Effect of Feed Water Type on the Performance of Reverse Osmosis for Water Desalination and cucumber Yields.

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Abstract

This study was carried out to evaluate the effect of water type on the performance of reverse osmosis system which was used for water desalination. Two type of water included well water (9.6 ds.m^{-1}) and drainage water (4.25 ds.m^{-1}) were used in this experiment. The feed flow rate was fixed at 4.8 m^3/h and operating pressure was fixed at 13 bars. Productivity, Recovery ratio, specific energy and electrical conductivity and cucumber yields were measured in this experiment. Complete randomize block design (CRBD) with three replicates was used. Least significant differences (LSD) were used to compare the means of treatments at 0.05 probabilities.

It was found that the use of drainage water (EC = 4.25 ds.m^{-1}) led to obtain higher productivity (3.04 m3 / h) , higher recovery ratio (63.91%) and higher rejection ratio (97.42 %) and led to obtain lower specific energy (2.56 kW/m^3) and lower electrical conductivity (0.109 ds.m^{-1}) . There is no significant difference on productivity between plants which were irrigated by using desalinated water while the plants which were irrigated by using saline water (well or drainage water) were affected. Increasing in cucumber yield which irrigated by desalination water comparing with well and drainage water significantly.

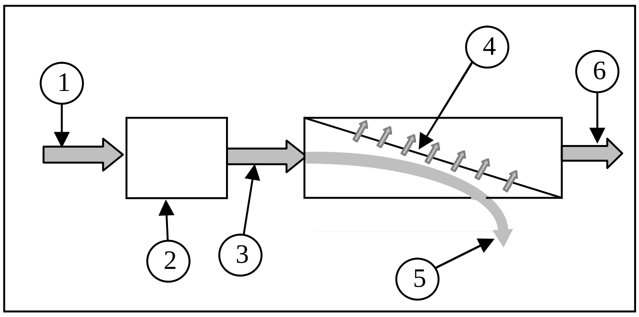
Keyword: Well Water, Drainage Water, Productivity, Recovery Ratio, Specific Energy, Electrical Conductivity

Introduction

The desalination of salty well water and drainage water is an important option to provide new resources of irrigation water. Reverse Osmosis is one of the most important methods of water desalination. For agricultural uses, reverse osmosis is the preferred desalination technology

because of the cost reductions driven by improvements in membranes in recent years. Al zubadi (1989) illustrated that the reverse osmosis is a scientific process to reverse the physical phenomena which called osmosis. (where : Osmosis is a natural process where water flows through a semi-permeable membrane from solution with low concentration of dissolved solids to solution with high concentration of dissolved solids).

Reverse osmosis allows separation of salt from solution whenever a pressure greater than the osmotic pressure of the solution is applied through semi-permeable membrane (Ghiu et al , 2003) . In reverse osmosis system feed water passes tangentially over the membrane surface . Water and some dissolved solids pass through the membrane while the majority of dissolved solids and some water do not pass through the membrane. Hence, one feed stream is separated into two exit streams. The solution passing through the membrane surface (permeate) and the remaining concentrate stream (Brine). The rejected particles do not accumulate but instead are swept away by the concentrate stream figure (1) illustrate Schematic of a simple reverse osmosis system.



1. Feed water. 4. Reverse osmosis membrane.
2. High pressure pump. 5. Rejected water (brine).
3. Pressured feed water. 6. Produced water (permeate)

Fig. (1) Schematic of a simple reverse osmosis system (Thomson, 2003).

In reverse osmosis The quantity of pure water that passes through the membrane during reverse osmosis is a function of the difference between the applied pressure and the osmotic pressure of the saline solution (URS Australia , 2002) . Faiq (2000) illustrated that when the feed concentration increased , the osmotic pressure across the membrane will increase and the product rate would be decreased . The feeds with higher osmotic pressures result in less flux through the membrane (Hamdzah , 2007) .

Sassi and Mujtaba (2010) said that the feed with low salt concentration water produced higher recovery ratios compared to that produced by high feed salinity. Macharg, et al (2011) found that the Feed water salinity has the most significant impact on power consumption. Kumar and Saravanan (2009) said that at the higher the concentration of salts, the more important the osmotic pressure becomes and therefore the greater the energy required. Watson et al (2003) said that as the TDS of feed water increases, the required operating pressure increases. Therefore, more energy is expended for making the same amount of water. Khalaf (2000) indicated that the permeate concentration essentially increases with the increase in the feed concentration. Arcadio and Gregoria (2003) illustrated that the reason why the product or the permeate contains solute (that ought to be removed) is that the solute has broken through the membrane surface along with the product water. consequently It may be said that as long as the solute stays away from the membrane surface, only water will pass through into the product side and the permeate will be solute-free; However, it is not possible to exclude the solute from contacting the membrane surface; hence, it is always liable to break through. Faiq (2000) conducted that the effect of feed concentration has the greatest effect on the solute concentration in product among other variables . Voutchkov (2010) found that the different ions are not rejected equally by the same RO membrane. Usually the larger the ions and the higher their electrical charge the better rejected they are. This means for example that divalent ions such as calcium and magnesium will be rejected better than monovalent ions such as sodium and chloride. Richardson et . al (2002) mentioned that with mixtures of salts in solution , the rejection of a single ion is influenced by its relative proportion in the mixture. The use of reverse osmosis for agricultural application in Iraq is still limited and needs evaluating their performance and sutability. Most of the previous studies on reverse osmosis were limited on either feed water containing NaCl solution (Faiq , 2000) or industrial waste water (Ahmed zeki et al , 2009).

Cucumber (Cucumis sativus L.) was chosen because it is one of the most popular and widely grown vegetable crops in the world, and considered moderately sensitive to salt stress. It is very important to evaluate the performance of reverse osmosis system and know the effect of water type on the performance of reverse osmosis system efficiency and performance parameters

Material and Methods :

The experiment was conducted to evaluate the effect of water type on the performance of reverse osmosis. Two type of water included well water and drainage water (table 1) were used in this experiment.

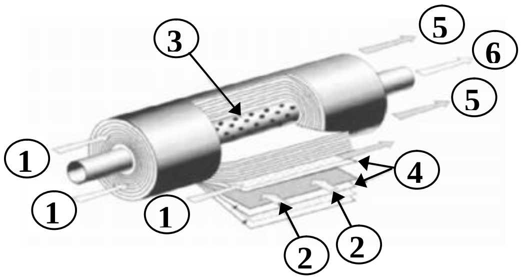
Table (1) Well and Drainage Water Analysis.

	Well Water	Drainage Water
PH	8.23	7.8
EC (ds.m-1)	9.6	4.25
Na (meq / l)	50.6	7.8
K ((meq / l)	0.158	0.238
Mg (meq / l)	25.4	16.18
Ca (meq / l)	19.2	18
HCO_3 (meq / l)	3.4	1.2
CO_3 (meq / l)	0.5	0
Cl (meq / l)	36.8	18.6
NO_3 (meq / l)	0.24	0.009231
SO_4 (meq / l)	50.2	21
PO_4 (meq / l)	0.29	0.06

Split plot under complete randomize block design (CRBD) with three replicates was used. Least significant difference (LSD) was used to compare the means of treatments at 0.05 probability.

The main parts of reverse osmosis unit are:

Feed pump , Multimedia pressure filter , Cartridge filters, High pressure pump , Membrane assembly unit (Membrane assembly unit consisted of pressure vessel and membrane elements (Fig 2) . Tow spiral-wound membrane elements (Dow FILMTEC BW – 365) connected in series were installed in the pressure vessel, Flow and pressure control valve (which were used together to achieve the desired feed flow rates and operating pressures) , Pressure gauges.



(1) Feed Water (2) Permeate Flow toward Collection Tube (3) Perforated Collection Tube. (4) Membrane. (5) Concentrated water (Brine) . (6).Desalinated water (Permeate).

Fig. (2) Deconstructed spiral-wound RO membrane module (Kucera , 2010) .

Studied variable:

The following variables were studied:

1. **Productivity (m^3/h):** productivity is the amount of water (m^3) which produced per hour. The productivity was obtained from the reading of the product flow meter.
2. **Recovery ratio %:** Recovery ratio is the percentage of the feed water that is recovered in the desalination process as fresh product water. the recovery ratio was calculated from the following equation (Kucera , 2010) :

$$Recovery\,\% = \frac{\text{Permeate flow}}{\text{Feed flow}} \times 100$$

3. **Specific energy:** The specific energy is the energy consumption per volume of produced permeate. The specific energy was calculated according to the following equation Thomson (2003):

$$\text{Specific energy} = \frac{\text{Input power (kW)}}{\text{product flow } (m^3)}$$

4. **Electrical Conductivity (EC) :** Electrical conductivity of produced water (permeate) was measured by using electrical conductivity meter.
5. **Rejection ratio (salt rejection):** Salt rejection is a measure of how well a membrane element rejects the passage of dissolved ions. The salt rejection was calculated by the following equation (Dow , 2007) :

$$\text{Rejection raio} = \left(1 - \frac{\text{Permeate conductivity}}{\text{Feed water conductivity}}\right) \times 100$$

The permeate conductivity and feed water conductivity were measured by using electrical conductivity meter. The experiment was also conducted to evaluate the effect of produced water type on plant productivity. The cucumber (Cucumis sativus L .) hybrid F1 ABHA was chosen to be as indicator . Some of these treatments used the water which was produced from reverse osmosis system while two treatment included using well and drainage water directly (without desalted them) .

Results and discussions:

1. Productivity :

Fig. (3) Shows that there was a significant effect of feed water type on the productivity of reverse osmosis system. The higher productivity (3.04 m^3/h) was obtained by using drainage water while the lower productivity (1.67 m^3/h) was obtained by using well water . This result might be obtained because that the well water (EC = 9.6 ds.m-1) had higher osmotic pressure then drainage water (EC = 4.25 ds,m-1) . Increase osmotic pressure of feed water would reduce driving force for water through the membrane. This result agreed with the results which were obtained by Faiq (2000) and Hamdzah (2007).

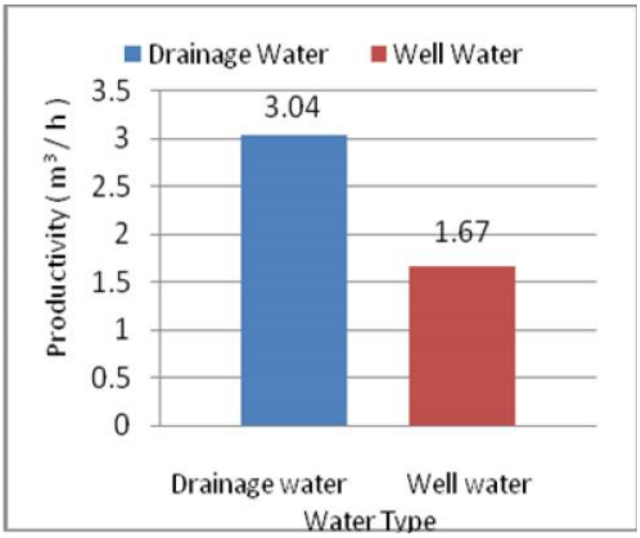


Fig. (3) The effect of feed water type and feed flow rate on the productivity (m^3/h) of reverse osmosis unit .

2- Recovery ratio % :

Fig. (4) shows a significant effect of feed water salinity on the recovery of reverse osmosis system. The higher recovery ratio (63.91%) was obtained by using drainage water while the lower value (35.01%) was obtained by using well water . This result might be obtained due to the differences between osmotic pressure of two solutions. Increasing feed water salinity would decrease productivity and recovery of reverse osmosis system. This result agreed with the result which was obtained by Sassi and Mujtaba (2010).

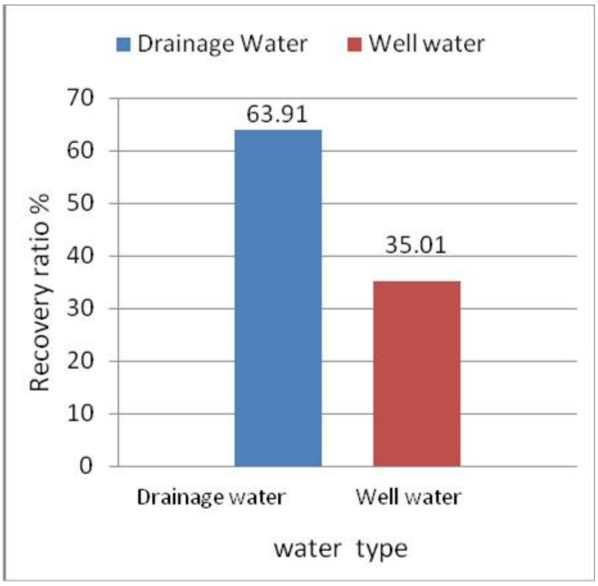


Fig. (4) the effect of interaction between feed water type and feed flow rate on the recovery ratio of reverse osmosis unit.

3- Specific energy (kW/m^3) :

Fig. (5) shows a significant effect of feed water type on the specific energy. The higher specific energy (5.07 kW/m3) was obtained by using well water while the lower specific energy (2.56 kW/m3) was obtained by using drainage water. This result was obtained because that increasing feed water salinity led to increase osmotic pressure. As the osmotic pressure increase the water flux through the membrane decreases and the power consumption increases.. These results agreed with the results which were obtained by Macharg, et al (2011).

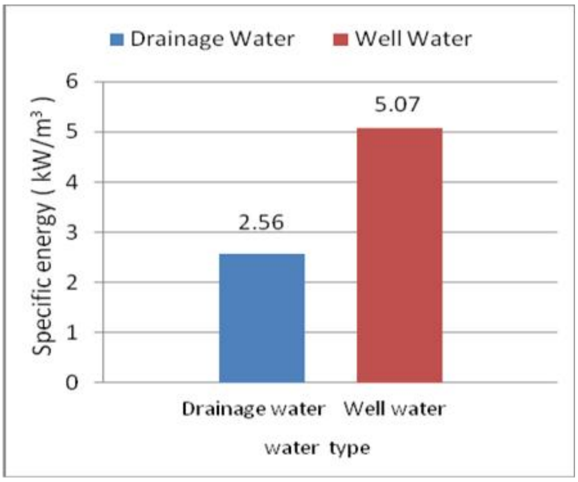


Fig.(5) the effect of feed water type, feed flow rate on the Specific energy.

4- Electrical conductivity of desalinated water ($ds.m^{-1}$) :

Fig. (6) shows a significant effect of feed water type on the electrical conductivity of produced water. The higher electrical conductivity (0.385 ds.m-1) was obtained by using higher feed water salinity (well water) while lower electrical conductivity (0.109 $ds.m^{-1}$) was obtained by using lower feed water salinity (drainage water). This result might be obtained because that the salts flux through the membrane increased when the salt concentration of feed water increased (more salt ions had broken through the membrane surface) . These results agreed with the results which were obtained by Khalaf (2000) and Arcadio and Gregoria (2003) .

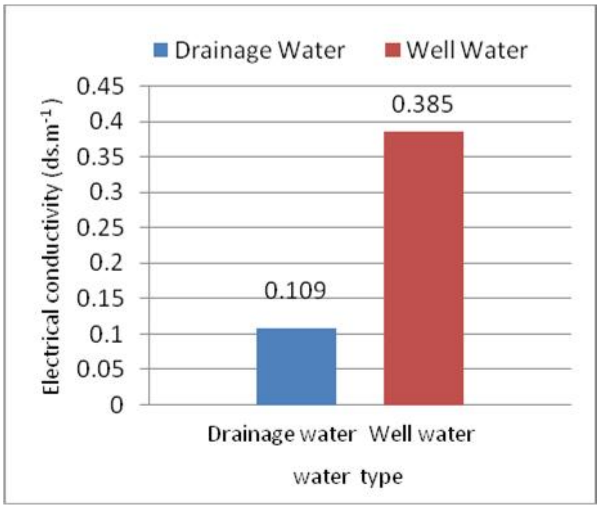


Fig.(6) The Effect Of Water type and Feed Flow Rate On The Electrical Conductivity Of Desalinated Water.

Cucumber Yields.

Table (2) shows a significant effect of water type on the yields of cucumber plants . The higher yields (1.053 to 1.385 kg /plant) were obtained from plants which were irrigated by desalinated water. Table (2) also shows that there is significant differences between the yields of cucumber plants which were irrigated by desalinated water comparing with the plants which were irrigated by using drainage water which recorded lower yields (0.275 kg/plant) . All plants which were irrigating by using well water were died. The reason for that might be that the water salinity of desalinated water was under salinity threshold, so that the plants were able to tolerate salinity without any effect on their yields. Salinity of drainage water (4.25 $ds.m^{-1}$) was above the salinity threshold which the cucumber plants can tolerate; so that it is affect yields of cucumber plants. Well water was very saline (9.62 $ds.m^{-1}$) so that the plants weren't able to tolerate this salinity and all plants which were irrigated by well water were died .

Table (2) The Effect of Desalinated Water , Well Water and Drainage Water on Cucumber Yields.

Water Type	Yields (Kg / plant)
Desalinated Drainage Water	1.275
Desalinated Well Water	1.115
Drainage Water	0.275
Well Water	0
L.S.D = 0.05	0.3614

L.S.D : Least significant difference at 0.05 level

Conclusions :

1. Using lower feed water salinity (drainage water) led to obtain the best performance .
2. There is a significant increase between plants which irrigated by using desalinated water comparing with which irrigated by drainage water and well water, and all seedling which were irrigated by using well water were died.
3. The reverse osmosis can used successfully to desalinate well water and drainage water.
4. The possibilities of using desalinate water which produced by reverse osmosis for cucumber plants yields.

Recommendations:

According to the above results, the recommendation will be as following:

1. Using reverse osmosis to desalinate well water and drainage water
2. Using desalinate water which produced by reverse osmosis for cucumber plants yields.

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