Journal of Engineering and SustainableDevelopment
http://jeasd.uomustansiriyah.edu.iq
https://doi.org/10.31272/jeasd.24.5.7

Vol. 24, No. 05, September 2020
ISSN 2520-0917

# REMOVAL OF $PO4^{3-}$ BY DIRECT CONTACT MEMBRANE DISTILLATION FROM DAIRY WASTEWATER

***Ali Abdullah Hasan[1]**

1) Lecturer, Civil Engineering Departmental-Mustansiriayah University, Baghdad, Iraq.

***Received 11/04/2019*** ***Accepted in revised form 04/02/2020*** ***Published online 01/09/2020***

**Abstract:** The dairy industry is one of the basic industries that are important for the sustainability of life and because this industry uses and consumes a lot of water to produce milk, it discharges a lot of waste water. Because of the acute shortage of water needed to meet domestic, industrial and agricultural needs and increase pollution on the other, and of high fresh water demand in recent years, therefore; treatment of wastewater present very important. The most important pollutants of dairy wastewater discharged are phosphate. The present paper offers an ability of membrane distillation process (MD) for the treatment of dairy wastewater and removal of phosphate in Iraq. Artificial samples of wastewater prepared to implement the proposal. Opinions will be considered to make these wastewater samples within the standard properties of world dairy wastewater classifications. To alleviate membrane disturbances by organic and inorganic substances applied to physical deposition. The results showed the ability of the MD to remove a high concentration of phosphate from wastewater from dairy wastewater, with a clearance rate of 95 per cent. This value affected by temperature and temperature affects the effectiveness of The MD and is directly proportional to the flow.

## 1. Introduction

It is not unfair to say the dairy industry – in general sense- is a blessing and indignation at the same time. Civilization, prosperity, and social wellbeing etc. are all shining aspects of the industry. However, the industry has still a gloomy side that is pollution [1].

The industrial sector contributes a lot to the environmental pollution. Supported by scientific and technologic excellence, the dairy industry was behind the emergence of pollution problems. Effluents from different industrial operations contain various pollutants. These effluents cause bad and adverse environmental consequences on land, air and water. The discharges may ultimately reach water bodies and other environmental elements adding to their load of pollution. Treatment of liquid discharges, control of air pollutants and protecting the land becomes a necessity. Among the various polluting industries, the dairy industry is mostly considered to be the biggest basis of producing wastewater in many countries and Iraq is no exception [1].

The dairy industry comprises marketing, storage, packaging, and transportation of the product that effect the environment. Because of the high prevalence of this industry and with all the

**Corresponding author:* aliabdullah70@yahoo.com

facilities of the transfers of manufactured goods management and packaging constitute waste in terms of quality and quantity different, which, if not addressed, can pull to increase the disposal and the difficulties of pollution?

Because dairy consumption increases, concerns regarding this issue increases, using water in this industry may be in different ways leading to produce milk's products [2].

The products from the dairy industry will be raw milk, butter, yogourt, cheese, condensed kinds of milk, milk powder and icecream. These products will be produced depending on different tools and processes like paseurization, chiling and homogenization. Normal by-products include buttermilk, whey, and their derivatives [3]. ***Deleted the main section and replaced by paragraph***

Waste water from dairy plants is loaded with many different properties and characteristics between physical, chemical and biological. The main characteristics that the identity of used dairy products may provide are chemical oxygen demand, biological oxygen demand, and nutrients. Draining this wastewater without proper treatment will lead to multiple problems in water, soil and air [4]. Because of the types of pollutants that have emerged from the manufacture of high concentrations of suspended solids, high organic and inorganic concentrations, high acidity differences and guidance to make treatment to prevent environmental pollution. Wastewater has volume fluctuation depending on management and organizing of factory as well as environmental regulation at a country so these two main items which determine the aspects of work and complexity of wastewater treatment [5].

Not only are inorganic-organic materials the main material of the dairy plant, but biomaterials are another source of pollution. From another hand, the wastewater contains sources of odour, colour and maybe dust [6].

**2. Introducing MD as a promising technology**

Among various treatment technologies that are effectively used to tackle pollution problems from this industry, membrane distillation MD appeared good enough to do this job.

This process has different advantages; however, it includes separation of components at a lower temperature compared with other processes, separation in its native state, low energy, etc. However, direct contact membrane distillation DCMD provides many prospective advantages greater than ordinary other processes, such as [7, 8]:

- It can be driven at relatively low temperatures (30 to 100 °C) and therefore can utilize low grade heat (solar or industrial waste heat);
- It requires low operating pressure matched to pressure-driven membrane filtration processes;
- It is gentle on temperature and/or shear sensitive products;
- It has a lower capital cost due to the lower pressure requirement;
- It produces a high quality permeate - typically >99% free of non-volatile suspended and dissolved solids;
- It uses readily available, inert membrane materials;
- It is less affected by concentration polarization phenomena matchedto pressure-driven membrane processes, and it is not subject to flux decline due to osmotic pressure increases [10].

Although, these advantages of MD, its energy consumption needs to be more competitive with other processes. RO is using electricity to as driving force for separate water from salts. This may be achieved by around 15-20 MJ/m$^3$, but these prices cannot use waste heat. For this reason, MD is cheaper than RO, if waste heat used instead of fusel fuel energy [11].

### 3. Definition of MD

Membrane distillation is the mechanism for separating two stages of material. First one is vapour while the second is solid materials which are salts. This mechanism will be achieved due to the driving force, which given by partial vapour pressure.MD (has fixable work rang in temperature and pressure; however, it can work under low temperature and low pressure[12]. The hydrophobic membrane will work as barriers between these two phases of materials [13]. Consistent with the MD has high rejection number compared with other types of processes, as well as MD has a large pore size compared with others; however this will reduce fouling. From another hand, MD has the flexibility to join with another type of treatment to build integrated treatment system. This combination will create an integrated separation system, such as ultra-filtration [14, 15] or with Reverse osmosis RO. In addition, MD can our other source of energy like solar energy [16]. The MD competes in the treatment of sea water and brackish water [17]. It does not stand on this point only for this our concept comes up. The removing of organic and heavy metals from aqueous solution may achieve from wastewater, these results also confirmed by waste water contaminated by radiation [18, 19]. Although MD has, some weak points like low permeate flux compared with RO. The second factor is the high capability of permeate flux to the temperature and concentration because of polarization concept [20]. Nevertheless, it has advantages like it designed with a minimum requirement of power [21]. It needs less equipment than others. This means fewer lands too; and effective temperatures are much lower, due to cancelling boiling to reach the boiling point of water. This point will reduce heat loss into the environment through the equipment surfaces [22]. From another hand, feed temperature ranged from 35-50 ℃. For these reasons, it is able to connect alternative energy, wind; solar energy and other types of clean energies [23]. Actually, MD is an economic and competitive process when compared with RO in remote areas and its lower operating pressure and less fouling other factor play an important role in this work is the trapped air. Although introduces a more mass move resistance, which also limits the MD permeate flux. Loosing heat by conveyance is the main weak point of these processes, but this process still contains a lot of advantages like the low operating temperature in contrast to those confronted in straight types of treatment. Nevertheless, the main feed either water or wastewater is not necessarily heated up to boiling temperature. Consequently, MD expected to be an ambitious future. There is a big idea in this process, which is summarized in the capability to use less expensive materials as a membrane.

MD phenomenon is very easy. The membrane distillation mechanism is very easy, due to the reasons that it is easy to manage by hands that are not very highly skilled, and because they do not need complicated and expensive energy sources, and there are no wastes that are a burden on the environment and therefore lead to major environmental problems.

The membrane used in this type should be compatible with some needs; however, the applied membrane one layer or multilayer, one of these layers should be contact with hot water and this layer should be hydrophobic. As well as there are some other requirements, layer touch with flux should be thin. For this reason, feeding should be working with the membrane.

Inlet flux is equally proportional to the membrane thickness. For this size of porous

Table 1. Surface energy and thermal conductivity of commonly used membrane materials

| Membrane Material | Thermal Conductivity ($W\ m^{-1}\ K^{-1}$) | Surface Energy ($\times 10^{-3}$ N/m) |
|---|---|---|
| PTFE | ~0.25 | 9–20 |
| PP | ~0.17 | 30.0 |
| PVDF | ~0.19 | 30.3 |

should be small (in the range of 0.1 to 0.5µm) because the entry pressure difference is inversely proportional to the pore size. Another condition is the small surface energy of the membrane material leading to higher hydrophobicity (a key property for the MD method also permeation flux inversely proportional to the membrane thickness. Because of the scale of pore size is tiny as the entry pressure difference is inversely proportional to the pore size; membrane used should have a high hydrophobic characteristic that is the main property in MD and this lead to low surface energy. Other item related to physical characteristics that guide to high porosity and low zigzag way as well as physical and chemical resistance. The liquid should be high entrance pressure (LEP) (which is a critical property for the MD). It should be a long life period to use for a long time in the treatment of water and wastewater and this is a major negative point in recent MD membrane. Resistance to the movement of thermal mass and low-lying high and here materials must be available and cheap. Through this process, both mechanisms (evaporation and condensation) take place at the liquid – vapour surfaces.

Here the crux of the matter lies in the application of this mechanism in removing phosphorus from dairy wastewater. And as a practical case comes, it is possible to take advantage of the low heat needed to operate this mechanism through the application of solar radiation.

## 4. Materials and methods

### 4.1 Samples:

Artificial samples of wastewater were prepared. The properties of wastewater discharged from dairy plants have been based on the basis that these synthetic models can give properties similar to wastewater actually released.

### 4.2 Membrane Materials

There are different types of hydrophobic membranes made up of different materials such as polypropylene (PP), Polyvinylidenefluoride (PVDF), Polytetrafluoroethylene (PTFE) and polyethylene (PE) available in tubular, capillary or flat sheet forms which have been used in MD experiments.

These membranes have porosity range 0.50 – 0.90, pore size which commonly used is in the range of 0.4 to 1.0µm, and the thickness is in the range of 0.04 to 0.25 mm [24, 25].

Between all materials, PTFE has greater properties like largest, contact angle with water, hydrophobicity, thermal stability and higher oxidation resistance and good chemical compared to PVDF and PP.

Two main characteristics are guiding to choose membrane material for use [26-28].

The membrane used at this topic is PTFE part#: MSPTFE 260045B, Lot#: 1801331008, pore size 0.45 µm, wet ability: Hydrophobic.

The setup for the MD application is shown in Figure (1).

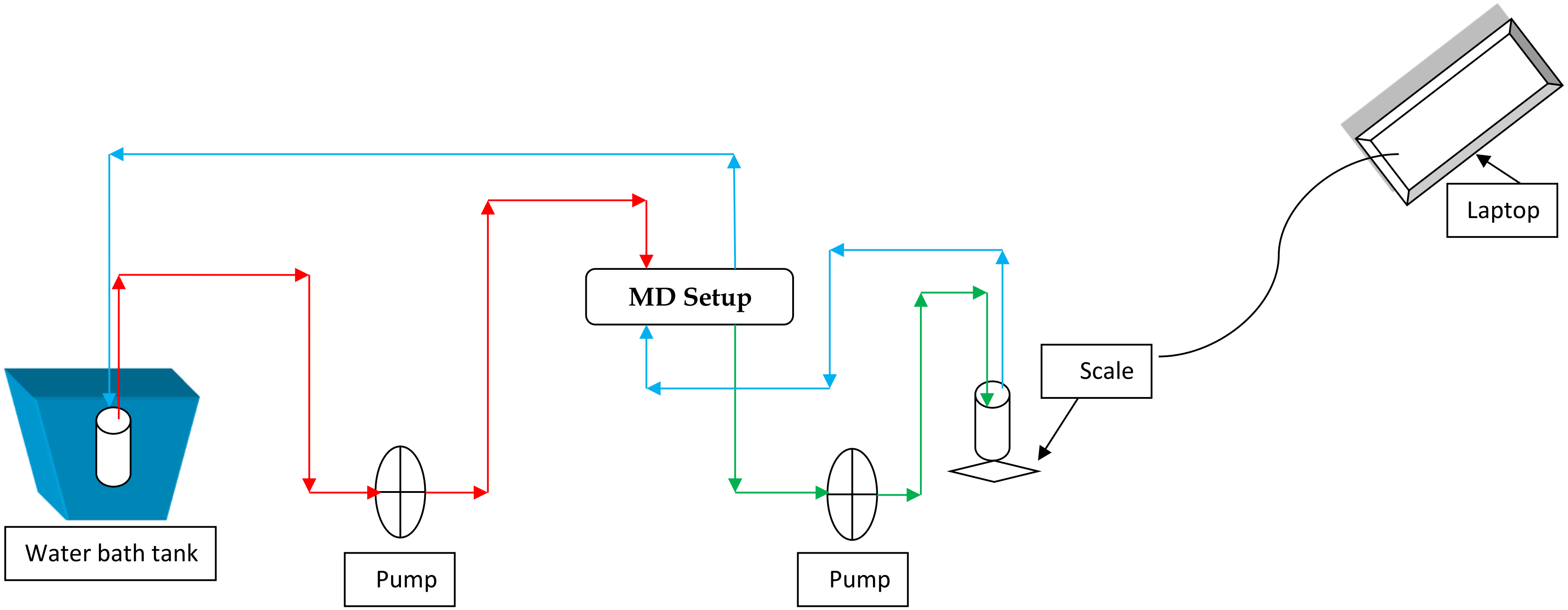


**Figure 1.** Schematic diagram of lab membrane distillation setup.

**The equipment's and apparatuses are stated below:**

Turbid meter – ANNA, Scale - 1kg Digital Bench Scale - IC-7264, COD Reactor - Hach Cod Reactor 45600-00 Digital 25 Well Dry Bath Incubator 115v AC., Spectrophotometer - Spectrophotometers, 6700 series ANNA, Dryer Oven - Digital Glassware Drying Oven, Fan Forced, Glasses and pipettes, cones, flasks, filter papers, etc…, Chemical Kits to measure COD, Total Phosphates (TP) HACH -Phosphate Test Kit, Model PO-23, EC - pH meter, Benchtop pH / MV Meter - IC860031, Total Nitrate meter., HCL acid and other chemicals like NaOH, etc…., Kaolin clay - 100% Pure Australian Kaolin White Superfine Clay DIY Skincare DIY Face Mask as well as Alum and Calcium hydroxide, NaCl salt.

## 4. Results and discussions

The heated solution will be brought in to the one side of the hydrophobic micro-porous membrane interface. Because of the nature of the membrane is hydrophobic and this will prevents penetration of liquid resulting in vapors liquid inter phase at each pore entrance. Porous of this membrane will pass vapour depends on porosity which is defined as the volume of the pores divided by the total volume of the membrane in the module.

Figure (2) describe the relation between flux and temperature and as the shown flux will increase with temperature which is confirmed points above.

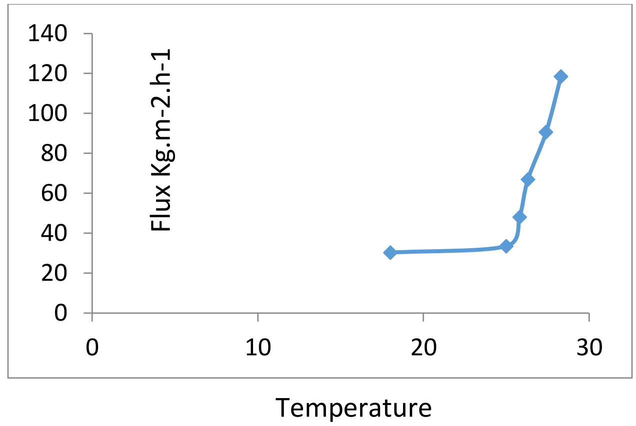


**Figure 2.** Relation between temperature and Flux.

The porosity of the membrane means the volume of pores that will pass vapor through the membrane in the module. The catalyst, which is part of the feed that does not pass through the pore membrane, contains a high concentration of phosphorous. In general, this stream is recycled again to increase efficiency. As a result, the phosphorous removal will increase as the feed temperature increases.

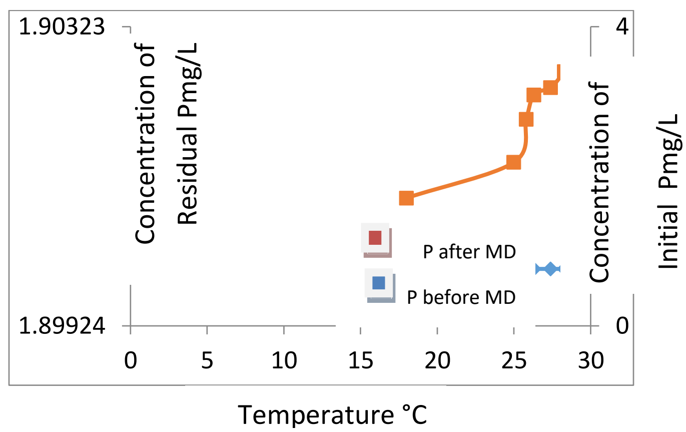


**Figure 3.** Relation between Initial P and final concentration after pass at MD.

## 5. Conclusion

- The ability of MD to remove P from dairy wastewater has reached 95%,
- Temperature affects the effectiveness of MD and is directly proportional to flux.

- It is very important to remove materials like organic and inorganic substances which may block the membrane,
- Connection of hoses and direction of flow have a direct impact on the surface area of flux.

## 6. Recommendation

- There is no study on the exploitation of heat energy produced as a waste in the dairy factory,
- Utilizing solar heat in hot seasons need more investigation.

**Acknowledgement**

I would like to give my thanks to my teacher M. Al- Rawi for supporting and helping me.

I would like to give my thanks for Dr Yaarob Mahjoob Al-Nidawi for supporting me and helping me.

## 7. References

1- Al-Rawi, S. and H. A. Al-khashab (2011). "Removal of Oil and Suspended Solids from Dairy Industry by Dissolved Air Flotation." Al-Rafadain Engineering Journal**19**(1).

2- Sarkar, B., et al. (2006). "Wastewater treatment in dairy industries—possibility of reuse." Desalination**195**(1-3): 141-152.

3- Cox, T. and Y. Zhu (2005). "DAIRY: ASSESSING WORLD." Global Agricultural Trade and Developing Countries: 161.

4- Kadam, R. and G. Saxena (1996). "Managing a dairy effluent treatment plant." Indian Dairyman**48**: 117-122.

5- Kroyer, G. T. (1995). "Impact of food processing on the environment—an overview." LWT-Food Science and Technology**28**(6): 547-552.

6- Singh, A., et al. (2015). "Study of sociodemographic characteristics and awareness about personal hygiene among the food handlers." International Journal of Medical Science and Public Health**4**(9): 1212-1217.

7- Rana, T. M. D., et al. "RECENT ADVANCES IN MEMBRANE SCIENCE AND TECHNOLOGY IN SEAWATER DESALINATION–WITH TECHNOLOGY DEVELOPMENT IN THE MIDDLE EAST AND SINGAPORE."

8- Miller, J. E. (2003). "Review of water resources and desalination technologies." Sandia national labs unlimited release report SAND-2003-0800.

9- Wang, Y., et al. (2011). "A review of polymer electrolyte membrane fuel cells: technology, applications, and needs on fundamental research." Applied Energy**88**(4): 981-1007.

10- Singh, R. (2006). Hybrid Membrane Systems for Water Purification: Technology, Systems Design and Operations, Elsevier.

11- Kesieme, U. K., et al. (2013). "Economic analysis of desalination technologies in the context of carbon pricing, and opportunities for membrane distillation." Desalination**323**: 66-74.

12- Wang, K. Y., et al. (2009). "Mixed matrix PVDF hollow fiber membranes with nanoscale pores for desalination through direct contact membrane distillation." Industrial & engineering chemistry research**48**(9): 4474-4483.

13- Curcio, E. and E. Drioli (2009). Membranes for desalination. Seawater Desalination, Springer**:** 41-75.

14- Daufin, G., et al. (2001). "Recent and emerging applications of membrane processes in the food and dairy industry." Food and Bioproducts Processing**79**(2): 89-102.

15- Gryta, M., et al. (2001). "Purification of oily wastewater by hybrid UF/MD." Water Research**35**(15): 3665-3669.

16- Gálvez, J. B., et al. (2009). "Seawater desalination by an innovative solar-powered membrane distillation system: the MEDESOL project." Desalination**246**(1): 567-576.

17- Banat, F. A. and J. Simandl (1998). "Desalination by membrane distillation: a parametric study."

18- Garcıa-Payo, M., et al. (2000). "Air gap membrane distillation of aqueous alcohol solutions." Journal of membrane science**169**(1): 61-80.

19- Zakrzewska-Trznadel, G., et al. (1999). "Concentration of radioactive components in liquid low-level radioactive waste by membrane distillation." Journal of Membrane Science**163**(2): 257-264.

20- Casal Valls, O. (2015). "Integration of Direct Contact Membrane Distillation on desalination brine concentration."

21- Kargari, A. and M. Shirazi (2014). "Solar-assisted membrane distillation: Water desalination." Encyclopedia of Energy Engineering and Technology (2nd Ed.), Taylor & Francis, DOI**10**.

22- Lei, Z., et al. (2005). Special distillation processes, Elsevier.

23- Shirazi, M. M. A., et al. (2013). Saline water desalination by low grade energy: Practical solution for water shortage in Middle East. 5th International Conference on Water Resources and Arid Environments (ICWRAE 5), Saudi Arabia.

24- J.Zhang, N.Dow, M.Duke, E.Ostarcevic, J.D.Li and S.Gray, ”Identification of material and physical features of membrane distillation membranes for high performance desalination”.J.Membr.Sci.2010, 349, 295–303.

25-A.M.Alklaibi and N.Lior, ”Membrane-distillation desalination: Status and potential”.Desalination 2005, 171, 111–131.

26- S.Bonyadi and T.S.Chung, “Flux enhancement in membrane distillation by fabrication of dual layer hydrophilic-hydrophobic hollow fiber membranes”, J.Membr.Sci.2007, 306, 134–146.

27- M.Tomaszewska, “Preparation and properties of flatsheet membranes from polyvinylidene fluoride for membrane distillation”, Desalination 1996, 104, 1–11.

28- E.Drioli, V.Calabrd and Y.Wu, “Microporous membranes in membrane distillation, “Pure Appl.Chem.1986, 58, 1657–1662.