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THE ROLE OF MEMBRANE DISTILLATION IN REMOVAL OF MG2+ FROM DAIRY WASTEWATER

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Abstract: The dairy industry has become a great source of human development in terms of providing the necessary amount of energy and calories, in addition to the vitamins needed to sustain life. Iraq is one of the largest countries that are dairy-producing and it is expected that the average per capita consumption of dairy products will increase from 52 litres to more than 60 litres during the next three years, then to more than 90 litres by 2025. Dairy production needs to consume large quantities of water It needs to consume 2-6 cubic meters of water to produce one ton of milk. These large quantities of water will lead to the discharge of large amounts of wastewater, which may reach 70% of the water used. Over the years I have used various techniques and methods for treating dairy wastewater. In this study, the membrane permeation removal technique (MD) was used to find out how efficient this technique is in removing the magnesium ion from the milk laboratory wastewater. The results came with the possibility of this technique in removing a small percentage of up to 9.76% at a temperature of approximately 45 degrees Celsius, which is a small percentage compared to the concentration of the interior and the effort exerted. For this reason, it is not recommended to use this mechanism to remove magnesium from dairy wastewater.

Keywords: *Dairy Wastewater; Membrane Distillation; Magnesium; Removal*

1. Introduction

The dairy industry includes the process of converting raw milk into simplified and sour milk and yogurt:

Fine cheese, cream, various products, ice cream, milk, powder, lactose, condensed milk, plus production of many various sweets. And because all of these materials are produced, they will generate a set of pollutants, they will be released to the environment in one way or another, and they will lead to a major change in the total environmental mass. The milk production growth rate is about 2.8 per cent annually, and the dairy processing industry is the largest [1, 2].

2. Characteristics of dairy wastewater

According to [3] yearly product of milk reach 600 Million ton and this value distributed according to source 85% bovine, 2% sheep and Goat, 11% Buffalo. Uses of this product will lead to different type of flavours like cheese 33%, or cream or my consumed directly which reach to 39% as a liquid.

Milk is a great miracle in that it is produced from complicated substances and this leads to being something very composite and contains a lot of dissolved and suspended matter and it contains more than 100,000 molecules is different. The

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installation overall milk determines as follows: 4.1% fat, 3.6% protein, 4.9% lactose, 0.7% different compounds such as Ores and vitamins and lubricants consists of fat in milk is composed mainly of three-Glycerin containing a wide range of fatty acid, which in turn contains a relatively high percentage "of saturated fatty acids and short chains of fatty acid [4, 5].

Milk was discovered 200 years and the contents of this compound are protein which is dissolved at pH equal to 4.6 called Caseins and which constitute 78 per cent of the total nitrogen in the cow's milk, and Section dissolved alleges Serum (Whey), (Walstra 2013). Lactose is the carbohydrate part of the basic product for all kinds of mammalian milk. Milk contains a few complex compounds compared to other forms of sugar such as glucose (50 mg / l) and fructose [6, 7].

The dairy industry is one of the largest industries that consume a lot of water in the process stage especially in Iraq. However, this industry is not linked directly with the environmental crisis but it has an organic stamp. The serum resulting from cheese manufacturing liquid is severe organic pollution so that it can be worth needing chemical oxygen (COD) to 70,000 mg/L. Much recent research suggests biological treatment anaerobic process success in the treatment of industrial pollutants with high organic content [8].

Dairy wastewater has a lot of organic material as well as different detergent materials used in the factory. In general according to [9], bovine milk has contains fat (4%), water (87%), protein (3.5%), ash (0.8%) and lactose (4.7%). The fat amount varieties are between 3 - 5% with the main component being triglycerides (98%). While other fat parts including sterols (0.2 - 0.5% of fat) and phospholipids (0.5 - 1% of fat) [10]. Because cows have different food system milk will contain different traces of other organic compounds [11]. However type of food is different, wastewater delivered is different. According to [12], features of dairy wastewater are shown in “Table 1” below. These products will participate with pollutants [13].

Table 1. Illiterates the characteristics of dairy wastewater factories

Chemical compositions	Synthetic Samples
COD (mg/l)	1000-3000
Nitrate (NO_3^-) (mg/l)	0.2-16
Magnesium (mg/l)	95
TP (mg/l)	18-27
Chloride (mg/l)	20-100
Sodium (Na^+) (mg/l)	50-750
Turbidity (NTU)	40-50
TSS (mg/l)	200-1200
TS (mg/l)	150-2500
TDS (mg/l)	150-450
EC (µ mhos/cm)	300-4000
pH	6.5-7.5
Temperature (°C)	25 – 35

3. Treatment of Dairy Wastewater

The source of industrial wastewater, especially dairy products is of relative value. Increased temperature, high organic content, and a wide range of acidity, which requires special purification to remove or reduce environmental damage. Dairy wastewater treatment application includes Mechanical, physical, chemical and biological methods.

Mechanical processing is necessary for the quantitative equation and mass flow changes. It also reduces the number of suspended solids. Physical and chemical processes are effective in removing variable compounds, but adding chemicals increases the cost of water treatment. Another major problem is the ability of large organic matter to deplete oxygen in water bodies, and here it is necessary to get rid of soluble chemical oxygen, which is demand (COD) in wastewater to prevent it from moving into the water. In a useful summary, the use of this technology requires effort and financial cost, as well as the space that must be available for the completion of the project [14] .

4. Membrane Distillation Process (MD)

This mechanism has extensive benefits in terms of exploiting the pressure teams generated by the temperature differential between the cold and hot surface of the robot body, which in turn will trigger the water molecules from the hot to a cold surface, thereby reducing energy costs and less stringent mechanical characteristics. In contrast to distillation and RO, can be separated solutions supply at a much lower temperature than the boiling point and atmospheric pressure. Typical supply temperatures allow about 30-60 and perhaps 80 ° C to reuse residual heat flows and use alternative energy sources such as sun, wind and geothermal. It can be a very efficient and economical way of separating components that are suspended or dissolved in a liquid. It can reclaim valuable milk solids or chemicals for resale, reuse or less expensive method [15, 16] .

4.1. Economic Technology of Membrane Distillation Process

- This process is the simplest type of MD, has recently gained more attention .
- It can explain the characteristics of this type briefly [17-20:[

1- Total (100%) rejection ,
2- Intensive to feed concentration ,
3- Mild operating conditions ,
4- Stable performance at high contaminant concentrations,
5- Osmosis characteristics play a big role in achieving treatment.

5. Materials and Methods

5.1. Samples:

1. Artificial samples of wastewater were prepared.
2. Considerations and consideration of making these wastewater samples among the standard characteristics of the global classifications of wastewater. The artificial samples were prepared similar to real samples discharged from dairy factories; these samples were prepared from salts below regarding be similar real samples. On the other hand, alum were prepared each week to keep the chemical characteristics of the solution.

- Alum $Al_2(SO_4)_3$.18 added to 1 litre and used as a solution in concentration 1% by adds 10 gm. to 1 litre of distilled water. This solution is remade every week to ensure its effectiveness.
- Sucrose hydrate $C_{12}H_{22}O_{11}.H_2O$
- Sodium Phosphate Dodecahydrate$Na_3PO_4.12H_2O$
- Ammonium sulfate$NH_4.2SO_4$

5.2. Membrane Materials

There are various types of membranes that are hydrophobically made of different materials such as polypropylene (PP), Polyvinyl fluoride (PVDF), and Poly tetra fluoro ethylene (PTFE) polyethylene (PE) available in the forms of sheet, tubular, hairy or flat used in the experiments MD.

These membranes are not the scope of the follicular, ranging from 0.50 - 0.90, the size of the pores as commonly used ranges from 0.4 to 1.0 µm, the thickness ranges between 0.04 and 0.25 mm [21, 22].

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.

Surface energy and thermal conductivity are properties to be considered while selecting membrane material for use [23-25].

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

Table 2: 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

5.3. Samples:

1. Similar industrial samples were prepared for the wastewater of the dairy laboratory.
2. The considerations and theory in making these samples have standard characteristics similar to the global classifications of wastewater discarded from dairy plants.

5.4. Test Procedure:

The concentration of magnesium in artificial samples was measured according to International standards and by using global instruments. This article has been using the HACH instrument with all kits needed to achieve the tests. For determination of calcium and magnesium hardness in water by the Calmagite Colorimetric method. HACH Method 8030. 100 mL Marked Dropping Bottle.

5.5. Setup:

A laboratory model has been built to achieve experiments, and the workflow in experimental implementation can be seen as shown in "Fig. 1".

The pumps used are 2 pumps of peristaltic pumps,

• Powerful and long-lasting motors • Robust pump heads • Large clear display screens • Wide flow rates available from micro to industrial • Dispensing pumps with optional dosing footswitches and PC control • Compact design to easily move around the lab • Foot pedal switch for quick and easy dosing - press to dose.

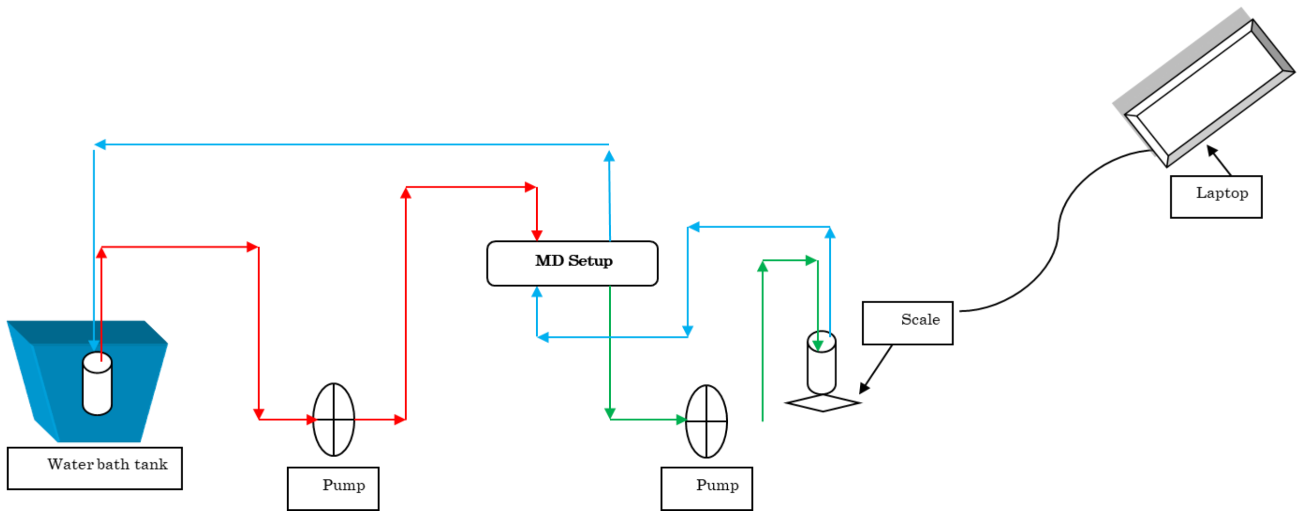

Figure 1 . Shows schematic diagram of setup used at the lab.

6. Results and Discussions

Due to the difference in temperature between the two separating surfaces of the pump pumps, a pressure difference will be generated that will lift the water molecules from the hot side to the cold surface. Here, the flow value will be increased for this reason, and it is observed from “Fig. 2”.

“Fig. 2”: Describe the relation between flux and temperature and as the shown flux will increase with temperature which is confirmed points above.

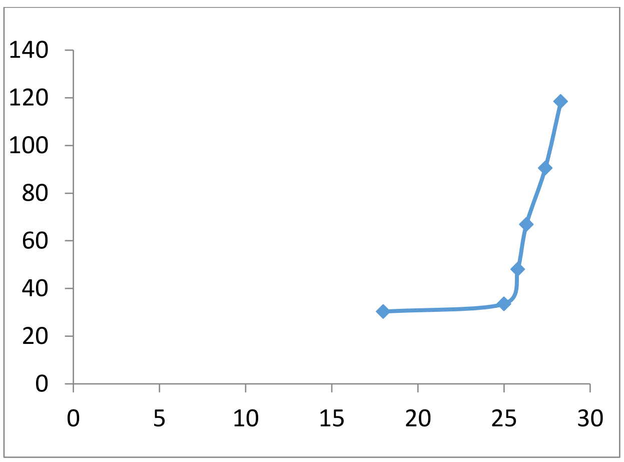

Figure 2. A relationship that shows the variability of the flow with temperature when passing dairy wastewater models onto MD.

It is observed from “Fig. 2” that the flow is constant with slight variation in the temperature limits between 20 ± 5 °C. Here, it is observed that the concentration of Magnesium transported during the membrane openings will increase with the increase in temperature, and this increases the removal of this ion.

It is noted from "Fig. 2” that the amount of flow increases with increasing temperature, and this is logical, as increasing the temperature to a certain extent will increase the vapour, and due to the difference in pressure between the two sides, these atoms will penetrate the permeable membrane through the pores to the other side.

When the reactor is turned on to transfer water vapour from the hot side to the cold side due to the different temperatures and pressures, the magnesium ions with a radius of 173 pm (1 pm = 1 × 10^{-12} meter (meter)), will begin to attach to the membrane walls. This property will give the membrane the ability to remove the magnesium ion from the wastewater of the dairy wastewater.

“Fig. 3” notes that the continued operation of the membrane will lead to increased magnesium removal at 45 °C, the best removal will take place, with removal reaching approximately 97.73%.

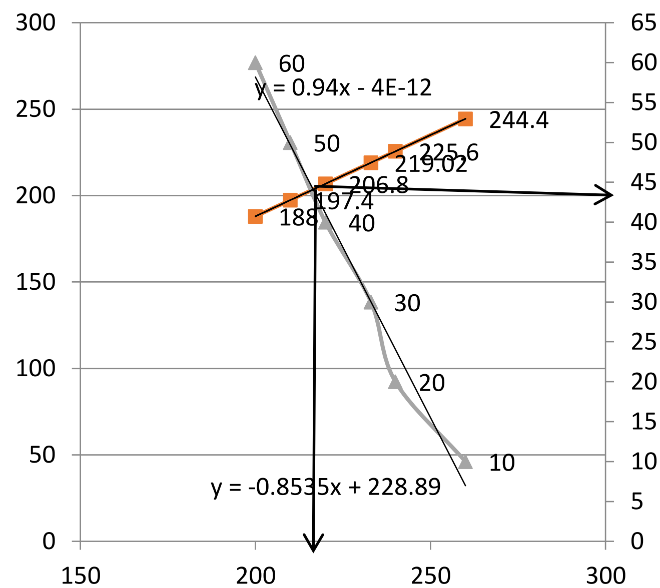

Figure 3. The relationship that shows magnesium concentration differences from the outside when passing the dairy wastewater models to MD.

Although this system can operate at low temperatures with an average of 30 degrees Celsius which is the optimum operating temperature in Iraq, we would have had the optimum removal at 45 degrees Celsius, and the clearance was not more than 9.72%. This technique removes magnesium from liquid wastewater for dairy plants.

Using the equations shown in "Fig. 3" and shown in the curves, the resulting concentration value can be expected at the flow temperature if 45 °C is 216 mg per litre.

If the equation is applied

$y = 0.391x - 23.18$ (1)

$y = -0.853x\ 228.8$ (2)

If the interior is 215 mg / l, then the outside at this temperature is about 194.11 mg / l, and this does not indicate that there is much removal.

Which is observed from "Fig. 4" that the percentage of Magnesium ion removal increases with increasing temperature, which is a slight increase that may be due to the Magnesium ion attachment and accumulation in the membrane and the closing of the holes in the membrane due to the formation of chemical pads? However, it is not possible to deviate from the usual operating systems and surrounding conditions. It is not possible to increase the temperature more than normal, which is approximately 45 ˚C or slightly more [26]. The decrease in Magnesium ion concentration in the outflow does not imply that the treatment process is performed optimally. Magnesium may crystallize on the membrane surfaces, which subsequently hinder the mother's action and lead to the fouling, then blocking the MD [27-29].

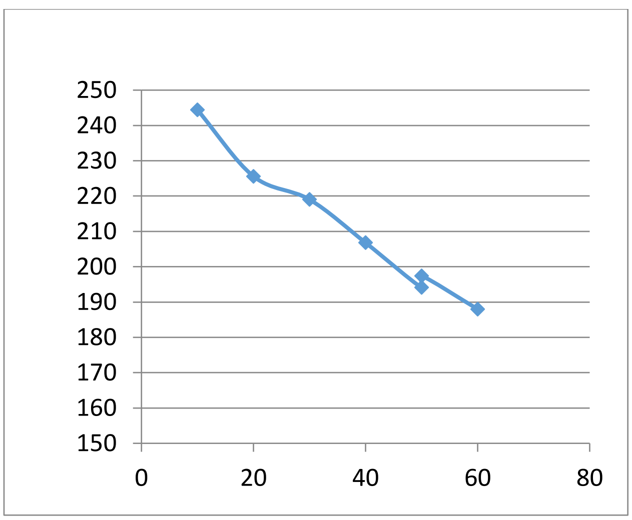

Figure 4: A figure showing the relationship between temperature change and the percentage of Magnesium ion removal.

7. Conclusion

1- The susceptibility of MD to removing Magnesium ion, but with an efficiency that does not reach within 9.72%. % of the concentrated liquid.
2- Temperature affects the value of MD and is directly relative to flux.
3- The presence of organic or inorganic substances in the effluent water of the laboratory leads to obstruction of the membrane work and possibly to occlusion and then stopping.

8. Recommendation

1- Try different membranes which give more suitability in removing Mg^{2+}.
2- The work of studying the possibility of utilizing the waste heat from the dairy units to be used in the efficacy of the permeable membrane.
3- Expanding research on the possibility of fouling in the use of MD, especially when using ions with a valence greater than one.
4- Provide a pretreatment process before applying MD to remove suspended and soluble organic and inorganic material to mitigate the load on MD.
5- Make a study that takes other variables with magnesium like temperature, pH, etc…

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Conflict of interest

The author confirms that the publication of this article causes no conflict of interest.

9. References

1. Walstra, P. (1999). Dairy technology: principles of milk properties and processes, CRC Press.
2. McGee, H. (2007). On food and cooking: the science and lore of the kitchen, Simon and Schuster.
3. Zemel, M. B., et al. (2008). "Effects of dairy intake on weight maintenance." Nutrition & Metabolism **5**(1): 28.
4. WANJIRU, M. J. (2015). DEVELOPMENT OF A LOW COST WATER PURIFICATION SYSTEM–A CASE STUDY CERAMIC FILTERS AND MORINGA OLEIFERA SEEDS, UNIVERSITY OF NAIROBI.
5. McManus, D. B. (2016). Eating Discourses: How Beliefs about Eating Shape the Subject, its Body, and its Subjectivity, University of California, Davis.
6. Varnam, A. and J. P. Sutherland (2001). Milk and milk products: technology, chemistry and microbiology, Springer Science & Business Media.
7. Phillips, G. O. and P. A. Williams (2011). Handbook of food proteins, Elsevier.
8. Hughes, J. D. (2009). An environmental history of the world: humankind's changing role in the community of life, Routledge.
9. Miller, G. D., et al. (2006). Handbook of dairy foods and nutrition, CRC press.
10. Paape, M. and A. Capuco (1997). "Cellular defense mechanisms in the udder and lactation of goats." Journal of animal science **75**(2): 556-565.
11. De Noni, I. and G. Battelli (2008). "Terpenes and fatty acid profiles of milk fat and “Bitto” cheese as affected by transhumance of cows on different mountain pastures." Food chemistry **109**(2): 299-309.
12. Barnett, J., et al. (1994). "Effluent treatment systems for the dairy industry." Australasian Biotechnology **4**: 26-26.
13. Kosseva, M. R. (2009). "Processing of food wastes." Advances in food and nutrition research **58**: 57-136
14. Sahu, O. and P. Chaudhari (2013). "Review on chemical treatment of industrial waste water." Journal of Applied Sciences and Environmental Management **17**(2): 241-257.
15. 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."
16. Shah, Y. T. (2014). Water for energy and fuel production, CRC Press.
17. Warsinger, D. M., et al. (2015). "Scaling and fouling in membrane distillation for desalination applications: a review." Desalination **356**: 294-313.
18. Curcio, E. and E. Drioli (2005). "Membrane distillation and related operations—a review." Separation and Purification Reviews **34**(1): 35-86.
19. Ali, A., et al. (2018). "Membrane technology in renewable-energy-driven desalination." Renewable and Sustainable Energy Reviews **81**: 1-21.
20. González, D., et al. (2017). "Membrane distillation: Perspectives for sustainable and improved desalination." Renewable and Sustainable Energy Reviews **80**: 238-259.
21. Shirazi, A., et al. (2015). "A review on applications of membrane distillation (MD) process for wastewater treatment." Journal of Membrane Science and Research **1**(3): 101-112.
22. Ghaffour, N., et al. (2015). "Renewable energy-driven desalination technologies: A comprehensive review of challenges and potential applications of integrated systems." Desalination **356**: 94-114.
23. Shirazi, M. M. A., et al. (2014). "Production of drinking water from seawater using membrane distillation (MD) alternative: direct contact MD and sweeping gas MD

approaches." Desalination and Water Treatment **52**(13-15): 2372-2381.

24. Shirazi, A., et al. (2015). "A review on applications of membrane distillation (MD) process for wastewater treatment." Journal of Membrane Science and Research **1**(3): 101-112.
25. Tiwari, G. N. (2002). Solar energy: fundamentals, design, modelling and applications, Alpha Science Int'l Ltd.
26. Lalia, B. S., et al. (2013). "A review on membrane fabrication: Structure, properties and performance relationship." Desalination **326**: 77-95.
27. J.Zhang, N.Dow, M.Duke, E.Ostarcevic, J.D.Li and S.Gray, ”Identification of the material and physical features of membrane distillation membranes for high performance desalination”.J.Membr.Sci.2010, 349, 295–303.
28. A.M.Alklaibi and N.Lior, ”Membrane-distillation desalination: Status and potential”.Desalination 2005, 171, 111–131.
29. 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.