Analysis of Seasonal Variations of Hydro-Meteorological, General And Particulates In Sea Water Along The Coastline Of Sultanate Of Oman

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Abstract

Detailed information on sea water composition is required to design an effective reverse osmosis (RO) plant as chemistry of sea water is one of the important factors that affect the performance of an RO system. This study was conducted to provide detailed information on seasonal variations of hydro-meteorological, general and particulates at ten locations along the coastline of Oman during the winter and the summer season. The seasonal effect of various parameters gave information for the current and future developments and operations of desalination plants. The air and seawater temperature was higher in summer at almost all the locations. The pH remained constant during both the seasons. Salinity during summer was higher and nearly same with wide fluctuations in winter. Conductivity in winter is constant at all locations with wide fluctuations during summer. Total dissolve solids (TDS) is nearly constant during winter with fluctuations in summer. Dissolved Oxygen (DO) in winter was higher. Turbidity was low and constant in winter with fluctuations at two places in winter.

1. Introduction

Like many GCC countries the Sultanate ofOman faces water scarcity as one of the major issues [1]-[3]. The country is located in south west Asia on the south east coast of the Arabian Peninsula. The coast is formed by the Arabian Sea on the southeast and gulf of Oman on the northeast. Oman lies between latitudes 16˚N and 28˚N and longitudes 52˚E and 60˚E. Due to its geographical location the country faces high temperature sometimes reaching 50˚C and an average annual rainfall of 80-100 mm[4]. Though the country has a long coastline of 2092 kilometers the available sources of fresh water are limited and not enough to sustain the growing population and industrial sector. Availability of fresh water is the basic need and plays an important role in the economic development of a country.It has been predicted by a recent research carried by the Maplecroft's Water Security Risk Index, 2011 that GCC will face serious water scarcity by 2050.Presently there are several desalination plants in the country and to meet the upcoming demands many more areneeded.The existing desalination plant uses mostly multi stage flash (MSF)distillation and RO technology for their operation. Though the recovery rate of MSF is more than RO the energy expenses to run an MSF plant are much higher than RO plants[5]-[6]. Hence construction of desalination plants based on the RO technology is underway.Desalination plant design becomes a great issue in consideration of efficiency, availability, reduction of installation and operation costs. The design and performance of a water treatment process is strongly dependent on the feed water source chemistry [7]-[8]. RO membranes are sensitive to various contaminants like scale forming substances, suspended and colloidal particles, organic matter and bio-foulants that may be present in the feed water. For the proper operation of an RO plant a balance has to be made between the best values of feed, flow, temperature and pressure[8]-[9].

Keeping this in view a project funded by Middle East Desalination Research Centre (MEDRC) was undertaken to analyze the complete composition of sea water at ten different locations along the coastline of Sultanate of Oman with the aim to provide adatabase on the chemistry of sea water at these

locationsfor the summer and winter seasons.

Sea water is an extremely complex solution of many different dissolved ions and molecules. The dissolved solids present in the sea can vary largely with location and climate as well as time [10]. For example, the parameters at a place where a fresh water body mixes with sea water are different from a place where there is no entry of any fresh water body into the sea. However the most important properties of sea water are remarkably constant ratios of the concentrations of the major constituents worldwide. Sea water is marked by high salt concentration, high electrical conductivity, relatively high and constant pH, buffering capacity, solubility for gases, especially oxygen and carbon dioxide which play role in the process of corrosion, large number of organic compoundsand existence of biological life. Some of these factors are interrelated and depend on physical and biological variables such as depth, temperature, intensity of light and the availability of nutrients [10]-[11].

2. Materials and method

Sea water samples were collected at selected ten locations covering the entire coastline of Sultanate of Oman from North to South over a period of two months during the winter (2008) and summer (2009)seasons. The hydro-meteorological, general and particulateanalysis of the collected sea water samples was carried out.A pre-calibrated rope was used to measure the depth at which samples were collected.The air temperature at the sample collection point was measured using the temperature probe connected to the water micro analyzer kit.Air humidity was measured using a psychrometer by measuring the dry and wet bulb temperatures at the sample location. Prior to this calibration was done for the temperature probe as per the procedure given in the micro analyzer water kit manual. The temperature of sea water at the surface of the sample collection point was measured using the temperature sensor connected to the water micro analyzer kit.Prior to this calibration was done for the temperature probe as per the procedure given in the micro analyzer water kit manual. The water micro analyzer kit was used to measure the salinity, conductivity, pH, dissolved oxygen and total dissolved solidsby dipping the corresponding probes into the sample (on-site) and noting down the corresponding readings displayed on the digital panel (analysis was repeated thrice to check for the accuracy). Prior to this, calibration was done for each parameter as per the procedure given in the water micro analyzer kit manual.Density of the sample was analyzed with the help of the digital density analyzer meter. Approximately, 10 ml of sample was introduced into an oscillating sample tube and the change in oscillating frequency caused by the change in the mass of the tube was used in conjunction with calibration data to determine the density of the sample. The total suspended solids were analyzed using gravimetric analysis while turbidity using a digital turbidity meter.The following locations were selected for collection of the samples: 1. Shinas, 2. Sohar, 3. Suwayk, 4. Barka, 5. Seeb, 6. Muttrah, 7. Qurriyat, 8. Sur,9. Duqam, and 10.Salalah. The locations were decided keeping in view the future demands for potable water at these places. Shinas, Sohar, Suwayk, Barka, Seeb, Muttrah, Qurriyat lies in the Gulf of Oman while Sur, Duqam and Salalah face the open Arabian Sea.

2.1. Sampling procedure

The sea water samples were collected by travelling on fishing boats, five miles into the sea at a depth of 5 m. A fabricated sampler was used to collect the samples. As chemical and biological changes are inevitable when the sample is removed from the parent source, standard sample preservation methods were followed to preserve the samples immediately upon collection [13].

Figure 1.Map of Oman showing locations of sample collection [12]

2.2. Categorization of parameters

The parameters to be analyzed were divided into the following three categoriesas presented in Table 1.

Table 1. Parameters of analysis

Category	Parameters
Hydro-meteorological Information	Depth of sample collection (m)
	Air temperature (˚C)
	Air humidity (%)
General	Temperature of sea water (˚C)
	Conductivity(µmho/cm)
	pH
	Salinity (ppm)
	Density (g/m^3)
	Dissolved oxygen (DO) (mg/L)
Particulates	Total suspended solids (TSS) (mg/L)
	Total dissolved solids (TDS) (mg/L)
	Turbidity (NTU)

2.3. Sample analysis

Some parameters like air temperature, air humidity, pH, salinity, conductivity, DO, seawater temperature were analyzed on-site while the rest were analyzed immediately upon reaching the laboratory.

3.Results and discussions

The trend in data variation for various parameters considered in this paper is shown in the form of line graphs.

3.1. Hydro-meteorological information

The hydro-meteorological parameters comprised of depth of sample collection, air temperature and air humidity.

3.1.1. Depth of sample collection

All the samples were collected at a depth of 5 m with a fabricated sampler.

3.1.2. Air temperature

Figure 2 shows the variation of temperature for winter and summer seasons. The air temperature was higher in summer as expected than in winter at all locations except Shinas and Sohar,where the difference was very low.

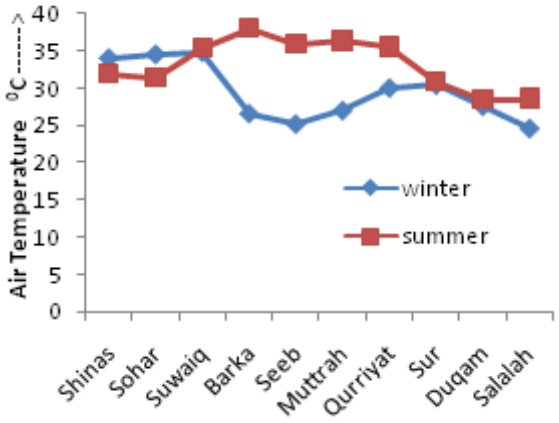

Figure2.Variation of air temperature across the coastal line of Oman for winter and summer season

3.1.3. Air humidity

The air humidityat Barka, Seeb and Muttrah was on the higher side in winter with not much variation at the rest of the locations as shown in Figure 3.

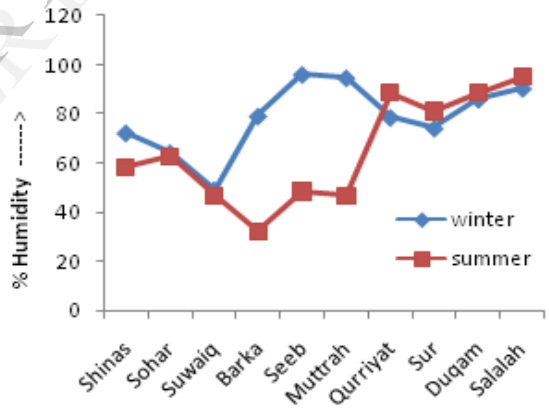

Figure 3.Variation of air humidity across the coastal line of Oman for winter and summer season

3.2. General

General parameters comprised of temperature of sea water, conductivity, salinity, pH value, density and DO.

3.2.1. Temperature of sea water

The temperature of sea water in summer at Shinas was lower than the winter temperature; this may be due to the conditions prevailing on the day of sample collection. While at rest of the locations it

washigher in summer than winter, as expected (Figure 4).Both the permeate flow and recovery in RO plant are increased if the temperature of the feed water is increased [14]. The RO flux reading can be affected by seasonal variations in temperature of feed water [15]. The temperature changes the viscosity of the water. At higher temperature the viscosity of water decreases and more water goes through the membrane [8].

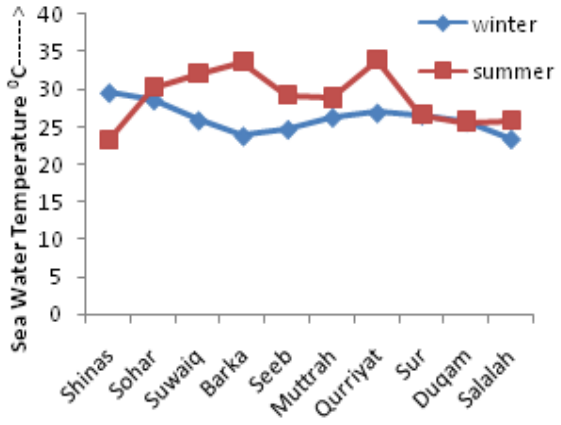

Figure 4.Variation ofseawater temperature across the coastal line of Oman for winter and summer season

3.2.2. Conductivity

Conductivity is a measure of ionic activity of a solution. High conductivity is an indication of high TDS. Sea water is highly conductive. There were large variations in the conductivity during summer along the coastline, Salalah showing the highest value. While in winter it was nearly same at all locations (Figure 5).

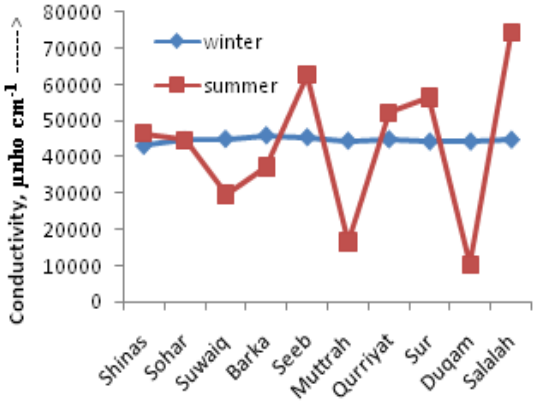

Figure 5.Variation of conductivity across the coastal line of Oman for winter and summer season

3.2.3. pH

The pH at Muttrah in winter season was on the lower side, otherwise it was nearly same at all locations in both thesummer and winter season (Figure 6).Most RO membranes operate at pH 5.5 to avoid scaling. Both high and low pH can induce corrosion of equipment. Lowering the feed pH with acid results in a lower Langelier Saturation Index (LSI) which reduces the scaling potential for calcium carbonate. Variation in feed pH can also effect the rejection of ions, e.g., fluorine, boron and silica rejection are lower when the pH becomes more basic [8].

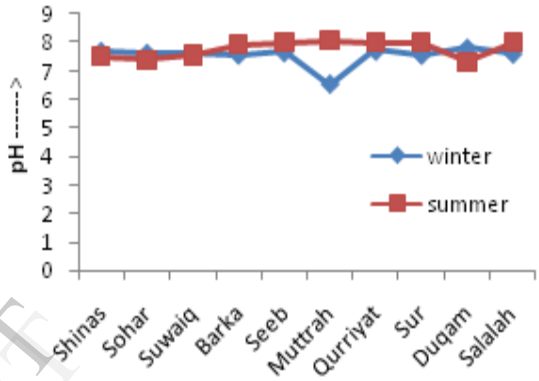

Figure 6.Variation of pH values across the coastal line of Oman for winter and summer season

3.2.4. Salinity

Although the sea water has salinity between 3.1% and 3.8% [10] it is not uniformly saline throughout the world. Oman faces temperature more than 45˚C during the summer months that leads to higher rates of evaporation. There is no rain and no inflow of any fresh water body into the sea. The outflow from the Persian Gulf which already has salinity as high as 40,000 ppm adds to it more [16]. The Oman gulf also serves as a route to ships. The ballast water from the ships also adds to increase in salinity. The quantity and recovery of the product water in an RO plant are increased as the feed water salinity is decreased. A lot of variation in salinity was observed during the winter along the coastline with Seeb having the highest, even higher than the summer value. In summer the salinity remains nearly same at all locations as shown in Figure 7.

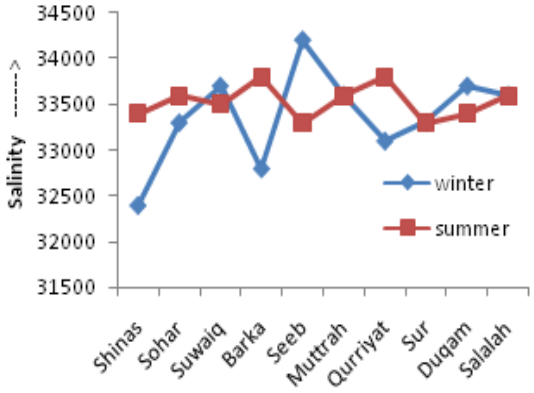

Figure 7.Variation of salinity across the coastal line of Oman for winter and summer season

3.2.5. Density

Density varies depending on the temperature and salinity. At larger depths under high pressure sea water can reach a density of 1,050 kg/m^3 or high. Density at Salalah during winter and summer was the lowest (Figure 8).

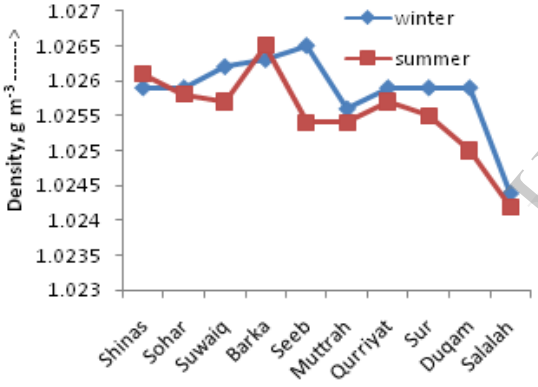

Figure 8.Variation of density across the coastal line of Oman for winter and summer season

3.2.6. Dissolved oxygen

Dissolved Oxygen (DO) is the volume of oxygen that is dissolved in water. Oxygen enters the water by photosynthesis of aquatic biota and by the transfer of oxygen across the air-water interface. The amount of oxygen that can dissolve in water mainly dependson temperature, salinity, and pressure of water. Gas solubility increases with decreasing temperature hence cold water will hold more oxygen [17]. DO is one of the most well established indicators of water quality.High DO conditions may result in large fish kill while a low value indicates high population of respiring organisms.DO at Sur during winter season was on the higher side as shown in Figure 9.

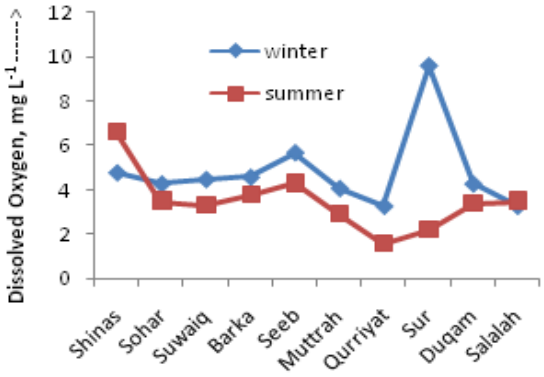

Figure 9.Variation of dissolved oxygen across the coastal line of Oman for winter and summer season

3.3.Particulates

Small pieces of solid or liquid matterassociated with the earth atmosphere are called particulates. This paper presents the variation of three common particulates found in sea water, viz., TSS, TDS, and turbidity.

3.3.1. Total suspended solids

Sea water contains organics, fine particles and silt as suspended particles. The total suspended solids were detected to less than 1.0 mg/L at all locations for both the winter as well as the summer season.

3.3.2. Total dissolved solids

TDS is a measure of total ions in a solution. The degree of hardness increases with the increase in TDS. High TDS degrades overall seawater reverse osmosis (SWRO) plant performance as product water recovery becomes low. Feed with high TDS also requires higher pressure and energy to operate SWRO. The rate of increase in yield and recoveryis inversely related to seawater feed TDS [18]. A large variation in TDS was observed during the summer season. TDS at Duqam in summer was on higher side as shown in Figure 10.

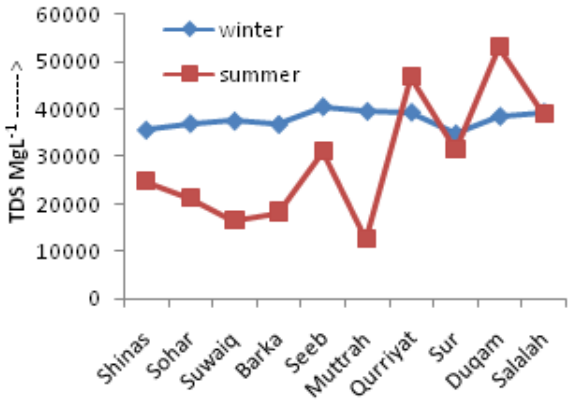

Figure 10.Variation of TDS across the coastal line of Oman for winter and summer season

3.3.3. Turbidity

Sohar being a newly developing industrial area has highest turbidity during summer season (Figure 11). The turbidity during winter season remains almost constant.High turbidity tends to degrade the desalination plant performance and should be removed essentially before the water passes through the membrane.

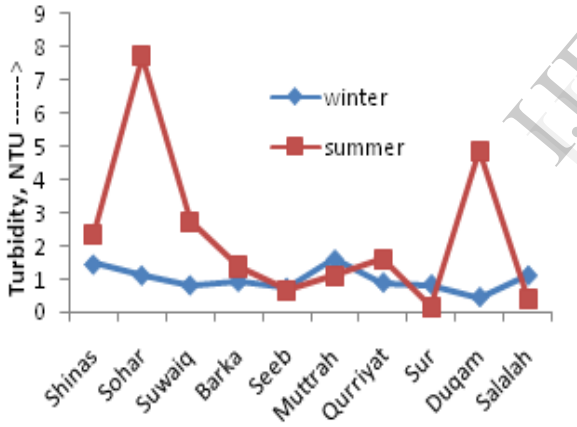

Figure 11.Variation of Turbidity across the coastal line of Oman for winter and summer season

4. Conclusion

The RO membrane is a costly investment in a SWRO plant and its life is strongly dependent on the feed water quality. From the observations of the values of the various parameters it may be concluded that the quality of the Oman seawater is fairly good. Still the observations of seasonal variations in the feed water parameters at the different locations will help to decide the most suitable pretreatment, type of RO membrane and operating conditions for the RO plants. An RO plant should be prepared to handle even the worst quality water effectively.

i) The salinity was nearly constant throughout the coastline during summer. In winter salinity shows variations with Seebhaving the highest value.
ii) The conductivity and TDS were constant in winter. Variations for both were observed during the summer season.
iii) The pH remained nearly constant during both winter and summer with the exceptional observation of low pH at Muttrah during winter.
iv) The DO was observed to be higher in winter than summer at all locations except Shinas. As the temperature of water was low in the winter season it could hold more water.
v) The density in summer and winter did not show much variation. Salalah observed lowest density during winter.
vi) The TSS were detected to less than 1.0 mg/Lat all locations for both the summer and winter season.
vii) The Turbidity at Sohar was maximum in summer. It remained constant throughout the coastline in winter.

5.Acknowledgements

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