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MEMBRANE FOULING REDUCTION FOR REVERSE OSMOSIS SYSTEM USING ZETA ROD

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Abstract

Reverse osmosis membrane desalination is one of the most significant water treatments that is used to offer freshwater. The aim of this research is to study the effect of controlling the value of the zeta potential on the suspended particles in the water and the proximity of the membrane surfaces in the colloidal solution, to keep the water stable electrically and disperse the colloidal particles. To achieve this aim, the experimental study was conducted in the Sanitary Engineering Laboratory, in the engineering college - University of Baghdad. Two systems were set up, one worked normally and the other worked by using the zeta rod placed before the reverse osmosis membrane. The results showed that the effect of the zeta rod increased all parameters (Total Dissolved Solids (TDS), Electric Conductivity (Ec), Tur., phosphate (pH), chlorine (Cl), calcium (Ca), Sodium (Na), and Fluoride (F)), when compared with the system that worked normally. This effect was due to the added effort of the colloidal particles that saved them in the suspension. This also improved the performance of the reverse osmosis membrane, by increasing the permeate flux by 23.6%, and decreasing the real feed pressure by 9.92%. Therefore, this effect increased the production of water in the system and extended the life of the membrane.The application of the zeta rod before the reverse osmosis membrane will affect the colloidal particles by adding them some efforts, so this keep them suspended and prevent the formation of sediments on the membrane

Keywords: Fouling, Membrane, Reduction, Reverse osmosis, Zeta Rod.

1. Introduction

Membrane technology is one of the best approaches to provide high water quality, and also the most effective film that can hold salt particles. The selective opening of the membrane allows water to pass through, while rejecting the rest [1]. Although, RO membranes are a major challenge, they can be relied upon for the performance of the membrane [2]. Fouling is a complicated phenomenon that includes different techniques under various conditions and can define the deposition of the suspended or dissolved particles on the surface of the membrane or within the pores. Fouling on the membrane surface can be of many types, such as, colloidal fouling, scales, and biofouling [3].

Two methods that can be used to remove and prevent blockages and calcification of membranes, and work to raise the efficiency of the system are shown below [4].

Method 1: The deposits are removed from the membranes after deposition by pulling the membranes out of the system and cleaning them with some chemicals (the operational cost of the system increases when blockages occur rapidly).

Method 1: The prevention of sediment formation before it reaches the membranes is done by controlling some of the physical properties of the membrane and the water that passes through the membrane, including the zeta potential control method.

Membrane blockage is due to the presence of colloidal materials and particles in the water, and these particles are characterized by electrolytic instability of the charge. These blockages reduce water flow and also increase the cost of operating these systems. The interaction between colloidal particles and membrane surfaces largely depends on the physical value (zeta potential) of both the membrane surface and colloidal particles in the water [5].

In recent times, some researcher has studied the technique of controlling membrane pollution by the influence of a microbial membrane reactor on an extracellular polymer substance [6].

Some researchers have been studying the changing of the zeta potential in water by adding some salts, so as to change the concentration of the efficiency of the reverse osmosis membrane, to work on unblocking these membranes, by preventing the formation of the fouling layer on the outside of the membrane. It also shows that the zeta effort of reverse osmosis membranes effectively and strongly affect the presence of non-reactive chemicals and impurities on the surface of those membranes [7, 8]. Successful results have been obtained by application of electrical technology, to remove and prevent the re-interface development of the reverse osmosis equipment operating the reverse osmosis (RO), by increasing the recovery rate and reducing the pressure applied by about 3%.

The main objective of this study is to use the high voltage casting through the ceramic zeta rod electrode, which increases the negative charge of the colloidal particulate matter in the water. Thus, this technique can control the voltage, and therefore, control the process of creating high values of zeta (negative or positive) in the water, so as to prevent the accumulation of particles between them, and hence, the formation of large blocks in the water. Therefore, this is an environmentally friendly physical water treatment, to enhance particulate dispersion and reduce membrane fouling.

2. Materials and Methods

In the present article, the experimental activity includes studying the performance of the reverse osmosis scale model and the effect of using a zeta rod in reverse osmosis membrane fouling, which will be described briefly. The bench-scale RO is composed of the following elements, polypropylene (PP) filter, granular activated carbon filter (GAC), block carbon filter (CTO), booster pump, and the membrane of reverse osmosis. In the following section, each element of the RO model is described in detail, as follows:

1. Polypropylene is used to reduce sediment (refers to the particle size that is tapped). By using PP, particles of sand, silt, dirt, and other sediments that may clog the system can be removed. Polypropylene with a pore size of 5 microns and a filter dimension of 10 inches × 2.5 inches (length × diameter) is used.

2. A Granular Activated Carbon filter (GAC) is the proven option to remove certain chemicals, particularly organic chemicals that are usually used for adsorption of the odor and taste in water treatment.

3. A carbon block filter (CTO) is used to remove chlorine, high chloramine, volatile organic compounds (VOC), bad taste, and odor. The filter pore size is 10 microns and the dimension of the filter is (10 inches × 2.5 inches) length and diameter.

4. The Reverse Osmosis membrane is a semi-permeable membrane used for removal of the mineral ion and salt from water, the pore size of the membrane is (< 0.0001 μm) and the dimension is (10 inch × 2.5 inches).

5. Zeta Rod Unit: The zeta rod is used for increasing the value of the negative charge (Zeta voltage) of the particles in the solution (water) as shown in Fig. 1. This pole is used as ZRS 20 (Zeta Corporation). This is said to be resistant to operational conditions, such as, heat, corrosion, and high pressure (35 bar). More than 600 μA at a constant voltage above 40 kV should not pass through the ceramic insulator in this electrode. The material of the container is made of stainless steel , in which an oiled pole is placed. This electrode is connected to the power supply, where the constant voltage ranges between 10 kV and 40 kV, according to the research requirements.

Fig. 1. Zeta rod (1. Room of reaction, 2. Power supply, 3. Power transmission cables and 4. Zeta rod pile).

6. The RO industrial type uses the normal working system and for the operation of the other type a zeta rod is used before the RO membrane, which is necessary,

to study its effect on the membrane fouling of reverse osmosis. The study began in the middle of March 2018 and was completed at the end of May 2018. Figure 2 shows the schematic diagram of the experimental study setup. Figure 3 shows the RO system in the laboratory and Table 1 shows the average characteristics of the water that enters the system.

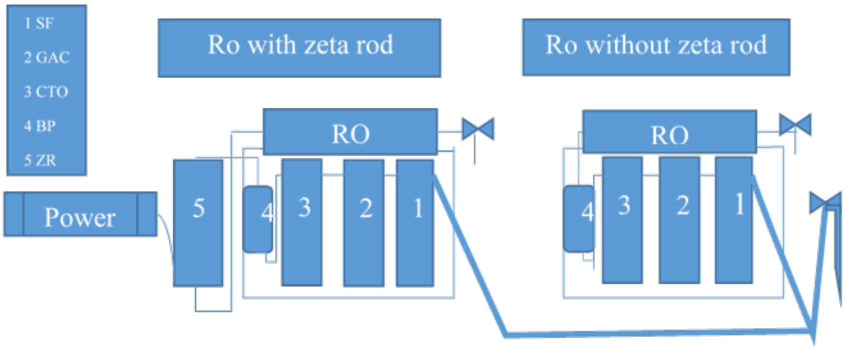

Fig. 2. Schematic diagram of the experimental setup.

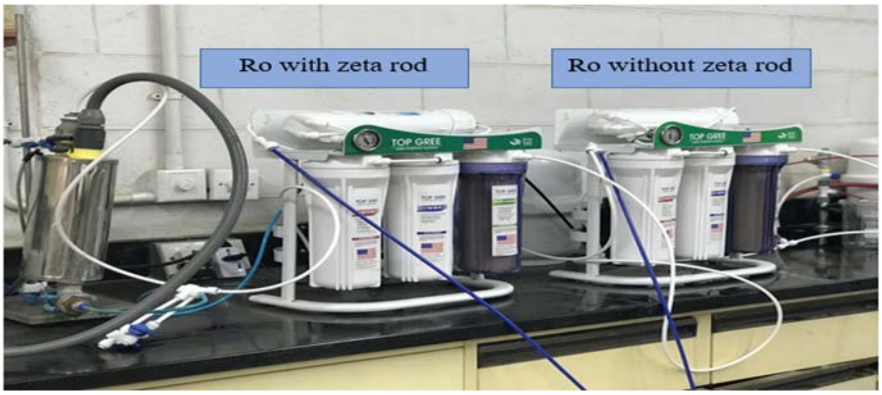

Fig. 3. Experimental work in the laboratory.

Table 1. Average influent characteristics of the bench-scale RO.

Properties	Unit	Mean ± standard deviation
TDS	**mg/L**	383.53± 40.58
Turbidity	**NTU**	3.02 ±1.77
pH		7.43±0.15
Chloride	**mg/L**	147.10 ± 45.50
Calusum	**mg/L**	71.42 ± 30.74
Sodium	**mg/L**	76.36 ± 17.39
Fluoride	**mg/L**	0.03 ± 0.02
Conductivity	**µs/cm**	586.26 ± 57.24

3. Results and Discussion

To For assessment's sake, the impact of utilizing a zeta rod on the reverse osmosis membrane in the study was, first, to measure the values of the zeta potential, permeate flux, and feed pressure, and second, to utilize a portion of the physical and chemical properties of water (TDS, Ec, Turbidity, pH, Cl, Ca, Na, F). The results of this study show the effect on the water properties by using the zeta rod, as shown in the figures below.

Figure 4 shows the experimental values of the zeta potential and the comparison between the two runs, first when the zeta rod is used before the reverse osmosis membrane and second when RO is working in normal mode. The value when zeta is added is greater and this value can give a brief review of the potential added and its effect on colloidal and membrane fouling. The value of ZP is -36.31 mv when using a Zeta Rod and when using a Normal ROM it is -.20 mv, so it has an effect on the stabilization of particles, as also on their dispersion in the water. However, when RO works in normal mode the value shows that the particle accumulates at the membrane and this causes membrane fouling during the time of use this result is agree with [8].

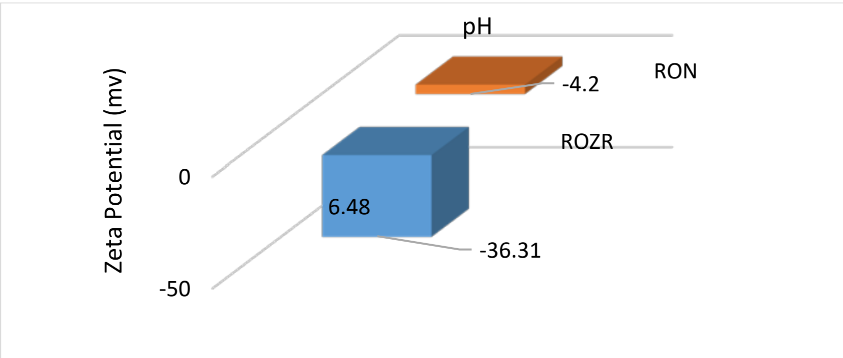

Fig. 4. Compare between zeta potential values of two ROM.

Figure 5 shows the relationship between the time and permeate flux. The effect of the zeta rod on permeate flux lesds to an increase in the permeate flux percentage (23.6%). This increase is explained by the fact that the water is subjected to the electrical potential of a high electric current when entering the metal cylinder. The container on the electrode earns a negative charge. There is an additional grouping of the colloidal particles on the surface. This assembly increases the internal voltage of the water, which in turn increases aversion and an action greater than the usual value of water. The system becomes more efficient and produces the same quantity of water that enters the two-type system of RO. From this result we can see that using ZR before ROM, increases the permeate flow and recovery rate and this result agrees with [9].

In Figure 6, the result shows the effect of the Zeta Rod. It decreases the real feed pressure percentage (9.92%). By operating this pressure, the RO membrane can work more efficiently and reduce the concentration of polarization and membrane fouling. Subsequently it can prevent membrane fouling, which leads to the membrane working for a long time. This result is compatible with [9] for decreasing the pressure applied on the membrane.

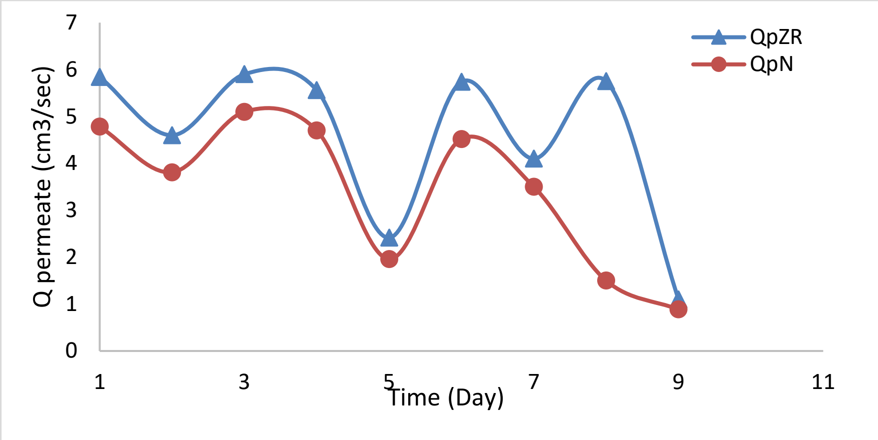

Fig. 5. The relationship between Permeate fluxes and time.

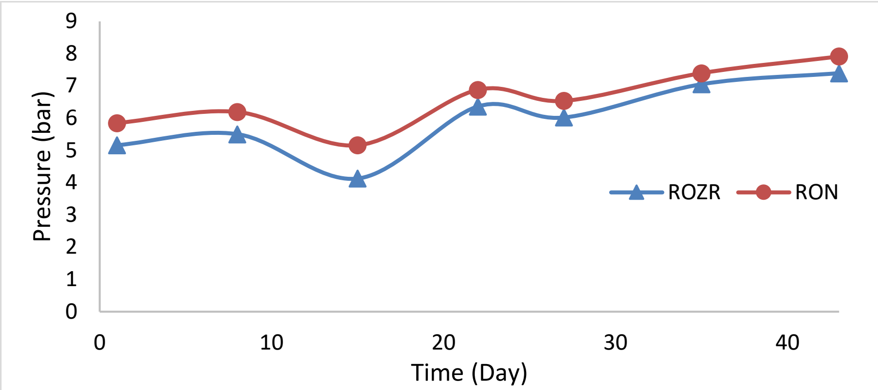

Fig. 6. The relationship between pressure and time.

Figure 7 shows the relationship between TDS concentration in feed water and TDS concentration in the treated water. In the experimental study, when the system was operated, the TDS of feed water ranged between 315 mg/L and 487 mg/L. This was compared with the treated water permeate concentration and percentage removal between two runs of RO. In the first instance the treated water permeate concentration of the remain-overnight (RON) operation reached between 3 mg/L and 8 mg/L, minimum and maximum values. Furthermore, the percentage removal was between 99.18% and 98.34%, maximum and minimum values. The second time, when ROZR was used, the TDS of treated water ranged between 7 mg\L and 16 mg\L, minimum and maximum values, and the percentage removal was between 97.78% and 96.69%, maximum and minimum values. The reason for this was the increase in negative charges by the zeta potential, which increased the percentage of dispersion in the salts and prevented the accumulation of salts on the surface of the membranes [10].

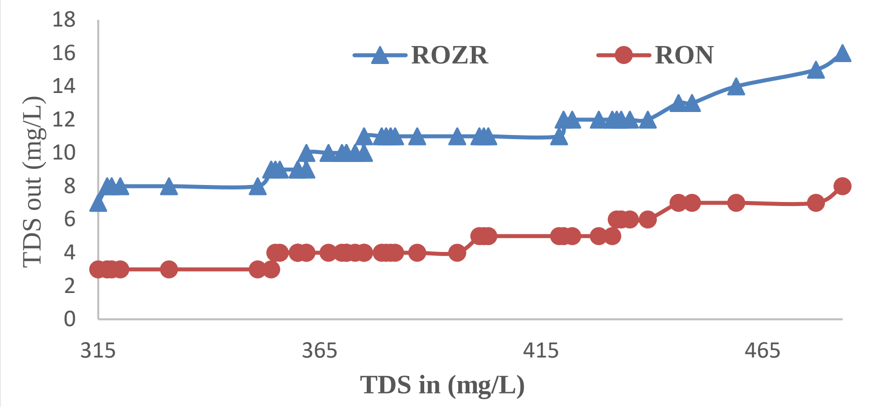

Fig. 7. Relationship between TDS in feed and treated water.

Figure 8 shows the relationship between the Ec of feed water and the Ec of treated water. The Ec value of RO with the application of the zeta rod is more than that of normal RO. The Ec value with RON is between 6.28 μm/cm and 45.01 μm/cm, minimum and maximum values. Furthermore, the percentage removal is between 98.74% and 93.84%, maximum and minimum values. The value of Ec ROZR is between 15.14 μm/cm and 58.40 μm/cm, minimum and maximum values, and percentage removal is between 96.96% and 92.01%, maximum and minimum values. This value increases when utilizing the zeta rod because this application, acts on the net charge, increasing the suspended particles by casting varying currents of high voltage through the ceramic rod in the system and this is compatible with [8].

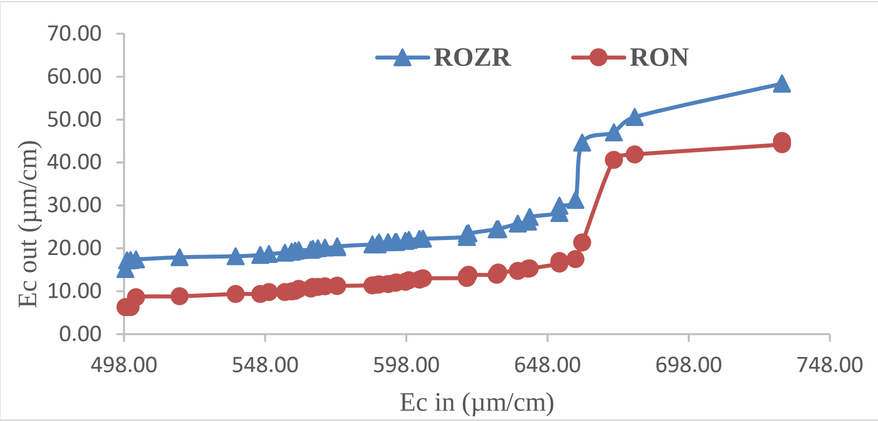

Fig. 8. Relationship between the Ec in the feed and treated water.

Figure 9 shows the relationship between turbidity removal and time. The result shows that the value of turbidity removal by using the zeta rod is higher than that with RON. Therefore, the best value of turbidity removal is by using the zeta rod, due to removing them. When the RON is used the turbidity accumulates on the surface of the membrane and the effect is a clogged membrane and formation of fouling.

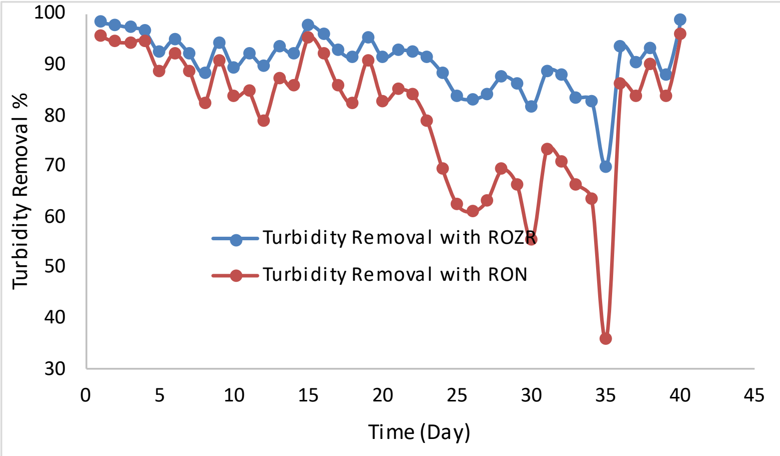

Fig. 9. Relationship between turbidity removal and time.

Figure 10 shows the relationship between the pH of the treated water with time. The result for RON is between 5.38 and 6.74, minimum and maximum values. The result for ROZR is between 5.44 and 7.29. pH is the most influential factor in the value of the zeta effort, which increases its value by increasing OH-, the negative. As the zeta rod generates a negative charge which is released in the water in the form of ions, these may bind to the suspended particles or remain suspended in a free form, so the pH value increases. When the pH of the water decreases, the water tends to be acidic. The colloids in the water will become more receptive to the negative ions from the Zeta Rod device [11].

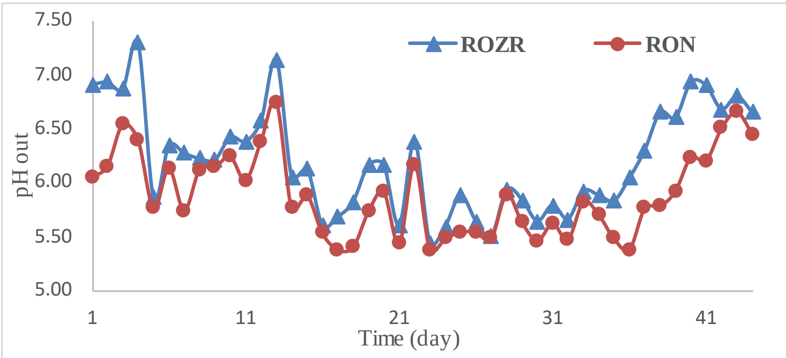

Fig. 10. Relationship between pH of treated water and time.

Figures 11 to 14 show the relationship between the change of concentrations in chloride (Cl), calcium (Ca), sodium (Na), and fluoride (F) with time. The results of the maximum and minimum values of permeate concentration and percentage removal values are shown in Table 2. When utilizing a high voltage capacity device it is noticed that the effect of the charge on particle dispersion, and the effect of the zeta efforts, increase the dissolved salt dispersion and break the big particles into smaller ones. Therefore, subsequently, the particles become suspended in the water and the number becomes larger. Thus increasing the reading rate for the same sample of water [9, 11].

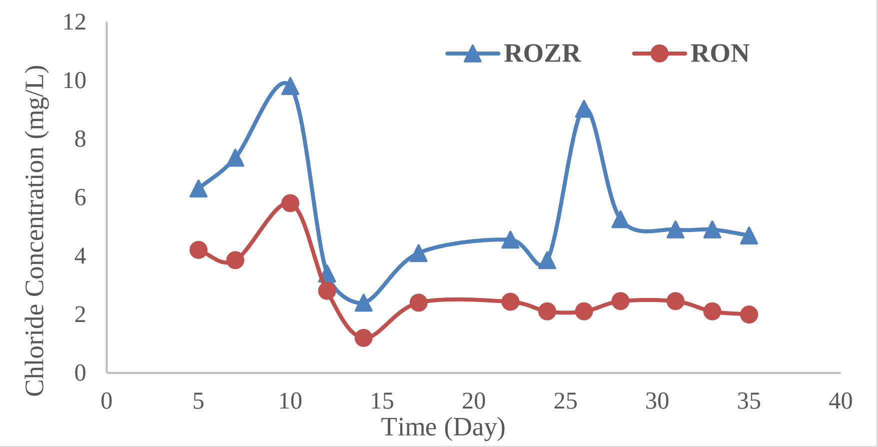

Fig. 11. Relationship between chloride concentrations of treated water with time.

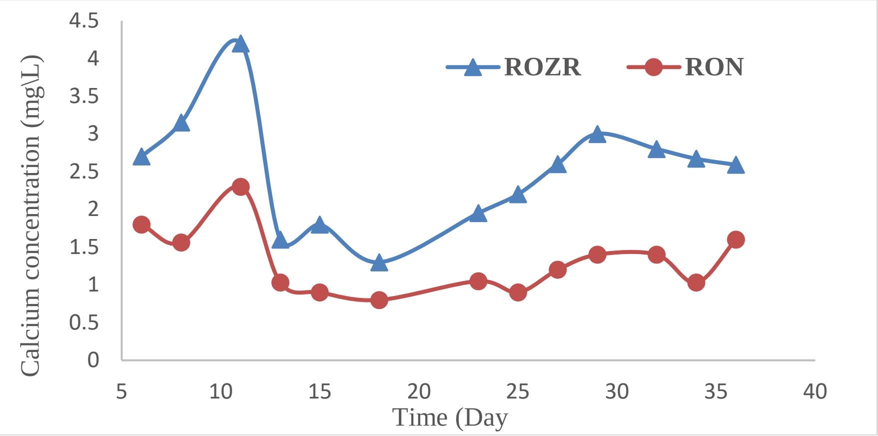

Fig. 12. Relationship between calcium concentrations of treated water time.

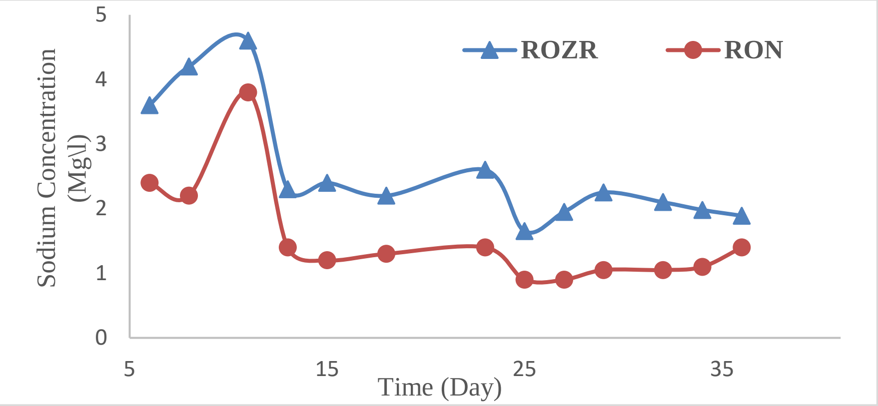

Fig. 13. Relationship between Sodium concentrations of treated water and time.

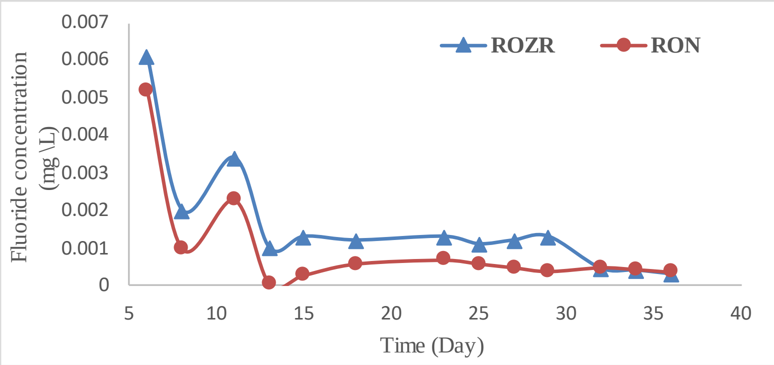

Fig. 14. Relationship between Fluoride concentrations of treated water and time.

Table 2. Maximum and minimum of ions concentration and percentage removal of Cl, Ca, Na, F.

ions	The instrument	Concentration mg/L		Removal percentage%	
		Max.	min	max	min
Cl	ROZR	9.8	2.4	98.25	92.43
	RON	5.8	1.2	99.18	95.52
Ca	ROZR	4.2	1.3	98.25	92.55
	RON	2.3	0.8	99.18	95.92
Na	ROZR	4.6	1.65	98.25	93.95
	RON	3.8	0.9	99.18	95.00
F	ROZR	0.0061	0.0003	97.17	32.97
	RON	0.0052	0.00007	99.79	42.86

4. Conclusion and Recommendations

From the results obtained, it can be concluded that adding a zeta rod device leads to an increase in the production water in the reverse osmosis systems by 23.6% and also reduces the pressure on the membranes by 9.92%, thus the reverse osmosis membranes can be kept clean. The main principle of making a zeta rod is to release the negative charges of the colloidal particles and keep them suspended. Thus, the membrane can be kept clean and no chemical washing or membrane replacement is required. Using this device will reduce the maintenance time on the reverse osmosis membrane, and thus reduce economic cost.

Acknowledgment

Our extraordinary appreciation and an abundance of thanks are sent to the staff of sanitary laboratory in civil engineering/engineering college-University of Baghdad and staff of water research center in the Ministry of Science and Technology without their support and encouragement this work would have not been done.

Abbreviations

pH	Potential of hydrogen
RO	Reverse osmosis
ROZR	Reverse osmosis with Zeta Rod
RON	Reverse osmosis Normal
TDS	Total dissolved solids

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