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Research and Application of Membrane Technology in Wastewater Treatment of Vietnam's Industrial Parks

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Abbreviate:
The goal of this article is to research and filter membrane technologies that have been used in the world and in Vietnam. The author synthesizes membrane technologies, then analyzes the characteristics, filtration methods, advantages and disadvantages of filtration technologies that have been and are being used such as MF, NF, UF, RO, MBR, etc. By observation and actual survey methods in industrial parks in Vietnam, the author has analyzed actual filtration membrane models applying MBR technology to treat industrial wastewater in industrial parks in Vietnam. From there, the article proposes recommendations to be able to perfect MBR filter technology.
Keywords: *Membrane technology, wastewater treatment, industrial park, Vietnam*

1. Introduction

Currently, the process of industrialization and modernization in Vietnam is developing very rapidly, associated with that, industrial wastewater pollution is an important and urgent problem today. According to statistics, about 70% of wastewater from untreated industrial parks is discharged directly into the environment. Therefore, wastewater treatment is a top concern in the world as well as in our country, especially the application of membrane technology to the treatment process (Bao et al., 2016; Polruang et al., 2018).

Industrial wastewater is a major cause of environmental pollution due to the content of SS suspended substances, organic matter (BOD, COD) and nutrients (N, P). Therefore, tightening waste discharge requirements, improving discharge requirements and standards is a matter of concern to the world in general and Vietnam in particular. The majority of wastewater treatment plants in industrial parks in the world are traditional biological treatment technologies with primary and secondary treatment to remove the majority of organic matter and suspended solids. However, many studies show that the application of these membrane technologies has not thoroughly filtered the waste in wastewater. Therefore, the problem is to improve the technology of factories to treat wastewater, improve the level of treatment, and enhance the removal of solids, organic matter, nutrients or toxic substances.
The structure of the article consists of 05 parts in addition to the introduction with an overview of membrane technologies, research methods, research results and conclusions.

2. Literature review

2.1. Membrane Concept

Filter membranes are very thin sheets made from synthetic materials with very small and fine pores or pores (Chen et. al, 2024).

The membrane has very small pores that provide the best efficiency in purifying water. To purify water, the membrane helps you remove bacteria, impurities, and even salts in the water. The filter membrane

separates the 2 phases, capable of creating resistance to separate some particles in the water such as suspended deposits, ions, microorganisms, etc. When putting the swing solution through the membrane. Through the working process of the membrane, the inlet mixture is separated into 2 lines, one part is the post-filtration solution and the material part is retained by the membrane. Thereby, the separation of substances is carried out on the basis of differences in the penetration of substances under the influence of different dynamics. The structure of the membrane must ensure selectivity corresponding to the substances to be separated, have minimum water strength and at the same time meet the requirements for mechanical-physical strength (Chen et al., 2024).

The purpose of the membrane process is to separate impurities from the aqueous environment. Membranes have different selective permeability for different constituents.

The pore size of the membrane will determine the permeability of the constituents. Except in the case of electrodialysis, dialysis, reverse osmosis, ion exchange,.. Other cases are characterized by solutes that are larger than the pores of the membrane will be retained without being transported through the film.

In accordance with the definition of the membrane process in the process of separation of substances, it is necessary to create the flow of water. If in the process of ordinary particle filtration it is possible to use the hydrostatic pressure of the water column, in the membrane process, an external pressure called dynamic pressure is always needed to promote the process speed because the smaller the flow section (pores of the membrane), the higher the resistance.

The flow rate is directly proportional to the pressure difference. The pressure required to squeeze water through the membrane is called *TransMembrane Pressure* (TMP). TMP is defined as the pressure difference of the membrane, or the average value of the difference between the intake flow pressure and the pressure of the seepage flow.

2.2. Principle of membrane filtration

The principle of membrane filtration is based on the separation of particles in the water through the septum (membrane) by the applied force (Gao et. al., 2023)

Based on the size of the retained matter and the pressure on the membrane, we divide the membrane into the following types:

- Microfiltration (MF): capable of separating bacteria, suspended substances, has been applied to separate colloidal and granular substances.
- Ultrafiltration (UF): capable of separating viruses, bacteria, suspended substances, has been applied to separate substances with large molecular weights
- Nanofiltration (NF): capable of separating viruses, bacteria, suspended substances and a part of high-value chemical ions, is applied to separate solutes with small molecular weight
- Reverse osmosis (RO): capable of separating viruses, bacteria, suspended solids, high-valent ions and I-valent ions, is applied to separate solutes with microscopic molecular weights (Judd, 2010).

The membrane helps to treat wastewater effectively. Membrane technology helps remove impurities, suspended solid particles, bacteria, viruses, heavy metals, and small organic substances. This helps to improve the quality of treated water, meet environmental standards and protect natural water sources.

Besides, the membrane also provides clean water. Membrane technology is applied in the water purification process to remove impurities, bacteria, and pollutants to provide a safe water source. Membrane technology allows water to be reused after treatment, minimizing the waste of water resources; Membrane technology helps protect public health; Membrane technology helps protect the environment.

In conclusion, membrane technology plays a very important and practical role in people's daily life, especially in industrial parks in Vietnam.

N.	Name	Depict	Filter hole size	Boom Pressure	Popular Applications	DURABILITY	Filter Objects	Advantage	Shortcoming	Application
1	MF Filter Membrane	Acts as a mesh that blocks particles larger than the size of the filter hole from passing through. The membrane is gradually blocked over time due to sediment	0.1 - 10 micrometers	1-3 bar (15-45 psi)	Water treatment, beverage processing, pharmaceutical refining	High – due to its construction from durable materials such as polyethersulfone (PES), polypropylene (PP), or cellulose.	Bacteria, algae, yeast, spores, some larger suspended particles such as sludge, soil, polymer particles, organic residue	- It is capable of effectively removing solid particles, bacteria and microorganisms larger than the pores of the membrane, thereby improving water quality.- It does not use chemicals to purify water, so it is extremely safe and protects the environment.- It can operate effectively at low temperatures.- The process is relatively simple, have high consistency and accuracy. - Consumes less power than Nano filters.	- Ions or dissolved substances in water cannot be removed.- Regular maintenance and cleaning are required to ensure efficient operation.- Operating costs are high.- Only suspended matter and bacteria larger than the opening hole are removed.	- Cold disinfection of beverages and foods or purification of fruit juices.- Removing bacteria from water makes it suitable for wastewater treatment, separating oil from water and reducing turbidity of water.- Processing dairy products while retaining protein content.- Used as a water pretreatment kit through RO systems to reduce load and protect membranes filter.
2	NF Water Filter (Nano)	The intermediary between 2 forms of filtration is UF and RO	1 - 10 nanometers	4-25 bar (60-360 psi)	Desalination, water softening, removal of organic and inorganic matter	Low – due to chemical sensitivity and requires thorough maintenance.	Ion>2 chemotherapy, small molecule organic matter, hormones, pesticides, complex organic compounds, heavy metals	- It is capable of effectively removing organic substances that are smaller in size than MF filters.- It can remove some heavy metal ions and water-soluble ionics such as nitrates, sulfates, chlorine,...- No electricity is used or wastewater is used during the filtration process,	- High pressure is required, so you have to use a strong pump system to make the product operate most efficiently.- It cannot be used in many areas, especially areas with water sources contaminated with limescale,	- Removal of pesticides from groundwater, heavy metals from wastewater and recycling of wastewater in laundromats.- Reduction of salt content in brackish water.- In the chemical industry helps in the recovery and exchange of

								which saves costs.- The water can be drunk immediately after filtration but has to be treated.	brackish, and salinity.- The water filter must be replaced periodically, so it is costly. - The filter membrane is easily clogged if the inlet water source is too dirty.	solvents.- Removal of some gas condensate cleaning components in the petrochemical industry.- In the production of essential oils used in the crude extraction stage, enrichment of compounds.- Extraction of amino acids, fats from blood and cultured cells in pharmaceutical production.- Use in milk and juice production.
3	Màng lọc nước UF (Ultra Filtration)	The mechanism is similar to the MF membrane, the filter hole size is smaller	0.01 - 0.1 micrometers	2-10 bar (30-150 psi)	Protein separation, wastewater treatment, food industry	Medium – constructed from materials such as polyethersulfone (PES) or polysulfone (PS).	Viruses, proteins, some types of colloids, enzymes, large organic molecules, organic and inorganic colloids	- Effectively removes solid particles, bacteria, microorganisms and impurities larger than the size of the pores of the membrane.- It can retain beneficial ions, minerals, and mineral salts.- The filtration process takes place at normal temperature and low pressure, so it saves electricity.- No waste of water.	- Dirt, moss and bacteria will be trapped at the bottom of the filter cup, and then the scale will close after a period of use, causing clogging of the filter head, affecting water quality.- Small harmful bacteria will easily pass through the filter membrane. Thereby harming the body when you use it for a long time.- Regular	- Making pretreatment sets for RO filtration membranes, including desalination of seawater, salt water and salt.- Used in the field of water purification, production of bottled pure drinking water.- Disinfection of industrial water, colloids, suspended impurities and organic molecules.- Industrial fermentation,

									maintenance and cleaning are required to maintain the filtration performance.	pharmaceutical technology focuses on purification and cleaning.- Treatment of water to create mineral water, spring water, filtered water, purification of total water for household life.- Treatment of industrial wastewater, wastewater and reuse.- Disinfection and removal of turbidity in the wine production process. - Aquaculture water purification.
4	RO (Reverse Osmosis) Water Filter	Use pressure to resist natural osmosis, pushing water through a membrane with very small filter holes. Only water and some particles that are similar in chemical properties and size can pass through.	< 1 nanometer	30-80 bar (450-1200 psi)	Drinking water purification, industrial water treatment, desalination	Low – prone to clogging and requires regular maintenance.	All ions (mineral salts, metals), very small particles, microorganisms, viruses, organic compounds, all kinds of dissolved impurities	- Can filter out dissolved substances such as ions, bacteria, viruses, organic matter, chemicals, and small impurities.- Creates a pure water source that can be drunk immediately after filtration without boiling.- RO filter membrane has the ability to flush itself when purifying water, saving you the cost of replacing the filter cartridge.-	- High operating costs.- Cannot be used in alum-contaminated and highly acidic water sources.- The filtration process discharges about 40% of the input water, causing water waste.- Using electricity, if the power goes out, there is no pure water to drink, even the purifier cannot operate.- Due to	- Used in bottled water filtration technology.- In the food industry: desalination, filtration of food liquids. Applied in wine production technology.- Car washing at the final stage helps the car to be clean and free of spots on the car. In addition, reverse osmosis water helps reduce car drying equipment such as air blowers, saving

								Often accompanied by additional cores of minerals substances that are beneficial to the body. - Water pump can be integrated for places with low water pressure.	the high ability to filter dirt, the filter membrane life is short. - It is prone to clogging and dirt, so it needs to be maintained and cleaned periodically.	time and effort. - Desalination in seawater or brackish water to create a source of fresh water. - Disinfection prevents pathogenic bacteria.

(Source: Summary of the author)

3. Research methods

Wastewater treatment technology with microfiltration membrane is an advanced technology widely applied by developed countries such as Japan, the United States, and Europe in the past two decades. Especially in which the technology of membrane bio reactor (MBR) has proven outstanding advantages in treatment efficiency, operating and investment capital.

Wastewater treatment with MBR technology is a combination of two basic processes in a single unit:

- Biodegradation of organic matter;
- Micro-filtration technology for separating bacterial biomass with micro-filtration**.**

Wastewater treatment with MBR technology replaces traditional biological treatment technology, combining bioreactor tank and sedimentation tank in just one simpler construction and operation (membrane assembly can be submerged in bioreactor tank or located outside). MBR technology is very effective in removing organics, metals, and bacteria, making it suitable for treating various types of wastewater such as domestic wastewater, industrial wastewater, and leachate. The water quality after treatment is very good and stable, with SS content <1mg/L, turbidity <0.2NTU. The filtration efficiency of Nitrogen and Ammonia is up to 90-95% and especially the efficiency of removing bacteria and viruses is very high. In particular, the filter here also acts as a barrier to retain bacteria that are dangerous to health and the chlorine disinfection process is also ineffective. The treated water is suitable for discharging into the natural environment or for reuse purposes such as watering plants, washing floors, flushing toilets,...

The application of *wastewater treatment by MBR technology* is a combination of membrane filtration technology and biological filtration tank as a stage in the wastewater treatment process that can replace (in some cases) for the role of descaling of the secondary sedimentation tank and the inlet water filtration tank. Therefore, it is possible to eliminate the secondary sedimentation tank, the disinfection tank and operate it with a higher concentration of MLSS to save the biological tank area.

Advantages of MBR filter in wastewater treatment technology

+ With a membrane pore size of 0.03 μm, MBR membrane can separate suspended solids, colloidal particles, bacteria, some viruses and large-sized organic molecules. Therefore, *wastewater treatment by MBR technology* does not need to build an additional bio-sludge settling tank and a disinfection tank behind, saving the area of the bio-tank, reducing construction and equipment costs, reducing operating costs and reducing the construction area that can be used for other purposes.

+ The water retention time is 2.5-5 hours shorter than that of conventional activated sludge technology >6 hours, reducing the necessary land area, especially for hospitals, hotels, office buildings and renovation and upgrading works without reserved land area.

+ The concentration of MLSS microorganisms in the tank is high and the sludge **retention time (Sludge Retetion Time (SRT**) is long, so the volume of residual sludge generated is small, reducing the cost of sludge treatment and disposal. In addition, due to the high concentration of sludge in the tank, it will reduce the buoyancy of the sludge, increasing the treatment effect of the activated sludge.

+ **MBR membrane** is designed with a high active sludge concentration of 5000-12,000 mg/l and a high BOD treatment load, reducing the volume of aerobic biological tanks, reducing construction investment costs.

+ The quality of the treated water is always the best without regard to the output water containing suspended activated sludge, pathogenic bacteria and residual chlorine control.

+ The water treated by MBR technology has a very low amount of solids <5mg/l, low BOD5 and COD, so the wastewater can be used for different purposes such as cooling, watering trees or washing roads....

+ The process of *operating the wastewater treatment system* is simpler and easier than the usual process. *Wastewater treatment by MBR technology* can be adjusted fully automatically during operation, there is no need to measure the SVI index daily (this is a very important indicator for the normal process) and it is less labor-intensive to operate.

+ In case the plant has increased its operating capacity, for the process of wastewater *treatment with MBR technology*, it is only necessary to invest in an additional MBR membrane module.

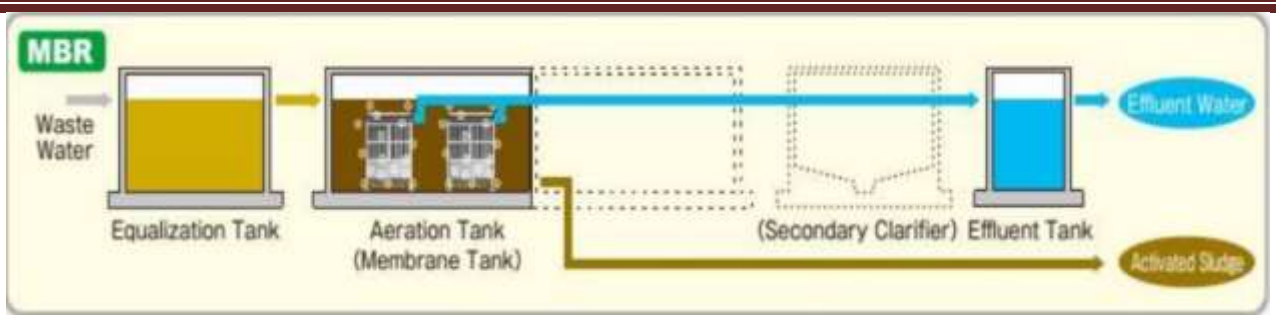

Fig. 1. Wastewater treatment technology by MBR

- Flow Equalization tank: The wastewater treatment system according to MBR membrane technology usually operates in constant flux mode, i.e. the inlet wastewater flux is kept stable. To stabilize the flow, the conditioning tank is used to minimize the fluctuation of the wastewater. The size of the conditioning tank is determined based on the flow rate of the raw wastewater, and also depends on the fluctuation of the flow as well as the treatment capacity of the membrane system.
- Anoxic Tank: Microorganisms adhere to the surface of the filter material layer. In the condition of gas shortage, the organic nitrogen in the wastewater will be strongly reduced by the indirect reduction mechanism to N2. Large-molecular-organic compounds are hydrolyzed and converted into small-molecular-organic compounds, which facilitate further oxidation. In which, a large amount (about 10-20%) of organic compounds are completely inorganic into CO2 and CH4. As a result, a significant amount of gas supply energy can be saved for oxidation.
- Aero tank biotank: In the aerobic buffer compartment, complete oxidation is carried out to thoroughly deconstruct COD, BOD and P. MBR membrane is regenerated quite stably.
- Membrane Tank: MBR membrane is installed as a module with a filter hole size of 0.04 – 0.4 μmm. At the membrane filtration tank, the separation process takes place between clean water and a mixture of activated sludge, suspended solids and pathogenic bacteria. The clean water in the core travels to the ducts to be pumped through the rear physicochemical system, to completely remove the phosphorus and small deposits left in the wastewater. Eventually, the water is discharged into the regional drainage network.
- Treated water tank: This tank is used to store clean water after it has been treated through a membrane tank. Sometimes, it is also used to dilute water. The water in the tank is discharged to the receiving source after it has been sterilized with sodium hypochlorite (if necessary).

4. Current application of membrane technology in waste treatment in industrial parks in Vietnam today

In 2023, water pollution in Vietnam is still complicated and causes many negative impacts on human life and the environment. According to the report of the Vietnam Environment Administration, more than 70% of rivers, streams, ponds and lakes in Vietnam are heavily polluted, with toxic substances such as livestock waste, industrial waste, especially plastic waste and waste from neighboring industrial parks.

What is worrying is that this pollution not only affects human health but also reduces soil productivity, affects the life of organisms in the water environment, and causes serious damage to the country's economy and sustainable development.

Fig. 2. Water pollution in the vicinity of Vsip_Bac Ninh industrial park

Wastewater treatment is an urgent issue in the industry. The ever-increasing production and consumption of goods has posed many challenges in the management and treatment of wastewater in factories, workshops, industrial parks and other production facilities. Wastewater generated from industrial activities contains a variety of toxic chemicals, bacteria, and other contaminants, which can be dangerous to human health and the environment if not treated properly.

Therefore, wastewater treatment is a mandatory requirement of industries worldwide. Wastewater treatment solutions and technologies are increasingly interested and invested in development to ensure environmental safety and human health. The application of **MBR technology** in wastewater treatment is becoming a popular solution due to its high efficiency and durability as well as cost savings for businesses.

Currently, in Vietnam, MBR filter technology has been applied to companies and businesses with thorough filtration, but due to the high cost, it has not been widely used, only applied in: domestic wastewater in residential areas, industrial parks, resorts, wastewater in health stations, etc hospital.

In addition, UF membrane technology is also widely used in the industries of food, pharmaceutical, chemical, bottled drinking water and wastewater treatment and in electronics manufacturing. UF membrane technology is widely used for drinking water purification, milk filtration, wine filtration, perfume production,... In particular, most UF ultrafiltration membranes currently use polymer materials such as polypropylene, polyvinyliden difluoride, etc. and are often imported.

In general, membrane technology is being commonly used in our country today, the quality of water used for daily life and wastewater treatment in industrial parks is also gradually improving.

Fig. 3. MBR filter is used to treat high-concentration industrial wastewater in Bac Ninh Industrial Park

Fig. 4. MBR filter is used to treat high-concentration industrial wastewater in Bac Ninh Industrial Park

Fig. 5. MBR filter is used to treat high-concentration industrial wastewater in Bac Ninh Industrial Park

5. Conclusion

Since the Law on Environmental Protection (Environmental Protection) in 2020 and a series of implementing policies have been promulgated and come into effect, it is a premise for the development of the recycling industry and the environmental industry to develop strongly. Some of the advantages of those policies are:

Consider waste as a resource; requirements for recycling and reuse; Considering waste, when it is classified, meets the requirements and conditions for recycling and reuse, must be treated as products and goods; it must not be considered that the waste that has been delineated and classified must meet the same conditions as the waste that must be treated.

It is required to classify waste to put waste into production and recycle as quickly as possible, ensuring that recyclable waste is of good quality to create recyclable materials of good quality compared to recycled materials from general dumping waste as it is today. The implementation of this classification will be applied synchronously throughout the country starting from January 1, 2025.

Currently, many provinces and cities have piloted the classification of domestic solid waste, achieving very positive results. To achieve these results is due to the attention and determination of provincial/city leaders, the efforts to find outputs for sorted wastes of urban environmental companies; is a long-term communication, guidance and propaganda for people and communities.

In addition to opportunities, Vietnam also has many challenges such as large-scale foreign recycling and pollution treatment technology companies, modern technology is also looking to access Vietnam's recycling and waste treatment market. That makes domestic waste recycling and treatment units face the risk of losing the playground right in their hometown.

Although there are still many difficulties and challenges, the waste recycling industry in Vietnam has had bright spots, that is, some businesses have found a new direction for themselves to develop with love for the profession and enthusiasm for the environmental cause.

In order to promote the development of membrane technology in waste treatment, our country needs to implement policies to research and raise people's awareness.

First, research and application of IoT technology in wastewater treatment stations.

Second, improve the quality of wastewater after treatment for the purpose of reusing wastewater.

Third, strengthen the inspection and control of government agencies to increase the number and quality of treatment stations/plants, and the government's environmental policies must adapt to the current state of environmental technology in Vietnam.

Fourth, we need to innovate higher education programs and environmental technology research programs to create "highly qualified human resources".

Fifth, the application of good scientific research achievements and environmental technology that have been tested in the world to Vietnam

Promoting the research and application of membrane technologies thoroughly and more widely in Vietnam's wastewater treatment is a very urgent and practical issue. In order for wastewater treatment to be more and more thorough, it is necessary to have creativity and application of high-tech technology, further research and investment towards protecting clean water sources and protecting human life.

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References

i. Chen, C., Yang, Y., Graham, N. J., Li, Z., Yang, X., Wang, Z., ... & Hou, L. A. (2024). A comprehensive evaluation of the temporal and spatial fouling characteristics of RO membranes in a full-scale seawater desalination plant. *Water research*, *249*, 120914.

ii. Gao, T., Wang, D., Xia, L., Zhao, S., Xu, R., Zhang, H., ... & Liu, W. (2023). Unveiling the residual membrane foulants in full-scale MBR plant after chemically enhanced backwash: insights into microbe-associated compounds. *Desalination*, *551*, 116421.

iii. Judd, S. (2010). *The MBR book: principles and applications of membrane bioreactors for water and wastewater treatment*. Elsevier.

iv. Bao, Z., Sun, S., & Sun, D. (2016). Assessment of greenhouse gas emission from A/O and SBR wastewater treatment plants in Beijing, China. *International Biodeterioration & Biodegradation*, *108*, 108-114.

v. Polruang, S., Sirivithayapakorn, S., & Talang, R. P. N. (2018). A comparative life cycle assessment of municipal wastewater treatment plants in Thailand under variable power schemes and effluent management programs. *Journal of Cleaner Production*, *172*, 635-648.

vi. Ping Chu, H., & Li, X. Y. (2005). Membrane fouling in a membrane bioreactor (MBR): sludge cake formation and fouling characteristics. *Biotechnology and bioengineering*, *90*(3), 323-331.

vii. Hoinkis, J., Deowan, S. A., Panten, V., Figoli, A., Huang, R. R., & Drioli, E. (2012). Membrane bioreactor (MBR) technology–a promising approach for industrial water reuse. *Procedia Engineering*, *33*, 234-241.

viii. Barreto, C. M., Ochoa, I. M., Garcia, H. A., Hooijmans, C. M., Livingston, D., Herrera, A., & Brdjanovic, D. (2018). Sidestream superoxygenation for wastewater treatment: Oxygen transfer in clean water and mixed liquor. *Journal of Environmental Management*, *219*, 125-137.