

PAPER • OPEN ACCESS

Drinking Water Bags Based on Chitosan Forward Osmosis Membranes for Emergency Drinking Water Supply

To cite this article: Saiful *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **273** 012047

View the [article online](#) for updates and enhancements.

Drinking Water Bags Based on Chitosan Forward Osmosis Membranes for Emergency Drinking Water Supply

Saiful^{1,*}, Ulfa Riana¹, Marlina¹, Muliadi Ramli¹, and Nizar Mahmud²

¹Department of Chemistry, Faculty of Natural Science, Syiah Kuala University, Jalan T. Tanoh Abbe No. 3, Darussalam, Banda Aceh 23111, Indonesia

²Department of Mechanical Engineering, Faculty of Engineering, Syiah Kuala University

*Corresponding author: saiful@unsyiah.ac.id

Abstract. A fast and simple method and technologies in drinking water supply are strongly needed in an emergency situation. One alternative method is based on membrane forwards osmosis (FO) technology. In this study, chitosan-based FO membranes have been developed into drinking water bags used as purification media for dirty water and seawater. The chitosan membrane used for the assembly of drinking water bags has a thickness of 0.043 mm, the porosity of 30.3%, the tensile strength of 28.83 kgf /mm², swelling degree of 43.5% and elongation of 7.16%. The drinking water bags are made from a combination of polypropylene plastic (PP) and aluminum foil plastic with the interface of the FO membrane inside. The drinking water bag can be applied to purify dirty water and seawater into energy drinking water, which can be used for drinking water supply in an emergency situation. Energy drinks water is produced from the FO process using a variety of draw solution, specifically glucose, fructose, and sucrose. The highest drinking water flux was obtained by using 3M sucrose concentration as a draw solution. The clean water fluxes for dirty water and seawater samples were 5.25 L/m²hour and 4.25 L/m²hour respectively. The parameters drinking water quality test are proved that pH, total dissolved solids (TDS), salinity, electrical conductivity, heavy metals and the content of Escherichia coli bacteria are agreed with drinking water quality standards based on PERMENKES regulations No. 492/MENKES/Per/IV/2010. The FO drinking water bag based chitosan membrane has the potential to be used as an alternative solution for energy drinking water supply in an emergency.

Keywords: drinking water, drinking water bag, chitosan membrane, forward osmosis membrane, emergencies.

1. Introduction

The clean water crisis, especially drinking water in various parts of the world, has attracted the interest of researchers to conduct studies and develop methods to obtain clean water and drinking water from various types of available water sources. Community access to clean water, especially drinking water is minimal both to meet local and global needs. The availability of surface water and soil that is abundant cannot be used directly as clean water or drinking water [1]. Water in nature that can be used directly for drinking water is less than 1%, this is because most of the available water is in the form of seawater (97%), glacier (2%), river and brackish which cannot be directly consumed as a quality drinking water [2]. Besides, polluted water sources that are not suitable for consumption are also the reason for the lack of availability of clean water that can be directly drunk, while the need for water continues to increase to meet human consumption [3]. The unavailability of drinking water can cause dehydration, and metabolic processes are disrupted, attacked by various diseases and even lead to death. Drinking water is a critical basic need and must be available even in emergencies situation [4].

Emergencies are defined as conditions that threaten and disrupt people's lives and livelihoods caused by natural or human factors to create emergency conditions in almost every aspect of life.



Indonesia is a country that is very vulnerable to emergencies. Geographically, Indonesia is a country with a high potential for disaster (hazard potential). The movement of the Eurasian, Australian and Pacific Ocean basins has caused earthquakes, tsunamis, active volcanoes, landslides, floods and others [5,6]. Aftershock requires readiness and preparedness in dealing with any disasters and handling during emergencies, one of them is the availability and quality of clean water, especially drinking water. Drinking water becomes difficult to obtain because of damage and contamination of clean water sources in disaster areas and the difficulty of access to isolated disaster locations. Therefore, the development of methods and technology for drinking water supply in an emergency situation that is easier, faster and simpler is needed. Innovation and technology development in the provision of clean water, especially drinking water, still needs to be developed further, especially to respond to emergencies that are very likely to occur, for example in disaster areas, water crisis areas, sea trips, backpackers and other emergencies. One of them is by procuring drinking water bags based on membrane technology through forward osmosis (FO) membrane process [7].

FO Membrane is an alternative method that is being developed to improve the efficiency of polluted water purification processes, brackish water, and seawater into clean water, especially drinking water. In the FO membrane method, water is purified by moving from a low concentration solution to a solution with high concentration through a semipermeable membrane due to an osmosis gradient [8]. The advantage of this method is that it does not require external pressure (hydraulic), the possibility of fouling on small membranes and the possibility of low contamination and does not require electrical energy in its application so that it is simpler, cheaper and practical to use [7]. In this study, a chitosan-based FO membrane has been developed as a filter bag for drinking water in an emergency. Saiful *et.al* [9] has reported that chitosan membrane is one of FO membranes that can be applied to brackish filtration into energy drinking water. The quality of the energy of drinking water product has met the drinking water criteria according to the Indonesian Government's drinking water regulations. In this research, further development of drinking water bag membrane FO made from chitosan which has been carried out for purification of dirty water and seawater. The FO testing process is carried out using a variety of sugar solutions as a draw solution, namely glucose, sucrose, and fructose. Energy water products from the FO process are analyzed for quality as drinking water related to the main parameters of drinking water quality, namely heavy metal, pH, salinity, TDS, electrical conductivity and *E. coli* bacteria content.

2. Material and Method

The equipment used in this study were a magnetic stirrer, oven, beaker, measuring cup, Erlenmeyer, ceramic, duct tape, glue, scissors and sealing machine. The chemicals used are chitosan, sodium hydroxide, acetic acid, dimethylformamide, distilled water, glucose, fructose and sucrose and Polypropylene (PP) plastic and aluminum foil plastic.

2.1. Membrane preparation

Dissolved 3 grams of chitosan with 100 mL of 1% acetic acid (v / v), added 100 mL of 10% (v / v) dimethylformamide solution as an additive. Erlenmeyer is closed and stirred using a magnetic stirrer for ± 24 hours at room temperature; a solution of the chitosan polymer is obtained. Then the solution is printed as a thin membrane on a ceramic at a thickness of 50 μm . The solvent is allowed to evaporate using an oven at a temperature of $\pm 30^\circ\text{C}$ until the membrane dries and detaches from the ceramic. After that the membrane was washed with 1% NaOH (b/v), rinsed with distilled water until neutral and dried at room temperature. The chitosan membrane obtained was used for FO testing (Saiful *et al.*, 2018^b).

2.2. Drinking water bags preparation

Drinking water bags are made using PP plastic and aluminum foil plastic. The two plastics are cut in a rectangular shape with the same size, then between the two are placed the chitosan membrane that has been made beforehand to form 3 layers. Next, the three plastics are joined together through lamination on all the edges of the plastic using a sealing machine to form a bag of drinking water and installed a lid on the front and back side.

2.3. Draw solution preparation

The draw solutions used in the study were glucose, fructose, and sucrose with concentration 3M dissolved by using distilled water. The draw solutions were fill in into the water bags for testing FO processes.

2.4. Use of drinking water bags

The drinking water bags were made as reported in the previous study by Saiful *et al.* (2018^a). The drinking water bags filled 100 mL of draw solution via the front lid and then feed solution of dirty water or seawater filled 200 mL from the back lid. During the FO process, the draw solution will attract the water in the feed solution through a semipermeable FO membrane. Therefore most of the water will move from the feed solution to the draw solution. The FO process is carried out for 1 hour.

2.5. FO water product analysis

Water quality FO products were analyzed by measuring several water quality parameters, specifically pH, TDS, conductivity, salinity, heavy metal and *E.coli* bacteria. pH was analyzed by using pH meter and salinity meter was used for salinity analysis. TDS and conductivity were analyzed by using conductivity meter, therefore analysis of heavy metals including Hg, As, Mn, Zn, Cu, Cr, Fe, and Cd by using Atomic Absorption Spectrophotometry (AAS), and analysis of *E.coli* content using the MPN (Most Probable Number) method.

3. Result And Discussion

3.1. Membrane preparation and characterization

The process of making FO membrane was carried out by dissolving chitosan in 1% (v / v) acetic acid and adding 10% DMF. The addition of DMF can increase porosity because DMF is a porogen additive compound, which is able to create greater space between polymer chains, causing more membrane pores to form and can facilitate more water to move through the membrane (Saiful *et al.*, 2017).

Chitosan membrane is physically transparent, thin and strong with a tight and porous structure [9]. The FO chitosan membrane has a thickness of 0.043 mm, the porosity of 30.3%, swelling degree of 43.5%. Mechanical characteristic FO membrane demonstrated the tensile strength of 28.83 kgf / mm² and percent elongation of 7.16%. SEM picture in Figure 1 shows that the membrane has an asymmetry structure, where the structure and pore sizes of the membrane are not uniform. Morphology shows that there are differences in structure between the top and bottom surfaces. The membrane morphology on the top surface is tight and flat, while the lower surface is rough. Most of all the forward osmosis membrane has an asymmetric structure [10]. In the cross-section of the membrane illustrated that the membrane has a well-connected structure and is free of macrovoid. In this study, the desired membrane for FO testing application is a tight and porous membrane structure.

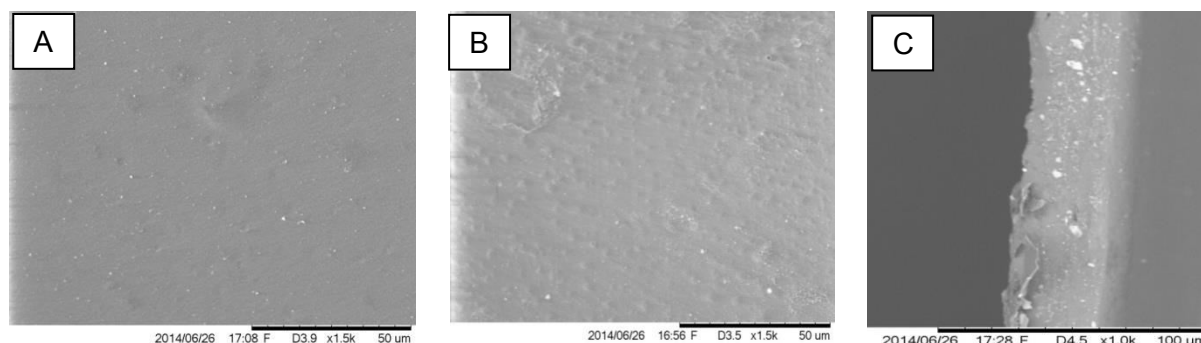


Figure 1. Morphology of 10% chitosan membrane DMF characterized by SEM with 2500x magnification (a) top surface (b) bottom surface (c) cross section.

3.2. Use of drinking water bags

The drinking water bag produced has a total volume capacity of ± 400 mL, which consists of two sides with a volume of ± 200 mL each, which is separated by an FO chitosan membrane. The front part is used to introduce a draw solution in the form of glucose, fructose or sucrose. Then the back part of the water bag is filled in the feed solutions specifically dirty water or seawater. The shape of the drinking water bag is shown in Figure 2.



Figure 2. The shape of the drinking water bag (a) front looks and (b) back looks

The use of drinking water bags for the FO process was carried out by inserting 200 mL of the sample as a feed solution through the back cover of the drinking water bag. Then added 100 mL of a draw solution specifically of sucrose, fructose, or sucrose with a concentration of 3M from the lid of the front of the bag. The FO process was performed for 1 hour with an effective surface area of 41.25 cm² membrane. Within 1 hour FO processes the volume of permeate product is close to the maximum volume of the water bag capacity. Besides, based on previous research, the first hour of the FO process is the optimum time with the highest flux value, while after that the flux starts to decrease to a constant [9]. The amount of water flux-product for each draw solution is shown in Figure 3.

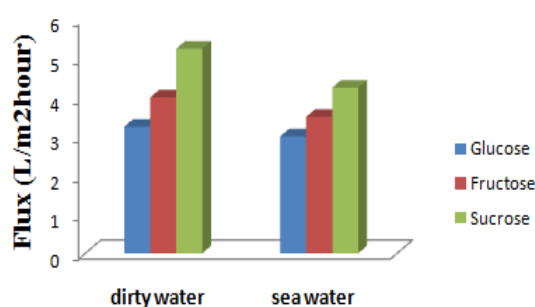


Figure 3. The clean water fluxes of FO chitosan membrane within 1-hour process for dirty water and seawater as feed solution

Based on figure 3, it can be seen that sucrose as draw solution was obtained as the highest clean water fluxes in both seawater and dirty water. The maximum clean water flux generated from 3M sucrose as draw solution for dirty water samples is 5.25 L/m²h, while for seawater the resulting flux value is 4.25 L/m²h. Sucrose produces a relatively higher clean water flux because it has a higher osmotic pressure and solubility compared to fructose and glucose, allowing the increased volume of water moving. Dirty water samples produce higher flux than seawater due to the total dissolved solutes in dirty water is lower than seawater, to facilitate more water and free to move towards the draw solution.

3.3. Water quality analysis of FO products

3.3.1. pH, salinity, conductivity and TDS analysis.

The feed solution used is dirty water taken in the Limpok, Aceh Besar village and seawater from the Alue Naga area, Aceh Besar. The water quality of the FO product was measured after 1 hour of the FO processes. Based on Figure 4. Illustrated that the results of pH analysis for all draw solutions were not a significant change in pH towards the draw solution. The pH of the water obtained from ranged from 7.46 to 7.72. This value is still in the range of pH requirements for drinking water according to PERMENKES No: 492/Menkes/Per/IV/2010, the pH allowed for drinking water is 6.5 - 8.5. According to pH analysis demonstrated that chitosan FO membrane could be applied for producing drinking from dirty water and seawater.

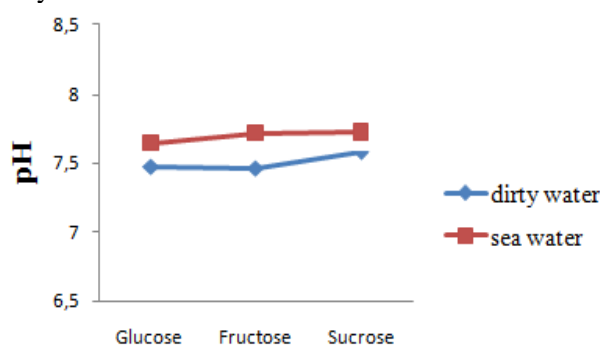


Figure 4. The results quality analysis of the FO drinking water products with pH parameters using a solution of glucose, fructose and sucrose

Another drinking water quality parameters specifically salinity, conductivity, and TDS for FO water product are shown in Figure 5. The Figure 5, it is proved that all the results of the measurement parameter are meet to drinking water quality standard. It means that the FO membrane is able to hold the substance or species dissolved in the feed solution so that it does not move towards the draw solution, while the one that is attracted to and able to pass through the semipermeable membrane is only water.

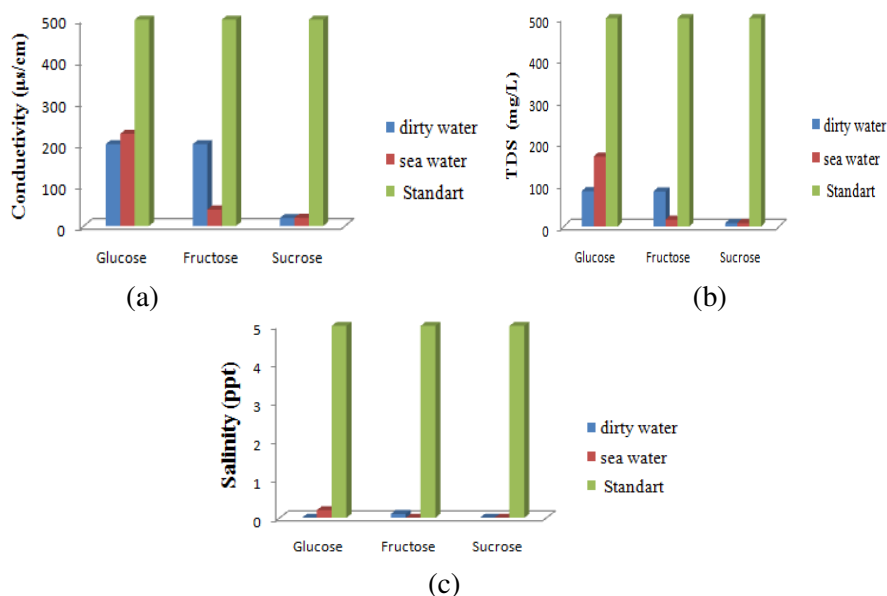


Figure 5. The analysis results of quality the FO drinking water energy product against the parameters: (a) conductivity (b) *Total Dissolved Solid* (TDS), (c) salinity.

The value of water salinity for FO water products also demonstrates that chitosan FO membrane can block all salt ion from the feed solution, where the salinity values obtained ranged from 0 - 0.2 ppt. This value confirms that the water produced is still classified as fresh water and is below the maximum salinity limit for fresh water which is commonly used 5 ppt. TDS values for FO water products ranged from 8-168 mg/L from the initial TDS of 427mg/L for dirty water and 48350 mg/L for seawater. Then the conductivity of the FO product ranges from 18.8–223 μ s/cm from an initial conductivity of 1016 μ s/cm for dirty water and 67800 μ s/cm for seawater. Overall TDS values and conductivity of all draw solutions after the FO process was permissible because the value was below 500 mg/L. The content of the TDS agreed with PERMENKES regulation No. 492/Menkes/Per/IV/2010 that is the maximum allowable TDS standard is 500 mg/L.

3.3.2. Metal contents analysis

Analysis of the content of heavy metals in feed water and FO product water was measured using Atomic Absorption Spectrophotometer (AAS). Where the types of metals measured are Hg, As, Mn, Zn, Cr, Fe, Cu, and Cd. All of these metals are chemical parameters requirement in standard drinking water analysis according to PERMENKES No 492/MENKES/PER/IV/2010. The results of the heavy metal analysis are shown in Table 1.

Table 1. Heavy metal analysis of the drinking water FO products.

No	Parameter	Unit	Analysis Result				Standard
			Dirty water sample	FO product	Seawater sample	FO product	
1	Mercury (Hg)	mg/L	<0,001	<0,001	<0,001	<0,001	0,001
2	Arsenic (As)	mg/L	<0,003	<0,003	<0,003	<0,003	0,01
3	Mangan (Mn)	mg/L	<0,002	<0,002	<0,002	<0,002	0,4
4	Zinc (Zn)	mg/L	<0,01	<0,01	0,8207	0,0488	3
5	Copper (Cu)	mg/L	<0,002	<0,0026	<0,0052	<0,0026	2
6	Cromium (Cr)	mg/L	<0,002	<0,002	<0,002	<0,002	0,05
7	Iron(Fe)	mg/L	<0,009	<0,009	<0,009	<0,009	0,2
8	Cadmium(Cd)	mg/L	<0,002	<0,002	<0,002	<0,002	0,003

The analysis results of heavy metals from samples from both dirty water and seawater indicate that the samples used do not contain metals with high concentrations, where the concentration of small metals is below the AAS detection limit. Then the water from the FO product did not show any excess metal content. Based on Table 1. It is described that all types of metals measured are still below the drinking water quality standard. However, based on previous studies reported chitosan-based FO membrane is able to block the heavy metal from passing through the FO membrane. Chitosan FO Membrane is able to filter the smallest size salt ion, and this means that it is automatically can block all bigger size heavy metal ions do not pass through the membrane towards the water of the FO product [9,11].

3.3.3. Bacterial analysis

Analysis of the presence of bacterial content in water from the FO process was carried out using the Most Probable Number (MPN) method. The samples analyzed consisted of seawater and dirty water as well as water from FO products. The results of the E. coli analysis are shown in Figure 6. Where in dirty water samples containing 43/100 mL of E.coli and seawater samples containing 23/100 mL of E.coli. In contrast, the water from FO products from both samples was negative containing E. coli (0/100mL). The FO membrane is proving to be able to filter E.coli from the sample because the membrane pore size is smaller than the size of the bacteria so that the FO product is free of E. coli.

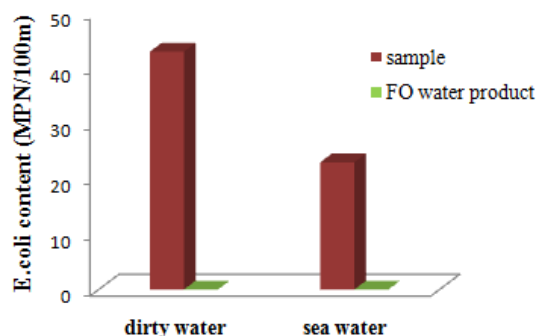


Figure 6. The analysis result E.coli content of FO water product

The type of membrane used as a filter in drinking water bags is a dense membrane with a pore size that is very small and dense. The pore size of the dense membrane has a pore $<0,0001\ \mu\text{m}$ in diameter while the size of bacteria is 0.2 to $1\ \mu\text{m}$, and the virus is between 0.02 to $0.4\ \mu\text{m}$. FO membrane is a membrane whose ability to filter out dissolved and suspended species in water including bacteria and monovalent ions [12,13].

4. Conclusion

Chitosan FO Membrane can be developed into ready-to-drink filter bags, where maximum flux is obtained with 3M sucrose concentration as draw solutions with a flux value of $5.25\ \text{J/m}^2\text{h}$ for dirty water feed solution and $4.25\ \text{J/m}^2\text{h}$ for seawater feed solution. The results of the analysis of drinking water quality parameters in the term of pH, TDS, salinity, conductivity, metal and E.coly bacteria content showed that the quality of water produced by FO process meets drinking water quality standards according to PERMENKES regulations No. 492/MENKES/Per/IV/2010. The FO membrane-based drinking water bag can be used as an alternative solution for energy drinking water supply in an emergency situation.

5. References

- [1] Jincai Su, Sui Zhang, Ming-Ming Ling, Tai-Shung Chung 2012 *Forward Osmosis: an Emerging Technology for Sustainable Supply of Clean Wate*, Department of Chemical & Biomolecular Engineering (National University of Singapore)
- [2] Budiyono and Sumardino, S. 2013 *Teknik Pengolahan Air* (Graha Ilmu, Semarang)
- [3] Su, J., Zhang, S., Ming, M.L. and Shung, T.C. 2011 *J. Membr Sci* 376:214–224
- [4] Haryoto, R. dan Hidayat, W. 2007 *Penyediaan Air Siap Minum Tanggap Darurat Bencana Alam*, Pusat Pengkajian dan Penerapan Teknologi Lingkungan (BNPD.JAI. 3(1))
- [5] Tejakusuma IG., 2005 *Alami*, Vol. 10 No.2, 19-21
- [6] KLH, 2007 *Analisis Potensi Rawan Bencana Alam di Papua dan Maluku (Tanah longsor-Banjir-Gempa Bumi-Tsunami)* (Deputy for Development of Technical Facilities and Capacity Building, Office of the Environment, Jakarta)
- [7] Cormick, J., Pellegrino, F., Mantovani, G., And Sarti. 2008 *.Journal of Membrane Science*. 325: 467-478.
- [8] Cath, T.Y., Childress, A.E., and Elimelech, M. 2006 *. Journal of Membrane Science*, 281: 70-87.
- [9] Saiful, Ulfa Riana, Marlina, Muliadi Ramli, and Nizar Mahmud 2018 *Aceh International Journal of Science and Technology*, Accepted for publication
- [10] Tang W dan How Yong Ng 2008 *Desalination*, 224, 1–3, 143-153
- [11] Saiful, Marlina, Muliadi. R, Nizar. M dan Maizar. 2017 *Proceeding ISC 2017* UNPAD-Bandung : 33-37.
- [12] Padaki, M., Arun, M.I., Jenifer, F. and K.Narayan, P. 2011 *Desalination*. 280: 419-423.
- [13] Shakeri, A., Hasan, S. and Masoud, R. 2017 *Carbohydrate Polymers*. 174: 658–68.

Acknowledgments

We want to acknowledge the financial support of this work through the Ministry of Research, Technology and Higher Education of the Republic of Indonesia has financed this research through Competitive Grant Research.