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Preliminary Study about Desalinated Water and Alkalinity

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Abstract:
One of the promising techniques to meet the needs of growing population for drinking water is the desalination of seawater and brackish water. Desalination is mainly carried out by multi-stage flash (MSF) or reverse osmosis (RO). After adjusting its salt content through blending, people can drink the water obtained from desalination processes (such as RO, MSF, and other methods). However, reverse osmosis can produce, under certain pressure, flow and feed water quality, water similar in their physic-chemical properties as conductivity, Total Dissolved Salts (TDS) to bottled natural water, widely marketed. It would be beneficial to distinguish reverse osmosis water from spring water. So, our study proposes determining alkalinity (TA) and pH and verifying their correlation. Also, a comparison of the physic-chemical quality of drinking water supplied by MSF and RO is made by discussing parameters such as, pH, conductivity, TA, TDS and hardness (TH). These two types of water are practically identical in physic-chemical quality since the blending is done similarly by injecting CO_2/Calcium carbonate. However, reverse osmosis water contains more sodium chloride due to the low retention rate of membranes against this ion.

Key words: Reverse osmosis, water pH, drinking water, alkalinity.

1. Introduction

Slightly acidic water with pH less than 7 is necessary to fulfill its role as a catalyst for almost biochemical reactions. It is also essential to properly assimilate vitamins, metals, minerals and proteins into food. On the other hand, biocompatible drinking water should have the following essential physic-chemical properties (Table 1)[1]:

Table 1: Essential physic-chemical properties of drinking water

Slightly acid	pH between 5 and 7.5
Low TDS	Conductivity to 200 µS/cm
Hardness	Less than 5°F (50 mg/L of $CaCO_3$)

Reverse osmosis water must meet these essential requirements (table 1) and standards to be used as drinking water. It can be mixed with filtered raw water or blended with limestone to achieve an acceptable mineral content for human consumption. Many households around the world use household reverse osmosis units for producing drinking water. And reverse osmosis was first introduced as a home water purification system in 1970. Industrial plants also produce large amounts of RO water, which is commonly used by bottled water companies. In 2018, there were 18,983 desalination plants worldwide, producing a total of 95.6 million m3/d. Drinking water treated with RO systems has the advantage of reducing nitrate-nitrogen to only 0.9 mg/L in the RO product water. As a result, RO treated water is often bottled and distributed as spring water.

However, there are health risks associated with consuming reverse osmosis water, as it removes minerals from the water and long-term consumption of poor mineral water can have negative health effects [2-5]. RO water can be produced from surface or well water, which is often polluted. Despite precautions, RO water may become contaminated by viruses and bacteria. The RO membrane technology is not effective in removing low molecular weight volatile organic compounds such as chlorine, bromoform, and trihalomethanes. But, bottled water consumption has been steadily growing around the world, and it is now the most dynamic sector of the food and beverage industry. To ensure safety and transparency, labelling criteria for packaged water must be respected, and the origin and treatment methods (natural mineral water, spring water, purified water, artesian water, or sparkling water) must be clearly indicated.
It is crucial to highlight that pH should be strongly correlated with TA (table 2) in natural waters [6,7] at an analytical level. This is because pH is mainly controlled by the balance between carbonate, bicarbonate, and carbon dioxide. In natural waters with a pH range of 6 to 9, bicarbonate is the dominant species, while carbon dioxide and carbonate ion become more significant below pH 6 and above pH 9, respectively. Moreover, when estimating groundwater salinity expressed by TDS, pH is used as an input parameter [8]. However, excess free carbon gas and carbonic acid in RO water distort these facts. Thus, it would be useful to differentiate RO water (treated water) from spring water by a straightforward verification of pH-TA correlation.

The Algerian coast currently has over 21 seawater desalination plants that produce drinking water and water for industry. In Algeria all of these plants RO technology, except for the KAHRAMA-Bethioua plant. Both RO and multi-stage flash (MSF) technologies use carbon dioxide and lime to achieve water blending. Lime is added to increase the pH and Langelier Saturation Index (LSI) of the water to the desired range. In reverse osmosis, carbon dioxide is also injected, because the level of CO_2 due to its passage through the membranes remains insufficient for the total dissolution calcium carbonate. Lime is relatively inexpensive and readily available, however its usage for blending poses several problems, such as the fooling of pipes by the deposition of lime on the injection equipment. It's also difficult to maintain the optimal parameters in the desired range: TA (35 to 65 mg/L of CaCO3): pH (8 to 8.5); TH (50 to 65 mg/L of CaCO3), and LSI (0 to 0.4). In this work, we compare the physic-chemical qualities of drinking water produced by RO and MSF technologies. We discuss various parameters like pH, conductivity, TA, TDS, and TH.

2. Materials and methods

In order to compare the drinking water (desalinated seawater) produced by MSF with RO water from KAHRAMA and Magtaa plants, various samples were analysed. These samples included wastewater (ER), seawater (EDM), drinking water (EP), and distilled water (ED). The analysis involved taking pH and temperature measurements in-situ and conducting conductivity measurements using a conductivity meter (HANNA, Hi 991300). The calcium Ca^{2+} content and TH were determined through titrations.
TA (Acid consumption method JIS K 0101): The neutralization of a volume of water by a dilute acid in the presence of a mixed indicator (Bromocresol green and methyl red): 0.02gr (methyl red) + 0.1 g (Bromocresol Green) in 100 ml of distilled water. Also, the determinations of TA in feed (spring) and its reverse osmosis water was carried out by acid titration using H_2SO_4 0.02N controlled by pH-meter assisted by Smartphone video (Figure 1).
A direct correlation between TDS and conductivity is carried out by TDS measurement. TDS (mg) = K * C (µS / cm). Where K is the conversion factor and C is the electrical conductivity in µS / cm. The chosen conversion factor is 0.55 for drinking water and 0.5 for distilled water.

Fig. 1 : Alkalinity determination : pH-titration assisted by Smartphone video

3. Results and discussion

3.1 Water alkalinity–pH correlation

The pH titration for TA determination of a spring water (Oran) (Figure 2a) (pH = 7.63) has an equivalent point at pH=4.5. Its RO water (permeate) (pH = 5.03) (Figure 2b) shows that two equivalence points are observed for RO water at pH=4.5 and pH= 3, probably due to the bicarbonate ion and the neutralization of free carbonic acid. Subsequently, a conclusion can be made about the distinction between spring and RO water. The discussion about the pH-Alkalinity correlation of natural and osmosis waters is interesting and complicated. Given that osmosis waters practically have a pH lower than 7 and using only the data in table 2, we immediately notice that natural waters having a pH lower than 7 are classified into two types. Firstly, water with high TA and TDS and a second type of water with a low salt level and TA. So by looking for a correlation between TA and pH for these waters we arrive at the result shown in Figure 2.

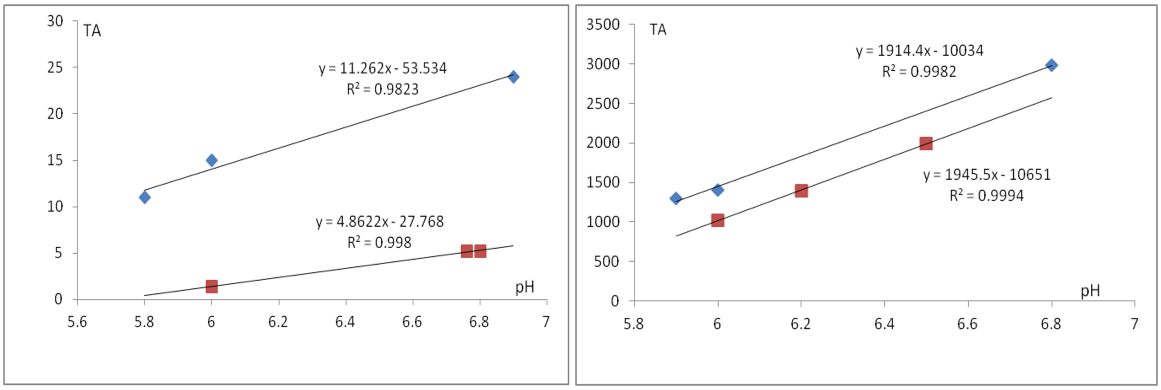
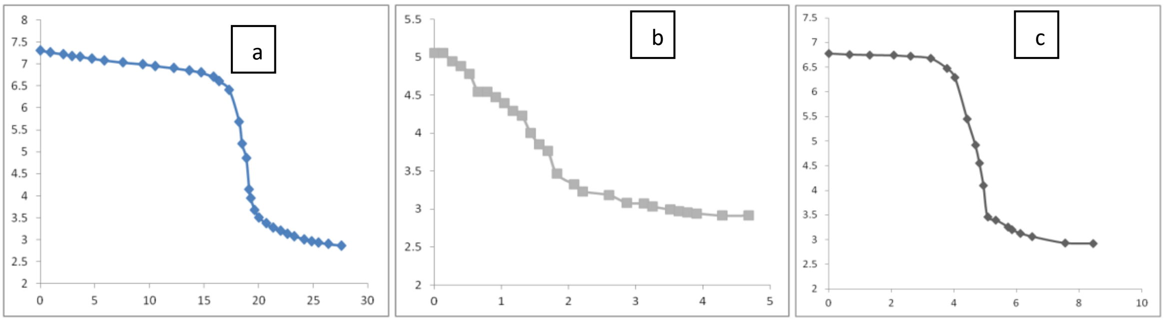


Fig. 2 : TA versus pH for natural (spring) water with pH< 7

Table 2: Examples of bottled water and their physic-chemical properties (TA ; TDS and pH)

Spring	pH	TA mg/L $CaCO_3$	TDS mg/L	Spring	pH	TA mg/L $CaCO_3$	TDS mg/L
Lalla Khedidja (DZ)	7.22	172	187	Doubia (GR)	5.9	1299.3	1170
Nestlé(DZ)	7.8	210	372	Loytraki (GR)	7.9	390	340
ain elhoutz (DZ)	7.12	355	730	Ballygowan (IR)	6.9	400	450
SPA (BE)	5.8	11	33	Bernina (I)	7.4	18.3	36
SPA Barisart (BE)	6.8	18	49	Courmaye ur (I)	7.4	168	2264
SPA Reine (BE)	6	15	33	Ferrarelle (I)	6.2	1397	1298
Vichy Celestins (F)	6.8	2989	3325	Levissima (I)	7.8	56.5	73.5

Montcalm (F)	6.8	5.2	28	Lynx (I)	7.45	167	164
Alet (F)	7.4	300	290	Perla (I)	7.6	390	613.2
Celtic (F)	6.61	24.4	46	Popoli (I)	7.3	320.1	298.2
Badoit (F)	6	1410	1325	Prata (I)	6.76	512.4	442
Evian (F)	7.2	357	309	S. Cassiano (I)	7.3	219	225
Salvetat (F)	6.0	1030	990	S. Pellegrino (I)	7.7	219.6	1109
Faustine (F)	6.5	2000	1750	San Antonio (I)	8	135.5	133
Eau de source (F)	7.60	399	480	Santa Clara (I)	7.6	117.6	125
Mont. d' Auvergne (F)	6.9	24.4	99	Sole (I)	7.12	421	382.5
Mont-dore (F)	7.2	27	46	Talians (I)	7.1	290	2590
St Diery (F)	6	1450	1800	Beckerich (LU)	7.40	256	286
La Provençale (F)	7.8	398	622	Cactus (MY)	7.4	62	135
Hépar (F)	7.00	403	2580	Agua (PT)	7.1	114.7	180.6
Vittel (F)	7.6	384	1084	Serra da Estrella (PT)	6.19	9.5	38
Mont Roucous (F)	6	4.9	19	Highland (GB)	7.8	136	136
Loytraki (GR)	7.9	390	340	Marwa (TN)	7.6	244	318



a- spring water, b- reverse osmosis water(permeate), c- blended reverse osmosis water

Fig. 3 : pH versus alkalinity (°F)

The conductivity of permeate is equal to 121 µS/cm (TDS = 66.55 mg/L)(Table 3), so water with low TA and salt content. From the titration curve, TA of RO water is equal to 11 mg of $CaCO_3$/L. But, natural water with the same pH, its TA can be estimated from the Figure 2 and in principle should be between 0.0 and 3.11 mg of $CaCO_3$/L.

Table 3: Physic-chemical properties of spring, RO, and blended waters

	TH(°F)	TA°F	Cl^- mg/L	pH	Conductivity µS/cm
RO water	1	1.1	28	5.03	121
RO + spring		11		6.78	630
Spring water	40	19	330	7.63	1470

3.2 Comparison between RO and MSF waters

The seawater feed for MSF (KAHRAMA) and OI (Magtaa) plants has the same pH (equal to 8), (Figure 4a) because the two stations are located in the same area about 15 km apart. However, the pH of drinking water (RO) or (MSF) greatly depends on the post treatment stage. The waste water produced by RO does not present thermal pollution, unlike MSF waste water (Figure 4b).

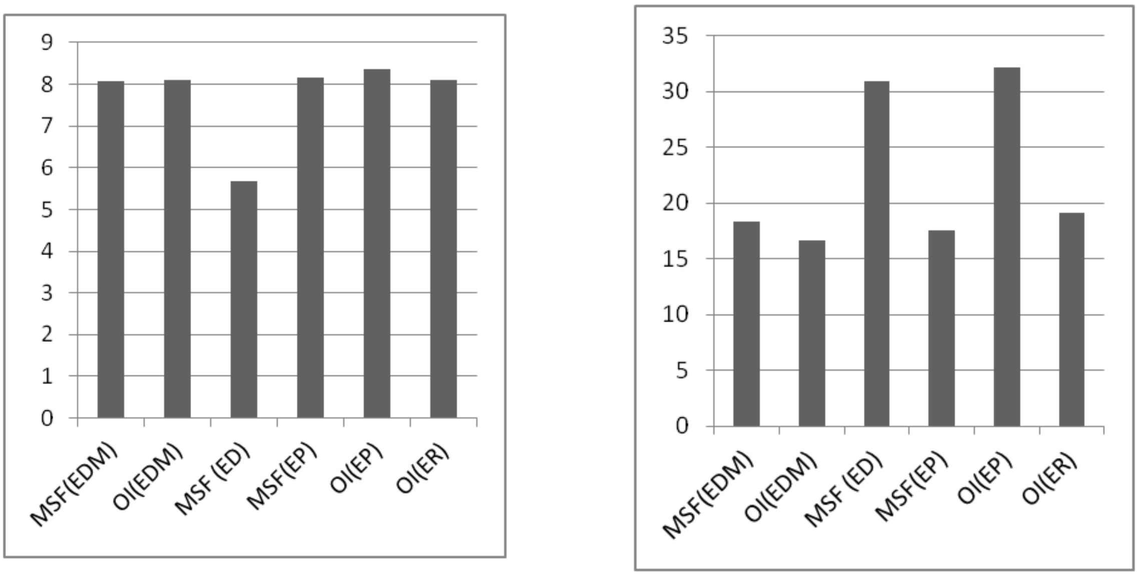


Fig. 4: a – pH ; b- Temperature (°C) of different MSF and RO water samples

The variation in the electrical conductivity of distilled water (MSF) (Figure 5a) is lower than that of reverse osmosis water (RO). This difference persists even after blending (Figure 5b). According to figure 6a, the hardness of drinking water of (MSF) is close to that of drinking water of (RO) despite the conductivity of drinking water of (RO) being 3.5 times higher.
Considering the TH values (Figure 6a), this indicates that the system water (MSF) contains about the exact amounts of calcium hydrogen-carbonates since lime/CO2 blends in the same way. However, the difference in conductivities is entirely plausible since reverse osmosis water can contain significantly more sodium ions.
The variation of calcium in drinking water (MSF) is almost the same as in drinking water (RO) (Figure 7a), this result confirms the previous conclusion about hardness (TH). And the TH is practically equal to the calcium content for drinking water (MSF and RO), which means that the addition of lime only provides the calcium ion.

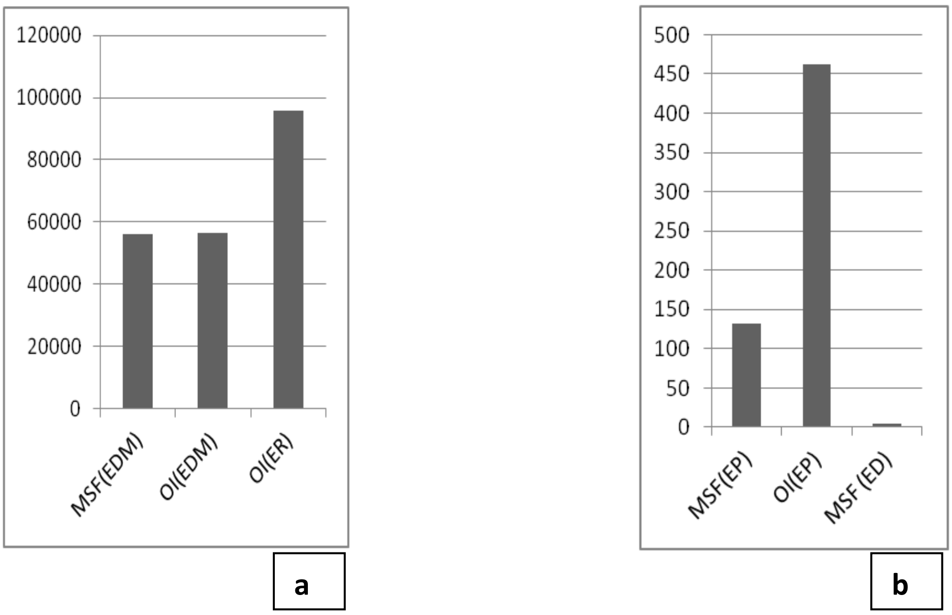


Fig. 5: a- Electric conductivity (µS/cm) of EDM-RO, EDM-MSF and ER-RO;
b- Electric conductivity (µS/cm) of EP-MSF, EP-RO, ED-MSF

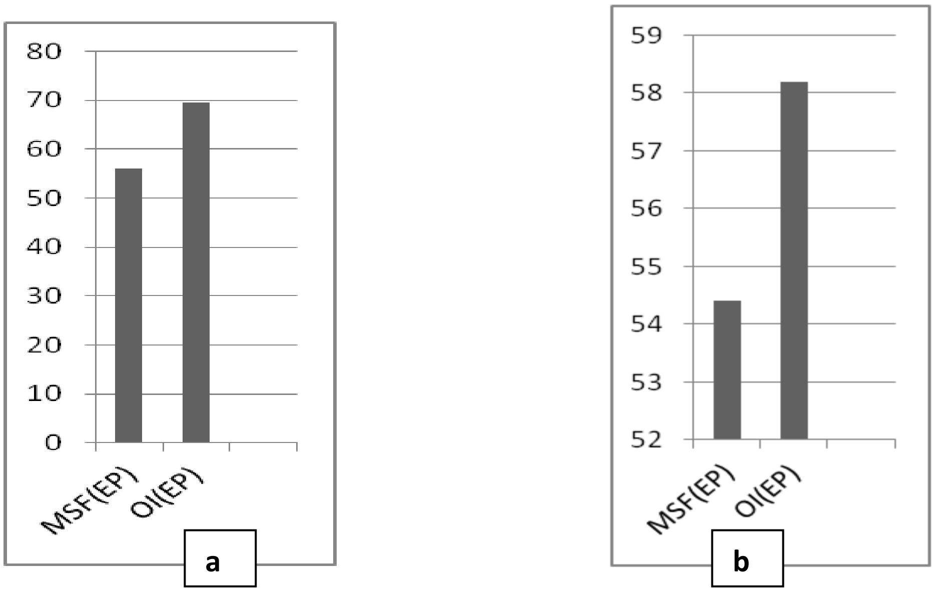


Fig. 6: a- TH (mg/L in $CaCO_3$) in drinking water of RO and MSF (4a), b- Calcium (Ca^{2+}) in mg/L of $CaCO_3$.

The mean values of TA of drinking water (MSF) and (OI) (Figure 7) are practically equivalent. This implies that blending is done similarly at both stations to adjust the pH and the LSI. This result again shows that the difference in conductivity is due to sodium. The TDS of treated water (RO) is four times greater than the drinking water produced by MSF (Figure 7b). This difference is due to sodium chloride because reverse osmosis membranes have a low retention rate for Na^+ and K^+ … it can also be due to the excess of free CO_2 responsible for rapid dissolution of lime.

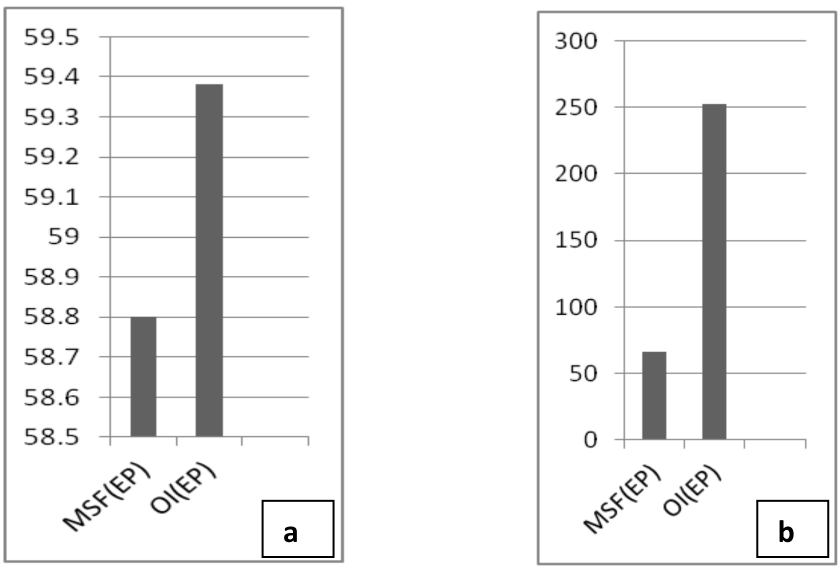


Fig.7 : a- TDS(mg/L) ; b- Alkalinity TA (mg/L of ($CaCO_3$) in RO and MSF drinking water

To distinguish reverse osmosis water from spring water, for example, if the pH > 7 and a TDS > 100 mg, TA must be close to the value that can be estimated from the correlation equation TA = 496.97 pH – 3430.3.

sample	pH	TDS (mg/L)	TA (mg/L) determined	TA (mg/L) Esteemed
EP-MSF	8.16	66.7	35.868	624
EP-RO	8.35	252.78	36.221	719

Conclusion

Due to increase of population, industrialization with unplanned urbanization, and the use of fertilizers and pesticides in agriculture, human drink and will drink in the future from the sea. Treated water stabilization approach has been to add lime ($CaCO_3$) as post-treatment to the sea desalinate water. This must contributes magnesium, calcium and other salts. Since the lime carbonate deposits are almost identical (> 95% $CaCO_3$), it may be that we will have water of almost the same composition worldwide. And the loss of RO water buffering capacity can be harmful for human health. But now, unfortunately, RO water it seems likely to be the only answer to the problem related to drinking water.

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