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Fouling Control and Waste Management of Membrane Based on Water Purification and Desalination

التحكم في الترسيبات وادارة مخلفات اغشية تنقية واعذاب المياه

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Abstract

In this study the membrane performance of reverse osmosis (RO) elements along longitudinal direction in a pilot-scale plant with two CSM-2540 RO elements during municipal tap water treatment at the constant recovery and flux is investigated. The continuous cleaning process is carried out with fresh water cleaning. The membrane performance is monitored by the system and element pressure drop and the rejection. During add Tio_2 (nano particles) in feed water with different concentration, with combined between different period for back wash and monitored the performance RO membrane. Moreover, the performance of fouled membranes is restored by using the conventional cleaning protocol. Soluble particles can enter the membrane pores and then build up on the pore wall, leading to a reduction in the total section area of the membrane pore, causing pore plugging into the membrane and increasing the membrane resistance. Membrane fouling is strongly influenced by solutions characteristics, operating conditions and membrane characteristics. The pumping power increases with increasing the fouling in membrane. The TDS also increase with increasing the fouling, . A simple unit can be used for fast fouling processes using the nanofluid concentration as TIO2. in feed flow during the backwash process. The nanofluid and washing time use the main role played in increases in RO system production. The SAW shape is the shape of the processes for all experiment. The maximum save in productivity is about 8.0% when using the washing time is 20 min.

Keywords;
(Desalination, Backwash, Cleaning, Reverse osmosis, Osmotic backwash).

1. Introduction

Membrane filtration is a process where a membrane is used as a physical Barrier to separate compounds by applying a driving force across the Membrane. In a membrane system, a feed water solution is separated into two Solutions, the product or permeates, containing solutes that have passed through the membrane and the concentrate containing solutes and particles Rejected by the membrane **(NIRIELLA, D. P. 2006)**. Reverse osmosis (RO) membranes are currently being used in a wide range of applications, including brackish and seawater desalination as well as in membrane mediated waste water reclamation. However, membrane fouling is a major problem to be typically caused by inorganic and organic materials present in water that adhere to the surface and pores of the membrane and results in deterioration of performance with a consequent increase in costs of energy and early membrane replacement **(Al-Amoudi 2010**). So far many full-scale water reclamation plants are challenged by low production yield and frequent membrane cleaning. Accordingly, a significant amount of research has been conducted to better understand the mechanism of RO membrane fouling and cleaning so as to develop preventative methods for membrane fouling **(Al-Amoudi, and Lovitt, (2007).**. In particular, most of controlled laboratory experiments have been performed to study different

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pollutants contributing to membrane performance including organic fouling and inorganic fouling **(Ang, et al. 2006**). Although these studies have improved our understanding of various aspects of membrane fouling during water treatment and desalination, laboratory-scale studies are limited in appropriately simulating hydrodynamic conditions of full-scale applications. The laboratory-scale with single membrane module could not provide valuable data for industrial application. *Consequently*, some researchers have both numerically and experimentally focused on the fouling type and mechanisms in the pilot- or full-scale system during the water treatment. With regard to experimental study, **Bu-Ali et al. (2007)** showed that dry matter and organic concentration decrease and the extended biofilm created an important pressure drop along the tube in a RO plant during brackish water treatment. **Chen et al. (2010)** demonstrated that the fouling of the lead elements was mainly caused by adsorption and deposition of effluent organic matter in a 2-stage pilot-scale plant with twenty-one 4040 spiral wound nano filtration NF/RO elements during filtration of the non-nitrified effluent. In addition, they found that membrane fouling was dominated by bio fouling in combination with organic fouling, colloidal fouling, and inorganic scaling during treatment of the nitrified/denitrified effluent. With regard to numerical study, **Dirk et al. (2008)** described the effects of fouling on the performance of a RO system treating microfiltered secondary effluent with a semiempirical model relying on mass and momentum balance equations and two empirical correlation coefficients. The model confirmed that cake formation predominated in lead elements causing a localized flux decline. Hence, a high flux in tail elements could enhance solute rejection and concentration polarization. Meanwhile, some effective numerical methods were used for assessing fouling characterization and indicating fouling development in RO process **(Hoek et al. 2008). Jacquemet et al. (2006)** reported that a full-scale RO system could maintain a constant average permeate flux for a period of time even though fouling development had occurred right from the start of operation with the increase in resistance as an indicator of membrane fouling. **Lee et al. (2010)** proposed the filtration coefficient relating to distribution of the membrane resistance as the indicators or measurements of membrane fouling in full scale RO processes. Roth et al. (1999) proposed a method to reveal the degree of fouling and the solute permeation mechanism by comparing the sodium chloride distribution in the outlets of the RO membrane modules.

1.1 Membrane Fouling

The choice of membrane for fouling and rejection studies is crucial. López-Ramírez et al(2006) pointed out that some membranes exhibit low fouling regardless of their rejection. For other membranes, their flux is controlled by osmotic pressure effects, which is indicative of rejection. Madaeni, and Samieirad (2010) pointed out that the most important membrane characteristic is probably Hydrophobicity. Membrane fouling in Membrane bioreactors MBRs is attributed to the physicochemical interactions between the bio fluid and membrane. As soon as the membrane surface comes into contact with the biological suspension, deposition of bio solids onto it takes place leading to flux decline. Since this cake layer is largely readily removable from the membrane if an appropriate physical washing protocol is employed, it is often classified as reversible fouling. On the other hand, internal fouling caused by the adsorption of dissolved matter into the membrane pores and pore blocking is considered irreversible and is generally only removed by chemical cleaning. However, restricting categorization of membrane fouling to reversible or irreversible is somewhat simplistic. Furthermore, severe fouling can permanently damage the membrane and reduce the overall productivity of a membrane system, both of which can reduce compromise the economic feasibility of a water treatment process and treatment facility. Fouling of RO membranes is defined operationally herein as the reduction in water transport per unit area of membrane (flux), caused by a substance or substances in the feed water that accumulate either on or in the membrane. While there are several common causes of RO membrane fouling **Rahardianto,** et al (2010) this paper will focus primarily on biological and colloidal fouling, which are less well documented than other fouling such as inorganic scales. Fouling is a problem common to all types of membrane processes. In the fouling phenomenon, constituents in feed water that are retained on the membrane surface or in the membrane pores are called foulants, i.e. precipitations of organic and inorganic matter or biofilm [**Shirazi et al., 2010].**

1.2 Fouling Control

Due to the many variables affecting fouling, fouling controls can be implemented in many ways, both directly or indirectly. Direct methods may include adding turbulence promoters, implementing pulsed or reverse flow, rotating/ vibrating membranes, periodic cleaning and backwash. Indirect methods include pre-treatment of feed water, membrane surface treatment/ modification, and selection of appropriate operating mode. The following sections discuss the three most common fouling controls used in a submerged hollow fiber system.

1.3 Membrane Cleaning

Finally, fouling can be removed to a certain extent by chemical cleaning. Changes in solution chemistry can minimize fouling (pH far from isoelectric point, low I), as can low pressure operation, high cross flow velocity, selection of modules, and hydrophilic membranes.

Pure water can be used to remove loosely associated solutes from the membrane. For irreversible fouling, chemicals are required. The chemicals to be used depend on the foulant in question and the resistance of the membrane to the cleaning agent.

This requires an understanding of the fouling mechanism if cleaning was to be optimized. **Redondo and Casaňas**. (2001) determined that a combination of alkaline solutions with detergents were effective in removing organic foulants in UF. Cleaning, however, reduced rejection of the membranes (which was restored with filtration) and membrane lifetime. **Roth,** et al. (1999) found acid cleaning very effective due to the inorganic component in fouling. **Sioutopoulos** et al (2010) suggested a washing routine for Ro membranes; however the cleaning frequency appeared rather high.

Subramani et al. (2009) used an alkaline solution to remove Natural Organic Matter NOM deposits, and both acidic and alkaline cleaning to remove inorganic precipitation.

1.4 Factor affecting membrane fouling in pressure based membrane process

1.4.1 Effects of feed properties

The properties of the feed solution such as solid concentration, particle properties, pH and ionic strength strongly influence membrane fouling. . Increase in the feed concentration results in a decline in the permeate flux. This is because of the increase in membrane fouling by the presence of a higher foulant concentration. In a filtration process, the particle sizes in the feed often cover a wide range. The presence of fine as well as coarse particles results in a lower cake porosity as the fine particles can slide between the large ones, filling the interstices. The particle size distribution plays a key role in the selective deposition at high cross-flow. In addition to the particle size, the particle shape affects the porosity of the cake formed on the membrane surface. In general, the lower the particle sphericity, the greater is the porosity **Tansel** et al (2006).

The other factors, such as: pH, ionic strength, and electric charges of particles, are also important. The pH and ionic strength of the feed affect the charge on the membrane, the charge on the particles, conformation and stability of, and the adhesiveness of particles and the size of the cake. For example, a study of the impact of pH of the latex emulsion on membrane fouling showed that the latex emulsion pH should be high enough to prevent the coagulation of latex particles, and hence, to increase the antifouling properties of the latex emulsion. Moreover, a reduction in pH can decrease the molecular size of NOM so enhance adsorption onto membrane, resulting in a significant fouling. According to film theory, an engineering model that predicts flux decline according to mass transfer effects, flux decreases exponentially with an increasing concentration of the feed fluid.

While film theory addresses concentration polarization specifically, it impacts fouling as described above. Generally speaking, increasing the concentration of a feed stream increases the level of reversible foulant (that which can be removed by cleaning). This amounts to an increase in observed cake layer formation and a decline in flux. Increasing the concentration factor (CF) during a membrane process has the same effect on fouling as increasing the feed concentration because the feed solids build up to a greater extent on the retentive side of the membrane.

1.4.2 Effects of membrane operating parameters

The effects of cross-flow velocity and membrane flux on membrane fouling depend heavily on one another. In general, increasing the cross-flow velocity increases the limiting flux **Xu,** et al(2007). When operating in constant flux mode, flux is maintained and pressure on the permit side of the membrane is allowed to increase until the system flux is too low and the system must be cleaned or the process is completed. The chosen flux in this operating scheme impacts fouling in the system because an increased flux at a constant pressure increases convection toward the membrane surface which fouls the membrane to a greater extent. Shear stress at the membrane surface can be increased by increasing the cross flow velocity on the permeate side of the membrane. Furthermore turbulent flow is promoted. This turbulence scours the surface of the membrane to break up the reversible foulant layer and provides inertial lift from the membrane surface which mitigates concentration polarization, thus reducing the potential for fouling.

1.4.3 Fouling reduction, conventional methods of cleaning in pressure based membrane process

Membrane cleaning methods can be classified into a) physical, b) chemical and c) physio-chemical. Physical cleaning methods followed by chemical cleaning methods are widely used in membrane applications. The chemical cleaning methods are usually applied for RO desalination and physical cleaning can apply for FO process.

1.5 Aim of the present work

In the present work the performance of reverse osmosis is experimentally investigated the effected of backwash on performance RO process , The operating parameter on RO system are feed water , temperature of feed water inlet, input pressure of feed water, and the concentration of salt on feed water. Combined between RO desalination system and effect of add the Tio_2 nanofluid in RO system would improve the performance of the system under the temperature limits to prevent scaling and fouling deposition.

2. Experimental Setup

This water purifier adopts the most advanced reverse osmosis (RO) technology in the world. RO membrane is one kind of membrane which adopts outside pressure to lead water molecule penetrate reversely. As the RO membrane's whole diameter is only 0.0001μm (0.1nm), which can effectively remove impurity, soluble salt, organism, heavy metal ion, microorganism, virus, bacteria, pesticide leftover and so on harmful substance from the water and reverse water molecule and soluble oxygen to provide clean and healthy drinking water.

2.1 Filtration mode

Adopting advanced international 5-stage RO technology to eliminate those harmful substances such as bacteria, disease germs and carcinogen etc., chemical and organic.

pilot plant performance

1. Perfect purification process to satisfy different requirements.
2. Use high quality components for product.
3. Adopt of imported filtration membrane to achieve stable purification water output.

Auto control

1. Auto-wash function: this equipment can realize auto-wash for 20 seconds each time when Wring on or before water purification.
2. Water-shortage protection: the equipment will auto-stop if no water or low water pressure.
3. Water-over protection: the equipment will auto-stop when purified water pressure reaches the pre-set pressure limit for the purified water container.

2.2. Pilot plant mechanism

A schematic of the membrane set-up (Figure 1) and all of the system components in the water treatment pilot plant are described below.

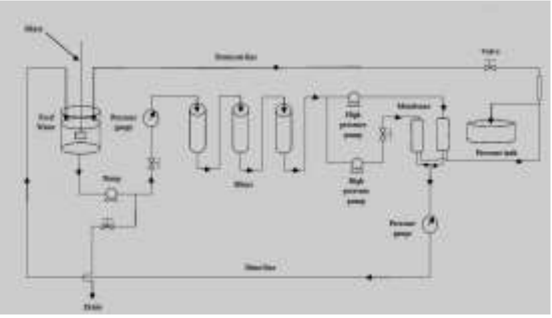


Figure 2.1: Shows the water treatment pilot plant schematic

2.2.1. Filters stage

Fife stages reverse osmosis filtration system:-

1. (Stage 1) 5 micron sediment water filter: With 5 micron polypropylene (pp.) sediment water filter, the machine will remove dirt, rust and sand particles in water
2. (Stage 2) Activated carbon water filter: The second stage is granular activated carbon, It takes out 99% of the chlorine and organic chemicals, it provides enhanced reduction of taste, odor, and color.
3. (Stage 3) carbon hardwood water filter: The third stage filter is filtrated effectively to protect the membrane; it optimized membrane performance up to 95% of salt rejection.
4. (Stage 4) Reverse Osmosis Membrane: The fourth stage is RO (reverse osmosis) membrane, high quality membrane that processes purified water and remove the following chemical contaminants in water: lead, cooper, barium, chromium, mercury, sodium, cadmium, fluoride, nitrite and selenium.
5. (Stage 5) Post carbon water filter: The fifth stage is postposition activated carbon .This carbon filter removes objectionable tastes and odors to improve the quality of your drinking water.it is approved carbon to guarantee the taste of water

2.2.3 Mixer tank

Before the feed water enters the system we have mixer tank 40 lit its used to add the chemical material to make fouling into the system.

2.2.4 Pressure gauge.

Two pressure gauges were installed on this RO system; their function is to show the pressure in the system (Figure2.2). There is one for the pressure input (feed) before the first membrane and one for the pressure on the rejection side of the second membrane. The water pressure indicated by the second pressure gauge is for the operating pressure inside the membrane pressure vessels and can be adjusted using a pressure control valve (PCVA).

Figure2.2 the two pressure gauge

A pressure drop may indicate fouling of the membrane. The reject flow rate can indirectly affect membranes and indicate fouling. Pressure control valve on the reject side is installed to adjust pressure across the semipermeable membrane(s).

2.2.5 TDS, ph., temperature measurement

ADWA INSTRUMENTS AD31 and AD32 are waterproof Conductivity, TDS and temperature testers. The housing has been completely sealed against humidity. All Conductivity and TDS readings are automatically temperature compensated (ATC), and temperature values can be displayed in °C or °F units. The Conductivity/TDS conversion factor (CONV) can be selected at one point. Measurements are highly accurate with a unique stability indicator right on the LCD. The models are also provided with a low battery symbol which warms the user when the batteries need to be replaced. The AD32P probe supplied with the meters, is interchangeable and can be easily replaced by the user. The encapsulated temperature sensor allows fast and accurate temperature measurements and compensation

The Dual Inline TDS monitor used in this set-up was used to define the total dissolved solids content in the two different water lines, before water entered the first membrane feed water and on the permeate side of second membrane. The installed TDS monitor showed if the filter cartridge or the membranes were or were not functioning properly. The used TDS AD31 and AD32 are waterproof Conductivity.

2.3 Water treatment pilot plant operation.

On the first day of practice in the laboratory add (12.5 gm) of the (nano titanium dioxide Tio2) to (40 lit) of water in the mixing tank, mixing occurs for two hours.

Turn-on the power switch at the machine backside. After the power indicator light, the machine will be at automatic operation status. Return purified water and the waste water to the mixer tank.

Record results every 10 minutes for each of the fresh water and waste water internal pressure and external pressure gauge with account temperature, ph, TDS and pressure for each of the fresh water and waste water. At the end of each working day we backwash process for 20 minutes, Turn-off the power switch at the machine backside. On the second day of practice we have to add (12,5 gm) of Titanium dioxide TIO2 to mixing tank for first day Where are added cumulatively

We repeat the process for a period of four days in four hours every day working Reverse washing at the end of the operating.

3. Results and Discussion

The reverse osmosis system is operated under various operating parameters values. Salinity, PH and conductivity value of the feed water and it influences on the performance of RO elements. The degree of fouling in RO systems is a complex function of feed characteristics, membrane properties and operating conditions. The main operating condition effect on RO system is the washing time.

3.1 Performance of RO without Washing

The operating pressure of test is increase for operating time, this increase due to the fouling above the membrane. The TDS also increase with passage of operating time. Shown in Fig.(3-1). The continuous flow in the reverse osmosis process and the continuation of the flow of water through the membrane found the increases of operating pressure accompanied by an increase in the amount of total dissolved salts TDS through the passage of time.

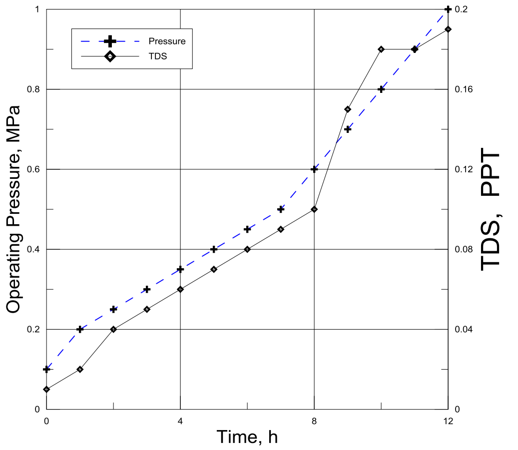


Figure (3-1). Operating pressure and total dissolved solids with operation time

The process of reverse osmosis and water flow through the membrane will note that there is an increase in the preparation of the ph. with high conductivity values whenever it continued in time. As a result of the accumulation of the fouling on the surface of the element and the pores of the membranes is shown in Figure (3-2).

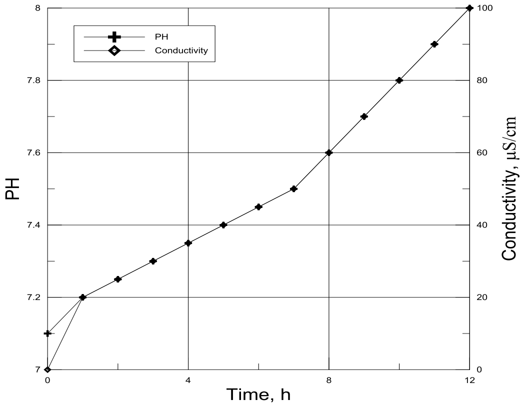
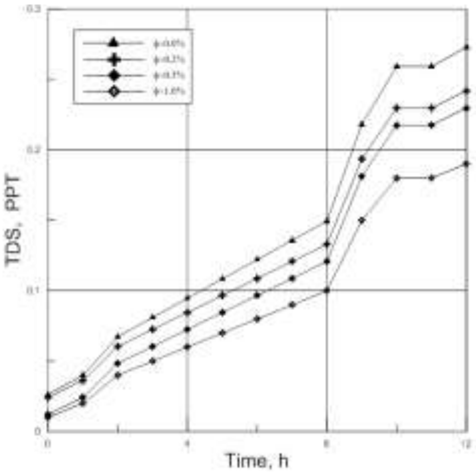


Figure (3-2). The ph. and conductivity of permeate with operation time

3.2 Add Tio2 without washing

During the operating time of the experiment is made in the laboratory that the fouling of NOM (normal organic matter) accumulates a great extent on the surface and the pores of the membrane. The effects of increasing rates and amounts of total dissolved salts TDS during the operating time is shown in Fig.(3-3) .and in fig. (3-4). Show how the relationship between the increased operational pressure with operating time during add the Nano fluid Tio2.



Figure(3-3). Total dissolved solids in RO system with operating time during add Tio2

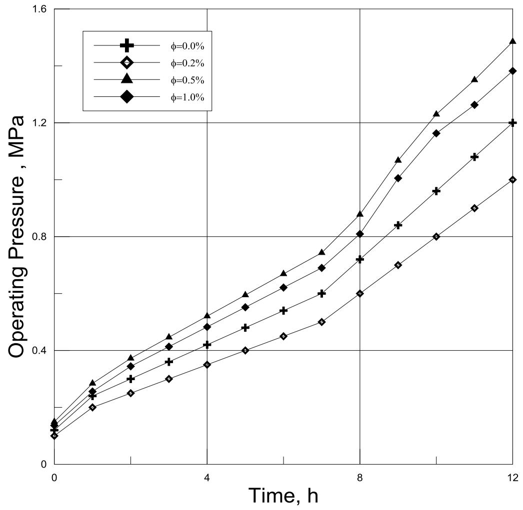


Figure (3-4). Operating pressure with operation time of the operating time during add Tio2

3.3 Performance of RO with Washing

The backwash water used in reverse process is the process washing water on the membrane where water flows in the opposite direction to clean up after the accumulation of membrane fouling in the form of layers such as cake layer on the membrane. When a backwash water system for the reverse osmosis process, where The RO applied pressure affect the concentration polarization layer. and usually backwash period for (5-20) minutes to be run for one hour where it note when the backwash that there is a remarkable increase in the operating pressure during the cleaning period and the accumulation of the fouling in membrane pores Where it is necessary to backwash operation to get rid of fouling and increase the efficiency of the process As in the following figure the effect of backwash on the operating system appears as the curves In the Fig.(4-5) Shows during the washing process for tow hour at different concentrations of reverse osmosis system, reverse fluctuation of total dissolved salts TDS through wash and shown the fouling is increase for increasing the time and the back flow of water clean it after certain period and the operating originally for the process.

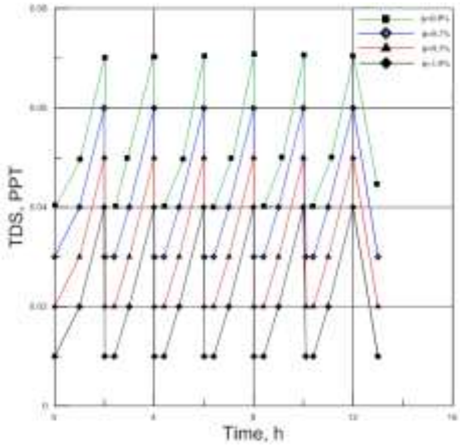


Figure (3.5). Total dissolved solids in RO system. With operating time pending the backwash experiment

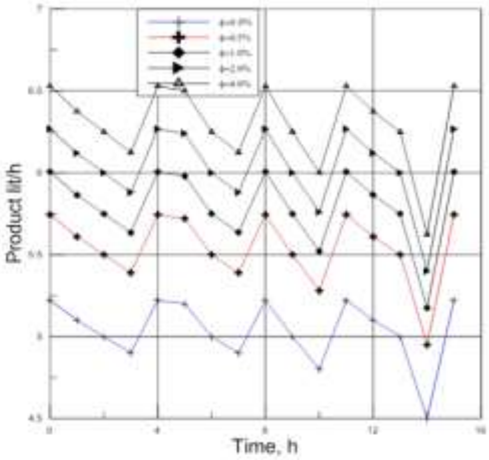


Figure (3.6). Product lit/h in RO system with operating time depending on the backwash

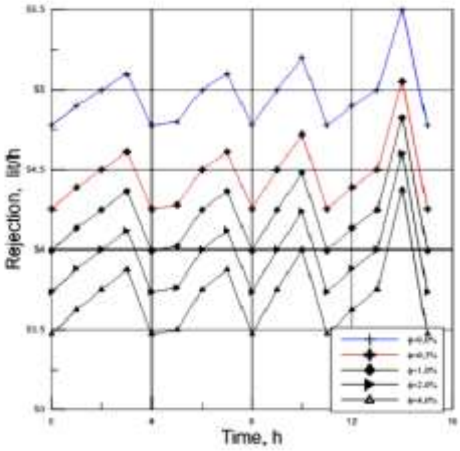
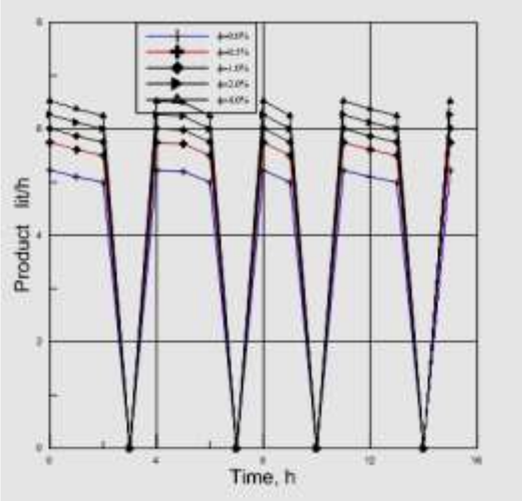
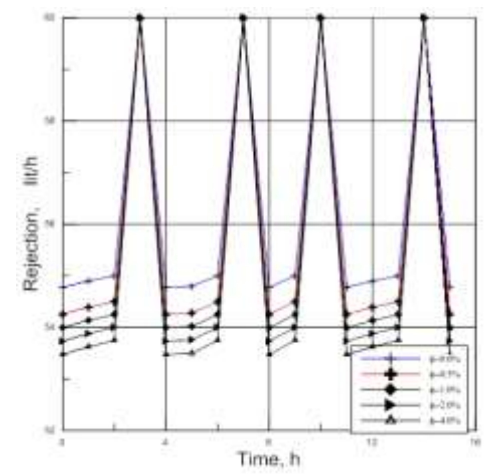


Figure (3.7). Rejection in RO system with operating time depending the backwash

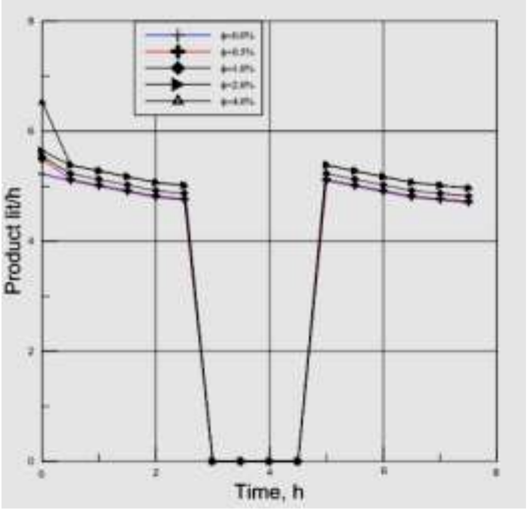


(a)

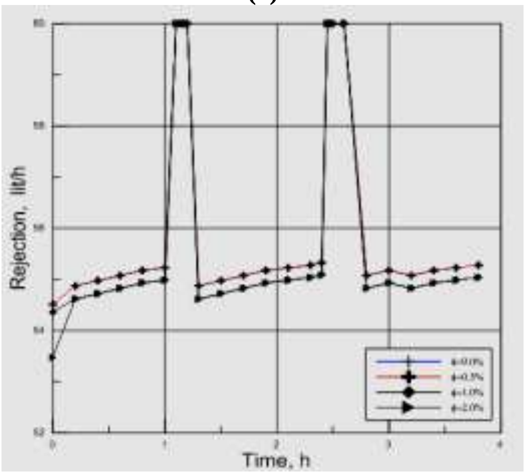


(b)

Figure (3.8) the permeate production (a) and rejection (b) of every membrane element before and after fouling and cleaning operation at 5min washing

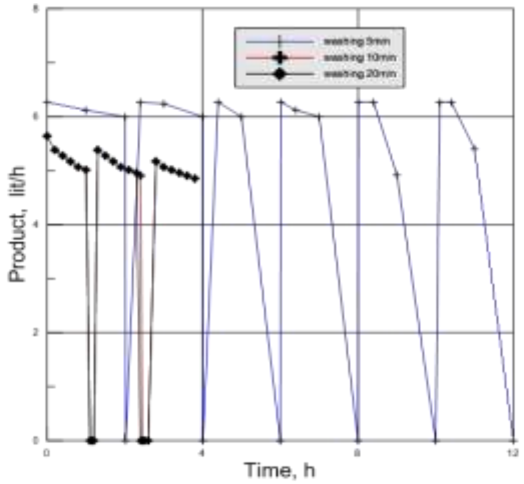


(a)

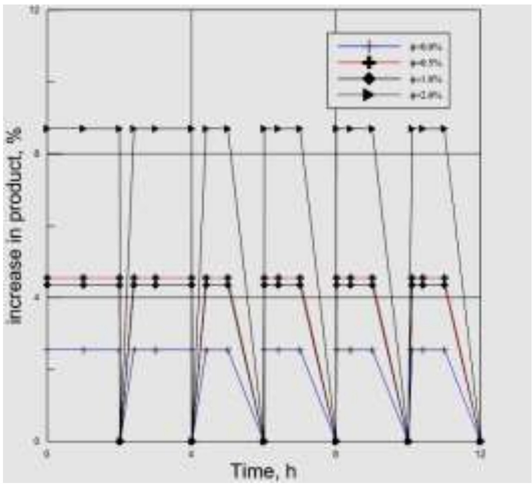


(b)

Figure (3.9) The permeate production (a) and rejection (b) of every membrane element before and after fouling and cleaning operation at 20 min washing



Figure(22) The permeate production of membrane element before and after fouling and cleaning operation at different washing time f=1%



Figure(3.10) increase in the permeate production membrane element before and after fouling and cleaning operation at 5min washing

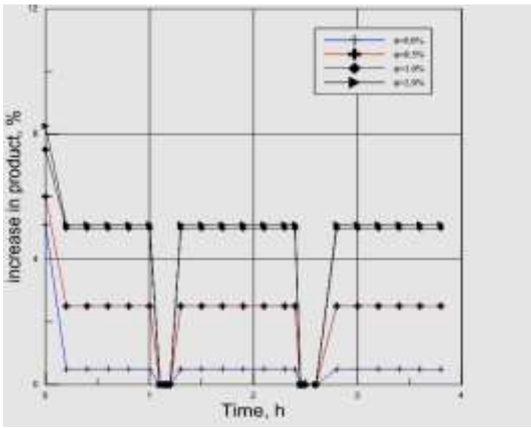


Figure (3.11) increase in the permeate production membrane element before and after fouling and cleaning operation at 10min washing

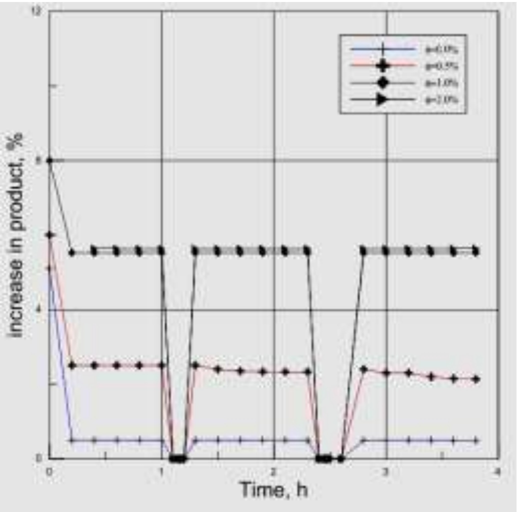


Figure (3.12) increase in the permeate production membrane element before and after fouling and cleaning operation at 20min washing

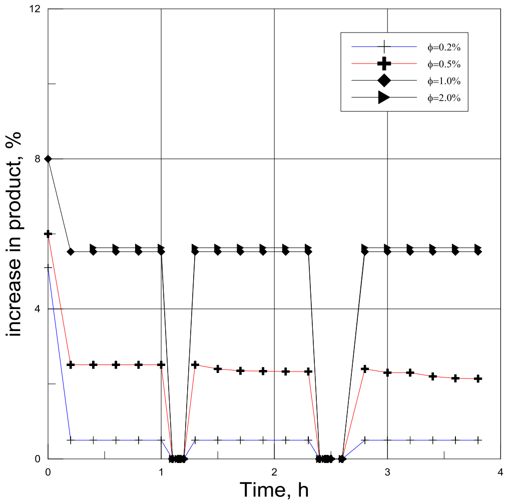


Figure (3.13) increase in the permeate production membrane element before and after fouling and cleaning operation

5. CONCLUSIONS

This study provided valuable insight into the membrane fouling by monitoring the pressure drop and rejection of organic and inorganic foulants of every element and system during municipal tap water treatment on a pilot-scale plant. It was found that the tail elements suffered more serious fouling than others in the RO system. The changes in pressure drop of membrane unit along longitudinal direction were associated with the hydraulic drag to the passage of permeate at the initial operation as well as high osmotic pressure and concentration polarization. the evaluated during Without backwash increasing deposition on the membrane it caused energy consumed increases for pumps with operating time and with at adding Tio2(nanoparticales) for feed water will reduce of fouling on membrane surface, the backwash processes in different period with add Tio2 nano in different concentration will decrease deposition on membrane. Best backwash period is 20 min where the increase in product at this period is most, and the rejection for RO system in pilot-scale plant will decrease in this period.

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