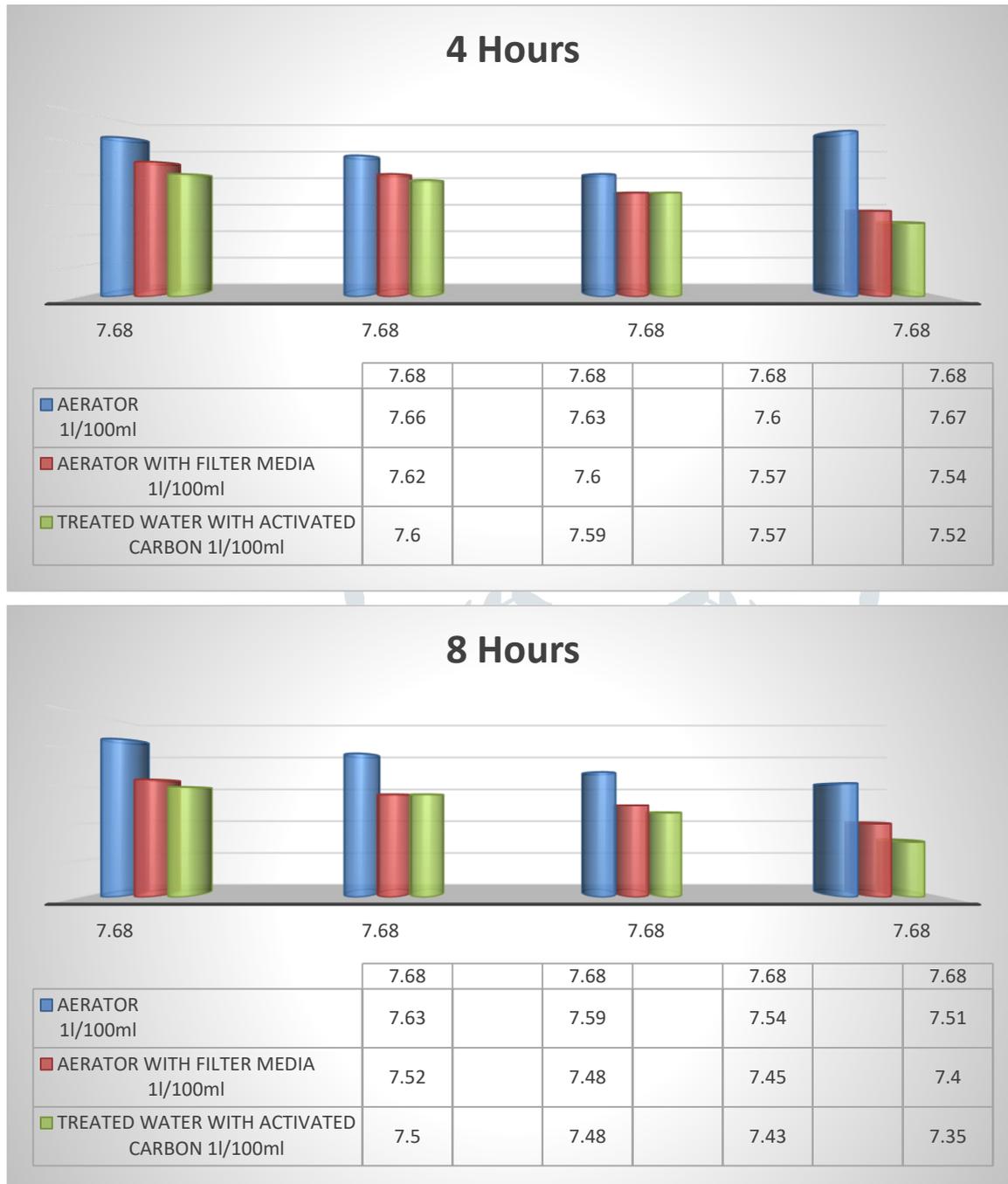


Fig. 15 GRAPHICAL REPRESENTATION OF 15 DAYS pH TESTING RESULT

The Tss value is being increased initially in the process of trail 1 and in the trail 2 Tss value is being increased gradually.

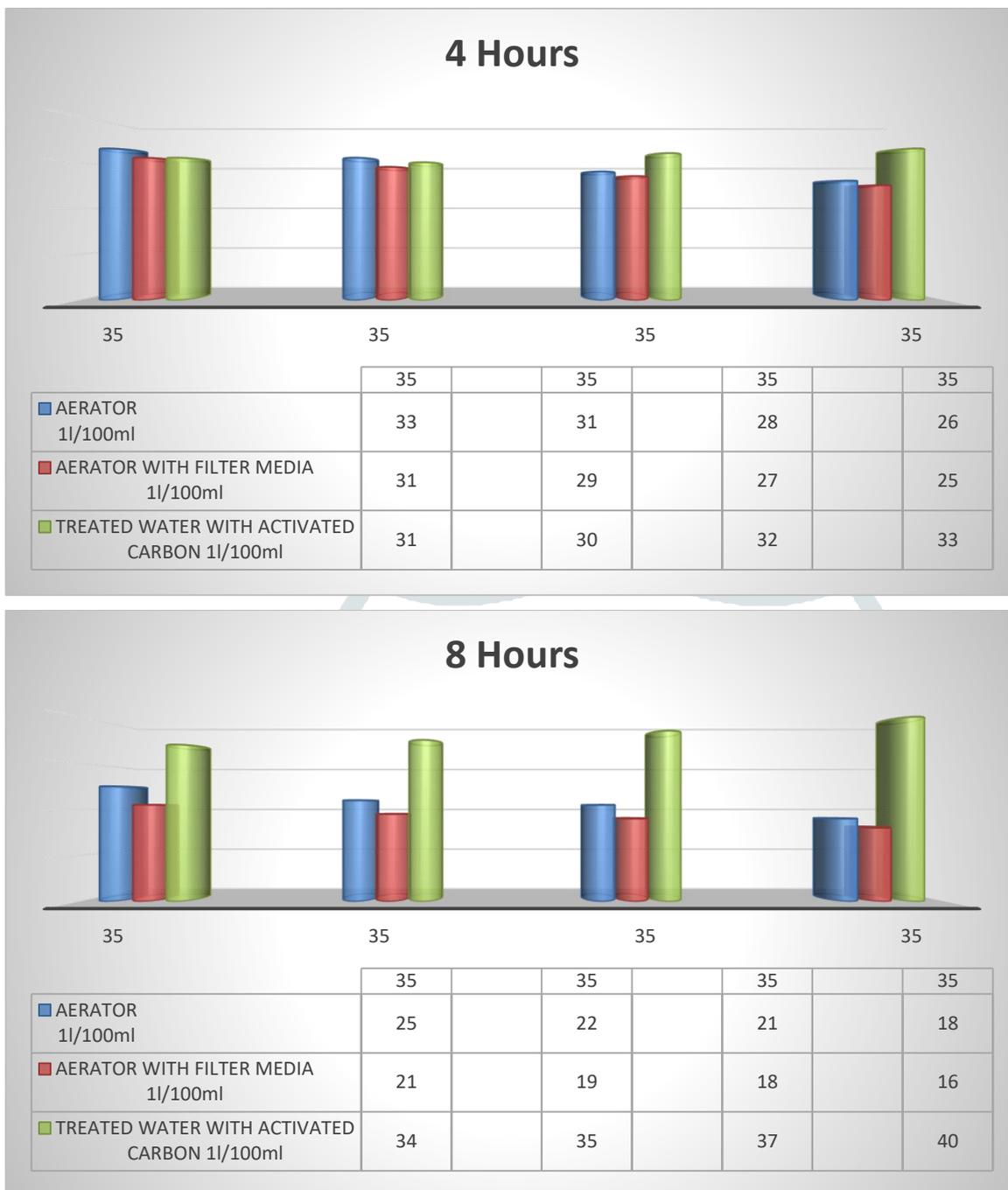


Fig. 16 GRAPHICAL REPRESENTATION 15 DAYS TSS TESTING RESULT

The TDS value is being decreased rapidly in the process of trail 1 and in the trail 2 TDS value is being decreased continuously.



Fig. 16 GRAPHICAL REPRESENTATION OF 15 DAYS TOTAL DISOLVE SOLIDS TESTING RESULT

The DO value is being increase at minimum in the process of trail 1 and in the trail 2 DOvalue is being increase at gradually

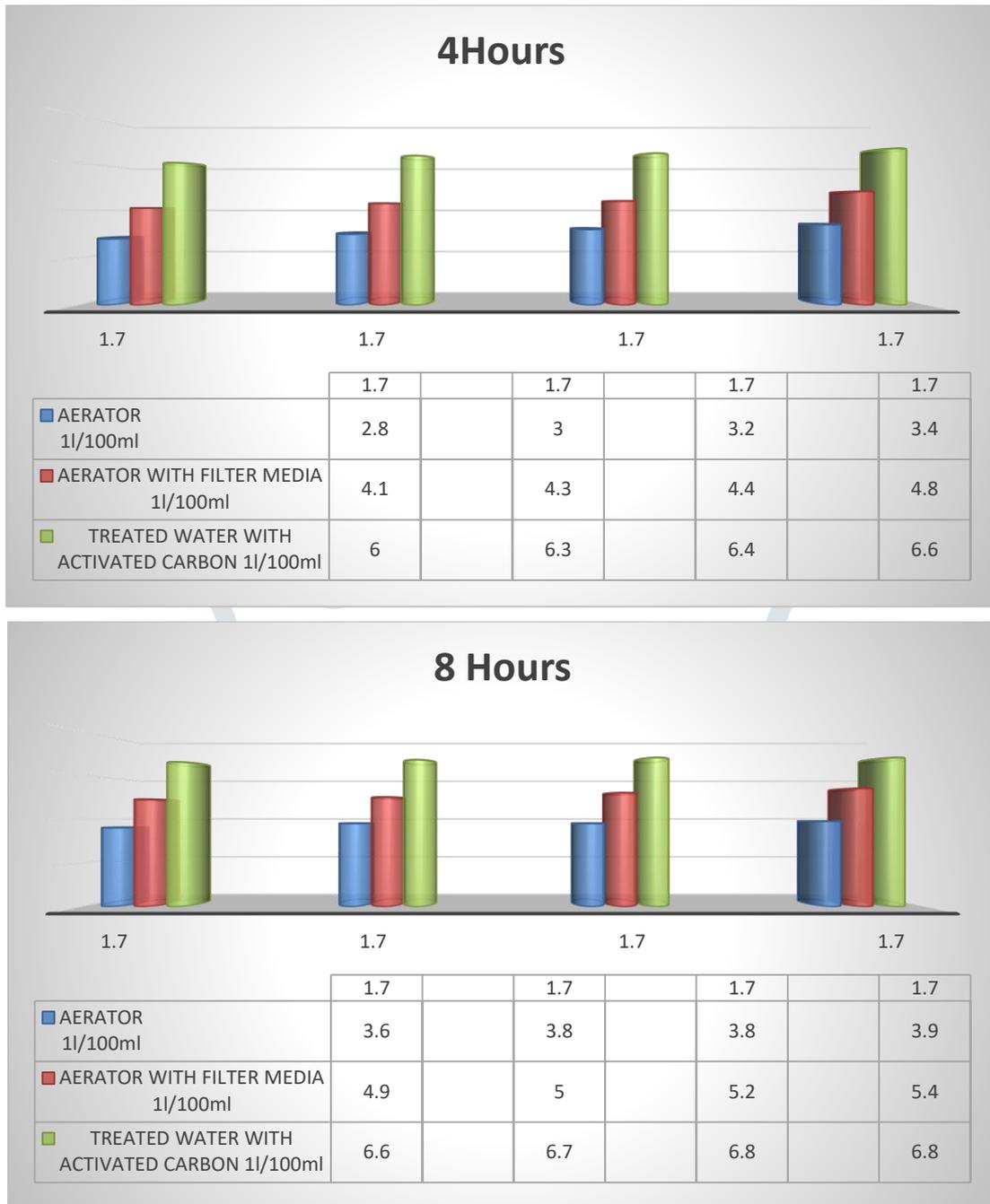


Fig. 17 GRAPHICAL REPRESENTATION 15 DAYS DISSOLVE OXYGEN TESTING RESULT

The COD value is being reduced in the process of trail 1 and in the trail 2 COD value is being decreased at gradually.

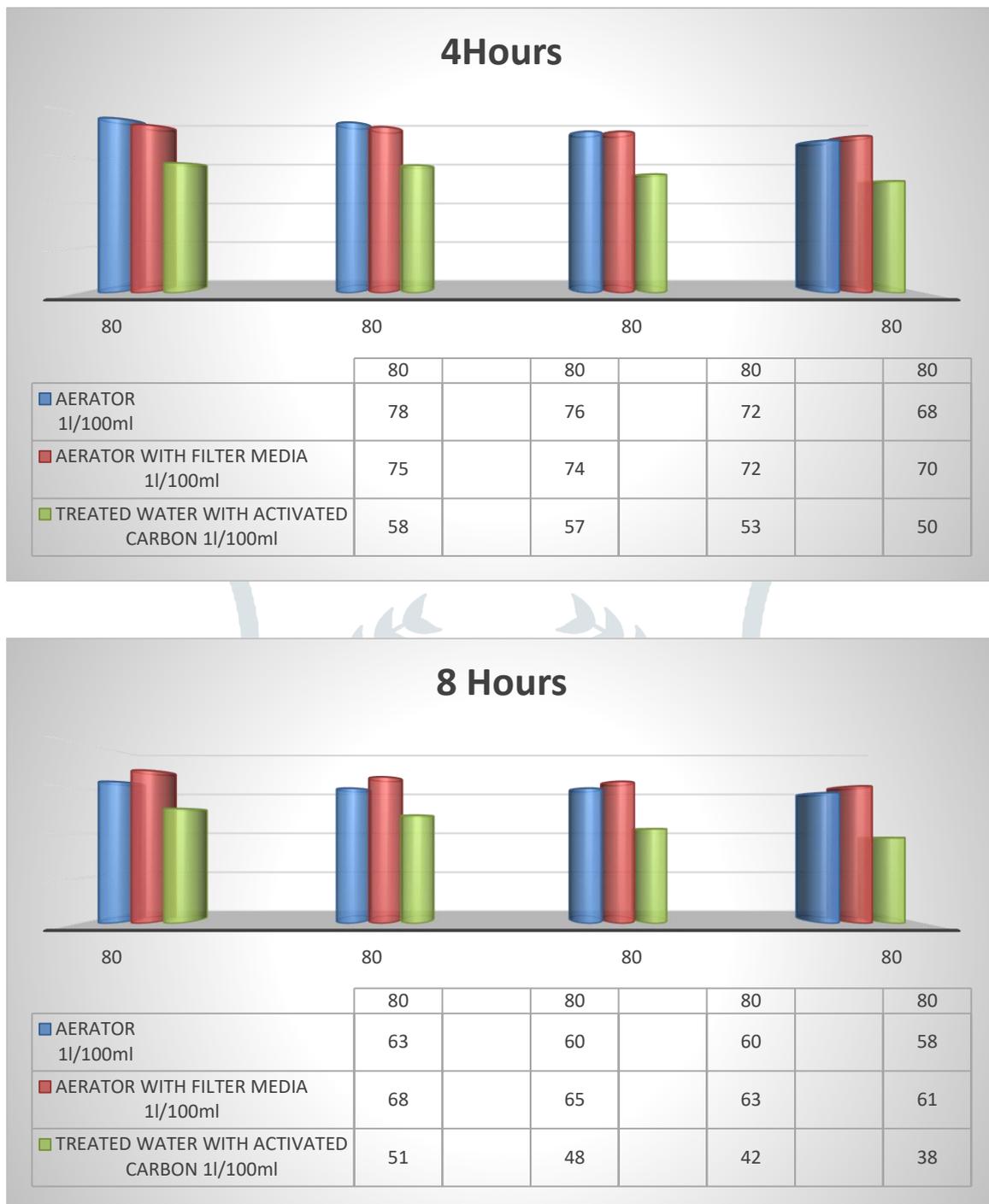


Fig. 18 GRAPHICAL REPRESENTATION OF 15 DAYS COD TESTING RESULT

CONCLUSION

This study concentrated on using a moving bed biofilm reactor (MBBR) to treat sewage. Three systems make up the experimental setup: the activated carbon process, filter media, and aerobic system. The sewage was treated in the presence of oxygen in the aerobic tank by continuously blowing with a tank air blower for eight hours over a period of ten days; the sewage was treated continuously with biochips in the filter media tank for eight hours over a period of fifteen days; and the treated effluent was then stored in the sedimentation tank to settle. The trial 1 value and the trail 2 value is shown in the result. The water has become colorless. And the COD value is being completely reduced

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