S&G 15 (2020), pp. 11-17

S&G JOURNAL
ISSN: 1980-5160

MEMBRANE BIOREACTOR: TECHNOLOGY FOR EFFLUENT TREATMENT

Joicy Alves Batista
joicyalves00@hotmail.com
University Center of Goiatuba – UniCerrado, Goiatuba, Goiás, Brazil.

Luana Rodrigues Costa
Costa_lu005@outlook.com
University Center of Goiatuba – UniCerrado, Goiatuba, Goiás, Brazil.

Mylena Luiza de Oliveira
mylenaluizaoliveira5@gmail.com
University Center of Goiatuba – UniCerrado, Goiatuba, Goiás, Brazil.

ABSTRACT

Most sewage treatment plants have classical processes, which are usually coagulation-flocculation of biological treatments. It is noted that in large metropolises the problems of sewage treatment have spread, and part of these effluents, both domestic and industrial, are usually discharged into the environment, causing problems and risks to the health of the population; therefore, new treatment methods are needed to avoid damage and contamination to the environment. In addition, the growth of urban environments has left few alternative areas available for the implementation of sewage treatment plants (STPs), as these require significant space for their installation. As alternatives to conventional wastewater treatment plants, a new technology has emerged from a simple biomass filtration concept: membrane bioreactors (MBR). This article aims to demonstrate how effluent treatment procedures are carried out using MBR technology, with which we have the possibility to work with high application rates, with the viability of an improved effluent and with viable water reuse options.

Keywords: technology in the effluent treatment system, membrane bioreactors, operation of effluent treatment systems.

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DOI: 10.20985/1980-5160.2020.v15n1.1538

S&G Journal
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1. INTRODUCTION

A proper domestic effluent treatment system is indispensable for the protection of health conditions, as it provides the control and reduction of the number of infections and diseases generated by contaminated water. Sewage collection improves the environmental and life quality of urban populations. However, it does not exclude the effects of effluent emissions in water environments. For this reason, its treatment is indispensable for the preservation of the water quality of the receiving bodies, as well as the environment and the health of the population. The Brazilian Institute of Geography and Statistics (IBGE, 2002) considers sewage treatment a good precursor to human development, since it shows, mainly, the quality of life of the population domiciled in a certain place.

According to data from IBGE (2002), the proportion of treated sewage compared to the total collected in Brazil in 1989 was 19.9%, and in that year 10,667,823 m^3 were collected per day. Eleven years later (2000), the total volume collected per day was 14,570,079m^3, and only 35.3% of these were treated, i.e. over 60% were left without proper treatment.

In the 1960s, the USA already used reverse osmosis for water desalination, but it was from the 1990s onwards that the use of membrane filtration resources was studied in sanitation. In Brazil, this strategy has been the object of study of several universities, such as the University of São Paulo (USP), Federal University of Rio de Janeiro (UFRJ), Federal University of Rio Grande do Sul (UFRGS), State University of Maringá (UEM) and Federal University of Santa Catarina (UFSC).

These studies, which have been developed in partnership with membrane manufacturers, have helped the membrane filtration process to decrease rapidly, which may contribute to its future use in several countries.

Among the processes related to filtration, the membrane bioreactors (Membrane Bio Reactor - MBR), whose method of use has shown great potential for sanitation, by linking biological treatment with membrane separation, stand out.

The main function of the bioreactor is to degrade organic and mineral matter, while the membrane performs the separation of liquid and solid phases. This alternative is highly effective in eliminating pollutants, generating low energy consumption necessary for the reduced area of installation, because it works with high concentrations of biomass (Maestri, 2007).

In large metropolises, whose growth has left few areas for sewage treatment plants (STP), MBRs work as a viable alternative for biological effluent treatment combined with membrane filtration.

Although the technologies typically used for sewage treatment (physical-chemical processes, activated sludge systems, stabilization ponds, biological filters, etc.) are successfully applied in effluent treatment, they can be replaced or combined with new technologies that provide wastewater, commonly known as sewage, with reuse quality, in the case of MBRs that stand out as a variant of microbiological processes, differentiating themselves by replacing the secondary decanter with a micro or ultra-filtration membrane unit.

Therefore, the general objective of this review study is to analyze how the effluent treatment procedures are performed through MBRs, as they provide an improved effluent with viable reuse options. The following specific objectives were outlined: to evaluate the MBR competence in the removal of contaminants from sanitary sewers; to analyze the development of biomass in the bioreactor; and to qualify the permeate for its use.

2. BIBLIOGRAPHICAL REVIEW

At the rear, the Industrial Revolution started in the 17th century, followed by a social model that incurred, for example, the amplification and distribution of consumer goods in ever greater volumes and with ever more accelerated rhythms. The analysis of natural resources was followed with industrial development, which over time caused a great environmental imbalance, given the sum of several factors, such as the uncontrolled extraction of natural raw materials and the production of waste (solids, liquids and gases) composed of several substances used. Another factor associated with the Industrial Revolution is the urbanization that triggered a high demand for consumer goods (Goulart and Callisto, 2003).

Given the growing concerns about the economy generated by water and the limitations of legislation, the reuse of water has been a topic of interest in the world context. Alternatives are sought for the integration of different activities so that the waste water from a given process is used directly in another process that needs lower quality water, thus contributing to water savings and the preservation of supply sources (wells and surface water). Another possibility is the reuse of water in a closed cycle, in which all the effluent generated must be treated, using an appropriate process, and reused.

About that, the following question is made: Are the effluents being treated? How?

2.1 Effluent treatment

The treatment of industrial effluents is governed by NBR 9800/1987, to which liquid waste from industrial activities, cooling water, polluted rainwater and domestic sewage are incorporated (ABNT, 1987). The effluents have numerous toxicological effects on the environment and public health. This is due to the physical, chemical and biological complexity of any tailings that are directly caused by production processes. The main parameters to be pointed out in the effluent discharge are turbidity, color, dissolved oxygen concentration, total dissolved solids concentration, pH, hardness, temperature, total nitrogen and phosphorus concentration, pathogenic microorganisms, chemical oxygen demand (COD), biological oxygen demand (BOD) and alkalinity (Dezotti, 2008). The parameters indicated in this control do not imply in the quality and proper disposal of the effluents in a given body as receptor; in this sense, each waste has characteristics related to its origin, such as specific compounds that often, even in low concentration, trigger environmental imbalance.

In general, when referring to effluent treatment, some levels that can help in understanding its efficiency are characterized. Such levels can be defined as preliminary, primary, secondary, tertiary and advanced levels that result in the combination of several unit operations.

Effluent is defined as all waste and unwanted material removed in an industrial or domestic process. Impurities can be organic or inorganic matter, broken or in suspension, such as microorganisms, heavy metals, oils and greases. Consequently, the appropriate treatment for a given effluent depends on the amount and type of material that composes it. In addition, there are undesirable characteristics such as acidity, alkalinity, turbidity, toxicity, color and odor, which summarize the type of residue contained therein and are factors considered in the treatment. In addition, effluents are defined as industrial or domestic.

2.1.1 Industrial effluents

This group includes the residues produced during the industrial process and which are no longer used by the company. As there are many classes of industries, industrial waste is also diversified (e.g. mining waste; and organic waste from the food industry). It is worth mentioning that there are federal laws that determine prohibitions and parameters regarding the minimization of environmental damage, such as the National Environmental Policy Law.

2.1.2 Domestic effluent

Even though they have less polluting potential, the materials produced in our homes also generate serious damage to the environment. The high level of organic material requires a proper destination, and any chemicals increase the environmental impact. Examples of domestic effluents are: sewage from buildings and commercial buildings; grease trap boxes from houses, restaurants and snack bars; and septic tanks, very natural in rural areas.

According to Mello (2018), the effluent treatment process comprises several steps that can generate physical, chemical or biological processes.

2.2 Preliminary treatment

In the preliminary treatment, through physical processes, there is a reduction of coarse solids, that is, materials with a diameter above 10 mm. Sieving is also used to remove coarse material of smaller diameters (grease trap box). However, depending on the pH and volume of the effluent, neutralization and homogenization, steps can be added.

2.3 Primary treatment

For primary treatment, the removal of suspended solids is carried out through coagulation, flocculation, sedimentation and flotation procedures. During coagulation and flocculation, the mechanism of dirt particles removal occurs with aluminum sulfate dosage, causing the flakes to move, gaining weight, volume and consistency. Sedimentation is the solid-liquid separation by density difference, causing the solid to accumulate at the bottom, and its speed is adequate to the size of the particles. The flotation is based on the addition of air bubbles. The particles bind to the bubbles, forming a set of density lower than the fluid, generating foam on the surface that is removed ahead.

2.4 Secondary treatment

The purpose generated through secondary treatment is the application of aerobic and anaerobic biological methods. The idea is to take advantage of the metabolism of microorganisms for the removal of biodegradable organic matter present, which acts as a substrate for these microorganisms. As a result, the biomass grows and this formed sludge can be sedimented and circulated in the process of increasing the efficiency of organic matter removal.

2.5 Tertiary treatment

The treatment of tertiary level effluent is little used in industrial processes; however, this treatment becomes indispensable to achieve the necessary quality for the reuse of

S&G Journal
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DOI: 10.20985/1980-5160.2020.v15n1.1538

inputs in the industrial process. Its final stage is the reduction of all the suspended solids, micropollutants, microorganisms and organic load that persisted to the previous stages. Some of the techniques used are maturation lakes for destruction of microorganisms, mainly pathogens, filtration and membrane processes for the retention of suspended solids, adsorption of micropollutants into activated carbon, ion exchange and chemical oxidation. After these procedures, the effluent has enough quality to be safely disposed of.

The current technologies for the treatment of effluents are quite diverse. Here are some options, with emphasis on new technologies; in particular, the MBR method will be analyzed more accurately.

It is essential to know that the treatment of effluents generally causes human and industrial waste to be disposed of without offering any risk to the health of the population or generating consequences to the environment, making them suitable for reuse, thus mitigating the impacts that can be generated due to lack of water.

It is remarkable that industries have been playing a major role in water and wastewater treatment, making new technologies efficient for the purification of waste before it is disposed of, as required by environmental agencies.

It is of utmost importance to emphasize the applicability of water and effluent treatment steps, as they are planned to achieve improvements in effluent and water quality and reduce suspended solids, biodegradable organic products, bacteria and other pathogenic organisms, and nutrients (including nitrate and phosphate).

2.6 Water and wastewater treatment technologies

- Most common physical processes

In effluents with water-insoluble substances or colloids the physical processes used are decantation, filtration or centrifugal separation. In addition, grids, filters or filtration membranes are used.

- Filtration membranes

This term is used to designate different physical separation processes that have in common the use of membranes, but of different types. This treatment of water and effluents aims to separate the substances considered soluble and insoluble from waste water, attracting the liquid to pass through a semipermeable membrane. Some of the positive points of this process are: it does not require the addition of chemicals; low energy use; and easy application and conduction of the processes.

- Flotation

Depending on the composition of the wastewater, it may be necessary to use a physical process called flotation, which uses adhesion forces so that finer particles are separated by adhering to small air bubbles.

- Chemical treatment processes

It is a method for adding chemicals to speed up the disinfection of effluents, as these products induce chemical reactions, usually associated with biological and physical processes for greater efficiency. The most common chemical processes are chemical coagulation, precipitation, oxidation, ion exchange, and neutralization and stabilization.

- Biological treatment

These are biological treatment methods used to remove dissolved and suspended organic matter in wastewater. Environmental conditions are improved to stimulate the growth of microorganisms that use organic compounds as substrates. These water and wastewater treatment processes also remove other wastewater components, such as: suspended solids; nitrogen; phosphorus; heavy metals; and xenobiotics.

2.7 Membrane bioreactor treatment

MBRs are the result of the combination of the biological effluent treatment process and membrane separation. This process is normally similar to conventional effluent treatment, except for the separation system of activated sludge and treated water. The main function of the membranes is to retain biomass, replacing the decanters of conventional biological treatment plants. The membranes are capable of retaining the total liquid located in the biomass, and significantly reduce the area occupied by the treatment plants, ensuring the production of better quality and better treated effluent (Holbrook et al., 2005).

This procedure was adopted in the late 1960s, when commercial micro and ultrafiltration membranes were released to the market. Smith et al. (1969) launched the original project, combining the use of activated sludge reactors with the membranes, operating in tangential flow. At the time, this project did not attract so much interest because of the expenses that the membranes caused, the low economic value of the product, and its high potential for loss of performance through its incrustations.

Later, Yamamoto et al. (1989) rediscovered the method with the idea of using submerged membranes located inside the reactors. These membranes needed their own space for their installations, with high pressures and tangential

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speeds. Another important step in the process, according to the authors, was the acceptance of modest flows and the idea of using bubbling to control fouling.

Other improvements have been introduced since the 1990s, including a considerable reduction in costs for the production of membranes, which has allowed the use of this process in industries.

There are two types of MBR available for the treatment of domestic or industrial effluents: with modules outside the aeration tank (Figure 1) and with modules submerged in the aeration tank (Figure 2). These reactors have hull, plate, frame, or hollow fiber configurations.

In the external modules, the contents of the reactors are pumped into the modules, usually tubular. This process operates cross flow, i.e. the solution flows parallel to the membrane surface, while the permeate is transported across it.

Although MBR with external module are simple and easy to operate, they have high power consumption to allow the necessary pressure difference for permeation and to provide speed to the suspension. The high shear produced in the suspended solution circulation may cause the release of macromolecules from inside the cells, increasing the concentration of compounds that can be absorbed in the membrane pores, thus decreasing their flow.

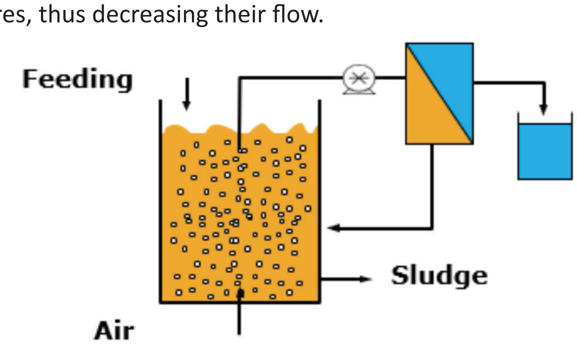

Figure 1. Membrane module outside the aeration tank
Source: Maestri, 2007.

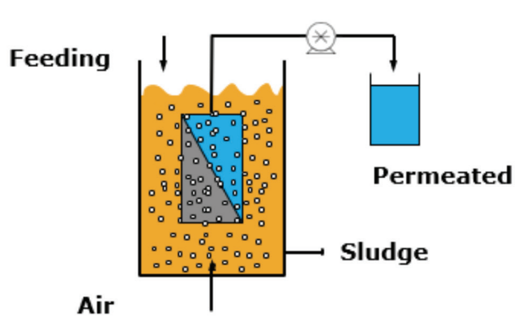

Figure 2. Membrane module submerged in aeration tank
Source: Maestri, 2007.

Although MBR with external module are simple and easy to operate, they have high power consumption to allow the necessary pressure difference for permeation and to provide speed to the suspension. The high shear produced in the suspended solution circulation may cause the release of macromolecules from inside the cells, increasing the concentration of compounds that can be absorbed in the membrane pores, thus decreasing their flow.

The submerged membranes use a type of hollow fiber, or flat plate. While flat membranes are installed vertically, hollows can be installed either vertically or horizontally. In this type of membrane, aeration has the following functions: to maintain cleanliness on its surface, to provide oxygen to the microbial community, and to maintain the biomass suspension inside the reactor.

The shear force generated on the suspension is lower than that produced for external module systems; as a result, activated sludge flakes with better characteristics are available. The turbulence present in the aerated tank and the effect of the bubbles become sufficient for the production of satisfactory conditions and operations to keep the flow practically constant, increasing the transmembrane pressure (TMP) low.

Submerged membrane modules are usually called membrane bundles, as fiber arrangements are employed without a particular housing wrapping. For industrial use, the fibres are prepared in such a way that both ends of each one are attached and closed in a solid resin, avoiding contamination of the permeate extracted through the interior of the fibres.

The main advantage of the submerged module is the low energy consumption. It is clear that the energy required for the production of vacuum for the bioreactors is often less than the energy applied for external module bioreactors using centrifugal or positive displacement type pumps. However, the flows permeate through the submerged modules are smaller compared to those obtained with external modules.

Among the difficulties in using MBR are concentration polarization and inlays. The relationship between the membrane and the reactor content occurs in all membrane separation processes and reduces permeate flow.

Generally, the operating technique applied for maintaining stable permeate flow consists of permeation, achieved by suction, alternated with backwash, in which a portion of the permeate is pumped in the opposite direction to the permeation. It is necessary to emphasize that, instead of the permeated, some authors use air to perform the backwash operation.

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2.7.1 Important aspects in MBR

Even with the simplest technologies for sewage treatment, such as lagoons, up to the most advanced, such as MBRs, there are several external factors that interfere with the performance of the treatment methods, they are: climate oscillation, variation and temperature in the characteristics of the affluent.

Other parameters suitable for the operation, which can be controlled, are oxygen concentration, pH and biomass concentration, considered common in sewage treatment steps with suspended biomass.

Other factors that may influence the performance of MBRs are:

- Aeration, which provides oxygen to the microorganisms contained in the biomass, ensuring their activity and the biodegradation of organic matter; and

- Concentration of dissolved, colloidal or suspended solids that are found in the reactor.

2.7.2 MBR for water reuse

The absence of specific legislation or standards on the reuse of water from treated effluents has ignored the economic and social interests of this practice.

Taking into account that part of the processes that reuse water, essentially in urban centers, use non-potable water, MBR (permeated) effluents could be used for reuse, since they reach the standards established by legislation.

The effluents generated by microfiltration or ultrafiltration are free of particles, coliforms and viruses, but organic and inorganic nutrients are not removed. The permeated is occupied by heterotrophic bacteria, whose population is controlled by complementary sanification with chlorine or ultraviolet light. The appearance of organic and inorganic contaminants in the effluents limits the reuse of this type of water for industrial or commercial purposes that do not support chemical contaminants. The reuse water that is established by microfiltration and ultrafiltration has a quality that can be improved using flocculants before the filtration phase (Schimmoller et al., 2001 apud Schneider and Tsutuya, 2001).

In Brazil, NBR 13.969/1997 and the manual for Conservation and Reuse of Water in Buildings - ANA/FIESP & SindusCon/SP (2005) establish quality standards so that treated sewage of domestic origin or with similar quality can be reused.

3. METHODOLOGY

It is a systematic bibliographic review study, suitable for consensus searches on some specific theme. A search in a bibliographic database, such as Google Academic, was performed in order to identify articles, theses and books on the subject. The descriptors used for the searches were: technology in the effluent treatment system, membrane bioreactors, and operation of effluent treatment systems.

4. FINAL CONSIDERATIONS

As already mentioned in this article, because it is a modern technology, few studies on MBRs have been conducted in Brazil. However, considering their high potential for reuse, it is suggested the development of new research that can evaluate the costs of facilities and operations.

The MBR presents itself as a new unchanging technology in the industrial sector; however, there are doubts regarding the cost-benefit for its use on a municipal scale.

The reuse of water is mainly to irrigate private and public areas; however, its production is linked to four domestic and industrial sewage treatment plants that operate from activated sludge, sand, stone and coal filtration, in addition to its chlorination. The installations are similar to drinking water supply, but their signaling must be adequate so that it does not contain the intake of reuse water.

Based on the premises of environmental law, as a source of precaution, the application of MBR has been more accepted, since it presents a better guarantee in the generation of water for reliable reuse and quality.

Thus, local water scarcity and restricted effluent discharge legislation should encourage the reuse of treated sewage and throw MBRs into the municipal sector. Compared to traditional sewage treatment processes that require more steps or adaptations to obtain a product suitable for reuse, it has been found that for this type of technology (MBR), only chlorination is sufficient.

It is understood that the purpose of this article has been achieved, demonstrating the feasibility of an improved effluent with viable reuse options.

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Received: May 21, 2019

Approved: Mar 03, 2020

DOI: 10.20985/1980-5160.2020.v15n1.1538

How to cite: Batista, J.A., Costa, L.R., Oliveira, M.L. (2020), Membrane Bioreactor: technology for effluent treatment, Revista S&G 15, No. 1, 11-17. https://revistasg.emnuvens.com.br/sg/article/view/1538