Author et al. 2019, 7:3
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science,
Engineering and Technology

An Open Access Journal

Removal of Pathogens From Waste Water By Membrane Technique: A Review

Asst. Prof. Maheswari P
Department of Chemistry
SRM Valliammai Engineering College
Tamil Nadu, Chennai, India
pmahichemician@gmail.com

PG Student Dharsiha G
Department of Civil Engineering
Tagore Engineering College
Tamil Nadu, Chennai, India

Abstract- Membrane technology is a worldwide term used for the separation process. The development of membrane technology is being done in many fields all around the world. From the beginning, as the year passes the membrane form, mechanism of working, types of membranes and the method of preparation has also developed in every possible way. The recent trend is using the membrane for the removal of the pathogens. As water being scared among all the nations, the urge to find new technology in improving the quality of the drinking water is necessary. The chemical method, like the addition of chlorine, lime, iodine and bromine, is the most effective method till now. But due to the longer consumption of the chemicals used in the disinfection process, humans get affected by long term diseases. So the need for 'no side-effect' method is essential. So, the membrane filtration technique is being used for this field. This paper gives an overall review about the uses of membrane technology in pathogen removal. The paper also deals with the various polymers being used in the water purification. If any disadvantage occurs, then the modifications are also done by easy and economical way to overcome those limitations. This review paper is given a clear idea about the types of membrane process involved in pathogens removal and interactions between pathogens and membranes.

Keywords- Water treatment, Pathogens, Membrane, Biofouling, Rejection.

1. INTRODUCTION

Water is one of the earth's most precious and threatened resources and health is one of each person's most precious resources. We need to protect and enhance them both. Water pollution is caused when the fresh water source (e.g. lakes, rivers, oceans, aquifers and groundwater) are contaminated by unwanted particles (1). These pollutants are directly or indirectly added into the drinking sources without proper treatment to remove the harmful compounds. pathogen is the term used to describe the disease causing microorganism. They enter a human body in many ways, in which water is the easiest way. Diseases caused by waterborne microorganism

Among the harmful compounds that pollute the water, pathogens give the most harmful effect. The High level of pathogen is caused when the drinking water source is near on-site sanitation systems (septic tanks, pit latrines) or due to not properly treated sewage discharges into the sources (2). Taste, odor and color are the basic quality of a good drinking water. Even if the water does not have these it should be free from pathogens. The necessity for the removal of pathogens is a must. In developing countries due to the poor quality of water each hour 90 children are dying (3). For improving the quality of water, there are many types of treatments are done for each type of standards. For the killing of pathogens, i.e.

disinfection, also many methods are being followed. The most used common and cheapest method is chlorination. But due to the pro-longed consumption of the chlorine several side-effects are found. When the chlorine adds with organic compounds in our body, it produces carcinogenic by-products. So the need for other types of disinfection is being necessary (5-9).Membranes are used in various fields. In water treatment the most common membrane system used will be reverse osmosis (RO). But other than that for the pathogen removal various types of membrane systems are used. Worldwide, many researchers are being going on to prove the use of membrane as treatment process and to modify them according to the needs (10). This review helps us to know about the role of membranes used in the removal of pathogens.

II. PATHOGENS

The majority of the pathogens in wastewater is enteric, which means they affect the digestive system and makes a serious health risk if ingested. The adverse health effects of these pathogens are serious, and especially in the case of children under the age of five, may be fatal if appropriate medical treatment is not administered in a timely manner.

1. Protozoa

Protozoa are single-cell organism. They can live even outside the host in some extreme situation as cysts or oocysts. They may be of size 3 to 14 μm in diameter. Some multi cellular protozoa can be seen even with the naked eye when they had matured. Some of the protozoa like Cryptosporidium, Giardia, Endamebas and Microsporidia, causes, diseases like Cryptosporidiosis, Giardiasis, Dysentery and Amoebic Meningoencephalitis (11).

2. Bacteria

Bacteria are the most common pathogen found in water contamination. The size of bacteria is from 0.6 to 1.2 μm in diameter and 2-3 μm in length. Bacteria are considered to be classified as: enter pathogenic bacteria and opportunistic bacteria. The most common disease caused by bacteria is gastrointestinal diseases, which spreads through water easily. Gastrointestinal diseases include diarrhea (e.g., cholera caused by Vibrio cholera and salmonelliosis caused by a number of Salmonella species) and dysentery (caused by various Shigella and Salmonella species). Other disease caused by bacteria includes typhoid and paratyphoid fever, which is caused by the Salmonella species (11).

3. Virus

Viruses are considered as the most infectious microorganisms. They have greater resistance to treatment and only a small dose is enough to cause infection. The size ranges within a few ten of nm. Enter viruses are commonly detected in water. They cause congenital heart anomalies, encephalitis paralysis, meningitis and respiratory disease (11).

4. Indicator Organisms

Due to the wide variety of pathogens, including bacteria, protozoa and virus, present in water make impractical to test them individually. Thus suitable markers indicating the contamination of water are used. The indicator organisms are not pathogen themselves. The widely used marker for bacteria is the coliform bacteria, either as total coliform or fecal coliform. For protozoa, anerobic spores, anaerobic spores and particle profiling. Bacteriophages virus, which infect species bacteria, are used as indicators while testing for the virus (11).

5. Log removal

The removal of pathogens are found in terms of log removal value (LVR)

$$\text{Log removal} = -\log \frac{\text{conc (out)}}{\text{conc (in)}}$$

If the LVR value is 1 then there is a 90% reduction in microorganism. If the LVR is 2 then 99%reduction and if 3 then 99.9% of microorganisms are reduced (11).

III. MEMBRANES

The Membrane is a thin, discrete layer which allows certain particles to pass through and will deny other particles. Membranes are classified under different categories. Based on the membrane material they are differentiated as Isotropic Membranes, Anisotropic Membranes, Metal, Ceramic, Zeolite, Carbon, and Glass Membranes, Liquid Membranes and Hollow Fiber Membranes (12-14). A module is a term which refers to the effective packing of large areas of membranes in an economic way. Depending upon the usage requirement modules are classified as Plate-Frame module, Tubular modules, Spiral-Wound Modules and Hollow Fiber Modules. Depending upon the application and the types of membrane the separation is done by different types, microfiltration, ultra filtration, nanofiltration, reverse osmosis and electro dialysis (15-18).

Membrane technology does not have heat energy. Thus, it is used in cold separation processes such as food technology, biotechnology and pharmaceutical industries. The advancement of membrane technology in water treatment has been increased recent days (19-21). With the help of the types of membrane, various particles like colloids, macromolecule and pathogens can be removed. The need for membrane technology is increasing in the field of environmental protection of water from various harmful substances. Various studies are being conducted by using membranes in the field of pathogen removal.

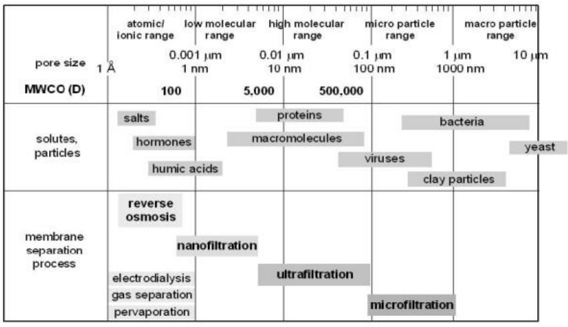

Figure 1. Schematic representation of the pressure - driven membrane separation processes and rejection capacities

The limitation of using membrane in pathogen removal is bio fouling. Due to bio fouling the flux rate decreases which affect the efficiency of separation. Also the reusability of the membranes will be reduced, which is affected in the economic ways. This study gives a clear idea about the application of the membrane in pathogen removal and its overcoming technology for biofouling (23).

IV. PATHOGEN REMOVAL STUDIES

During the starting stage of the experiment of using the membrane for the pathogen control commercial membranes were used which makes the finalization of the usage of membranes in the disinfection process. T. Wintgens et. al investigated the studies about the water reclamation and reuse by membrane technology was done by the researches.

They made studies from five countries by using seven examples which proved them that the membrane technology is really a future trend both in treatment and in the removal of pathogens. They preferred that ultrafiltraion and microfiltration can be used as a pre-treatment for the nanofiltration and reverse osmosis (24-26). Decostere Bjorge et.al created a flat sheet membrane by electros pinning technique. The membranes were fabricated with a mean pore size of 0.4 μm. The fiber diameter was between 50 and 100 nm and had a thickness of 120 μm. The applications include the use of this membrane for pathogen removal. They took samples from general hospitals, local pond and collected rain water. Also, they had inoculated coliform bacteria in a nutrient agar culture medium to the samples. They made the membrane as two type as functionalized and non-functionalized membranes. The functionalized membranes were prepared by dipping the membranes in silver nitrate solution, thus impregnating silver particles to the membrane surface for anti-bacterial effect.

The test for the efficiency of the separation of bacteria, the non-functionalized membrane did not give much result. But the functionalized membrane removed log3-log4 bacteria. The results of their experiment made us clear that the pores of the membranes are an important factor in the removal of the pathogen. Also, they pointed out that the addition/modification of the membrane is necessary for making it anti-fouling in property (27).Vertically aligned carbon nanotube (VA CNT) also shows good results in the water treatment process with low biofouling tendencies. Youngbin Baek et. al experimented VA CNT in the aspects of flux, rejection performance, and membrane biofouling tendency with comparison to commercial ultrafiltration membranes.

Pseudomonas aeruginosa was used as the test bacteria. In the comparison of VA CNT and commercial membrane they have found that in both membranes permeate no bacteria was found. Regarding the flux, the more flux decrease was noted on the VACNT membrane (67%) than the UF membrane (55%). But the biofouling of the VA CNT has reduced to 2 log less than the commercial UF membrane. Due to the less physical damage in the CNT's membrane the anti-fouling property has increased (28).

N. Daels et. al amined to study about the use of electrospun microfiltration membranes for water disinfection. They evaluated the membrane using different functionalizing agents like, nano silver, bronopl, WSCP. The experiment results showed that the WSCP resulted in 5.2 log10 removal of the bacteria in the hospital waste water. Long term lab scale tests showed a 5.6 log10 CFU/100 ml removal for Staphylococcus aureus and a 4.0 log10 CFU/100 ml removal for Escherichia coli, indicating a better removal of Gram positive bacteria. Leaching experiments showed a 10% wash-out of the applied functionalising agent. This leaching did not obstruct the pathogen removal capacity of the functionalised nanofibres (29).

Aravind Dasari et. al prepared a non-woven elctrospun polyactic acid (PLA) membrane. They compared the removal efficiency between PLA and PLA containing sepiolite fibrillar particles (5 wt%), which were Ag (26 wt%) and Cu (26 wt%), having negatively charged that increases with pH. The test pathogens were of Saccharomyces cerevisiae (pH 4.5) and Pseudomonas putida (pH 7.5). The test was conducted for 24/48 hrs. The test results showed that the membranes with sepiolite fibrilla have good removal efficiency. In the sepiolite fibrillar membrane, the membrane with Ag gave 85% reduced Saccharomyces cerevisiae than neat PLA (30).

Taro Urase et. al had tested many types of membranes for the retention of the virus. They used coliphage Q/3 and T4 as model viruses. In their study, they used microfiltration, ultrafiltration and nano filtration, including ceramic membranes. Also, they used flat sheets and hollow fibers to check the retention efficiency between the module types. After the study, they made their conclusion, that even though ultrafiltraton and nanofiltration was not a complete barrier for virus their retention rate was 99-99.999%. Also, they proved that the shape of the membrane, whether flat sheet or hollow fiber, did not matter unless their pores are very small capable of stopping the virus to pass through it (31).

Katherine Zodrow et, al studied the removal of a variety of bacteria, including Escherichia coli K12 and Pseudomonas mendocina KR1, and the MS2 bacteriophage by using nAg incorporated polysulfone ultrafiltration membranes (nAg–PSf). The membrane was made by wet-phase inversion process and by incorporating 0.22 wt% of nAg in the polymer solution. In the antibacterial test conducted in nAg-PSf membrane, there was 2-log (99%) removal of E.coli was found. Due to the release of Ag+ ions on the surface of the membrane, the bacteria were inactive which reduced the cake formation. In the anti-viral test 5 ± 0.2 x 105 PFU/mL was done by the nAg-PSf membrane (32).

The use of membranes as Membrane Bio Reactor (MBR) has also made its record in the removal of the pathogens (33-34). The polymers used for the antifouling property are also given importance. Such polymer is Polyvinyl-alcohol (PVA). The membranes made with PVA are used in various fields, but its use in water treatment is being studied. These membranes are incorporated with silver particles which gives a good result. Escherichia coli and Staphylococcus aureus are the bacteria used for the removal experiment (35-40). Another polymer used is this study is Polyacrylonitrile (PAN). The PAN membranes have many advantages in the water treatment process. They had attracted much attention because of its properties like thermal stability and tolerance to most solvent and bacteria. They are also used in many fields other than water treatment like pervaporation, enzyme immobilization and hemodialysis. But its disadvantages, such as poor hydrophilicity and biocompactibility, make the membrane susceptible to cell adhesion which is the reason for biofouling (41-44).

The limitations of the PAN membrane need to be overcome to make it a success in the disinfection process. For this, the surface modification of the PAN membranes is made using a different process like grafting, hydrolysis and (Bio-) macromolecule immobilization (45-49). Modifications are done with different types of particles. The PAN membrane with silver nano particles provide a good result due to the presence of the Ag+ ions (45-50). Other particles are also used for the surface engineering like chitosan, lithium chloride (LiCl), calcium chloride (CaCl2), hydroxylamine hydrochloride and different types of diamines (51-54).

V. CONCLUSION

Waterborne disease outbreak is occurring worldwide. The reason for this is the lack of proper water treatment system and the ignorance to save the fresh water source. Due to the water crisis the water should be reclaimed and reused. But due to the lack of good waste water treatment system the water is not being reused. . Another aspect of water quality is the degree of bacterial contamination. If the degree of bacterial contamination is more, than more amount of chemical disinfection should be done. The disadvantage is that chemical treatment does not absolutely ensure that by the time our drinking water comes out of the treatment is free of unhealthy microorganisms. Dangerous bacteria (such as e-coli and coliform) are still found in chlorinated tap water on occasion. And also chemicals have been linked to various types of cancer, kidney and liver damage, immune system dysfunction, disorders of the nervous system, hardening of the arteries, and birth defects Thus, relying on chemical disinfection alone is a false guarantee that the water is safe to drink. Thus, membrane technology plays a good role in removing all these defects and provides us a safe and quality drinking water.

So the need for new technology is necessary. Membranes are attracting much attention in this field. Various membranes and its modifications done to match their needs have been discussed in this paper. This concludes us that the membranes are most promising technology in the disinfection process. Regarding the shape of the membrane used, the PAN membranes with surface engineering had given us a good pathogen removal percentage.

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