BEHAVIOR OF OIL POLLUTION IN SEA WATER DESALINATION PROCESSES

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ABSTRACT

Oil spills in coastal areas have raised concern that oil may become entrained in the sea water intakes of sea water desalination plants. In addition, many countries especially in the middle east and other areas, depend on desalination plants for a vital supply of drinking water. The majority of these desalination plants are located in oil producing area or close to oil tankers routes and oil terminals. This paper reviews the findings of an experimental investigation on the behavior and effects of all sorts of expecting oils that can contaminate sea water on desalination process as well as the distilled product water quality. Extensive study has been made to minimize the severe impacts of oil contamination on the product distilled water. This can be done by dumping the product distilled water of the 1st to the 3rd stages of the multi stages desalination process.

Keywords: Oil pollution; oil-in-water emulsion; sea water desalination

INTRODUCTION

Oil pollution of the sea has steadily grown with the increasing use of oil. But it is only in recent years that it has become a world wide problem. The present rate of oil that enters to the sea water is measured in millions of tons each year. When crude oil or refined petroleum products are released to the sea, the threat of oil pollution becomes highly sensitive especially to the coastal areas.

Oils are mixture of hydrocarbons with diverse molecular weights and chemical structures ranging from light gasoline fractions to heavy tar and wax fractions [1]. The properties of oil spill are also influenced by the weather and intensity of the physical and chemical processes they are exposed to during and after spilling. The process of considerable importance in sea water oil pollution is emulsification. The formation and stability of emulsion depend on many factors, including oil properties (such as, viscosity and density) and environmental conditions (such as, wave climates, water current and wind level). The amount of energy required to form a stable emulsion has been shown to be relatively small in an even calm sea water surface [2]. This finding has been confirmed by a number of studies in which processes of forming the oil-in-water emulsion have been quantified following the oil spill events. Many of the reported experiences with these highly viscous emulsions also indicate that they respond poorly to treatment, are difficult to contain, difficult to remove and so kept for long time in sea water. For example crude oil will begin emulsifying in 24 to 48 hours after entering the sea water [3]. So, although the harmful effects of oil pollution on marine environment may often be all too obvious [4], their impact may also be presented long after visible evidence has disappeared [5]. The water content began to gradually increase in the oil spill and remained at less than 5% for the first 24 hours, increasing to about 50% over the next 6 to 10 days. Density also increased from 0.88 to 0.98 g/ml owing to evaporation of lighter hydrocarbons in the oil and in the presence of solid particulate in the water, this density increase was sufficient for the weathered oil to sink [6, 7, 8]. Walker et al. [9] stated that for different crude oils release to sea, there is rapid evaporative loss of about 35 to 40% over the first few hours then a gradual increase in loss. In their findings, they noticed a loss of about 40% over 4 hours to be associated with complete loss of alkalis up to C9. After about 24 hours on sea, a loss of 45 to 50% are result of loss of alkalis to C12. Finally from 48 hours onwards the loss of about 50% are due to loss of components to C14. Forrester [10] has found that after the Arrow oil spill incident, oil was found down the sea water depth as far as 30 meters. There is also abundant evidence [11, 12] that freshly spilled crude oils contain low boiling components which are acutely toxic. A variety of crude oils and oil products have been studied, the investigation proved that within each series of hydrocarbons the smaller molecular weight components are more toxic than larger. This indicates that lighter crude oils and products such as gasoline have a higher immediate toxicity. Of the facilities using sea water, desalination plants appear to be most susceptible to contamination from fresh oil spill as well as weathered oil. Oil can contaminate the desalination plant product making it unfit for its intended use. Unfortunately despite the number of significant oil spills which have occurred around the world little good quantitative data are available from desalination facilities which have been impacted by these spills. In most instances, the operators have been too involved in containing the spill. In other cases, facilities were shut down until the threat oil contamination diminished. This is never guaranteed as seen above, since once oil spill occurred their impacts on the sea water lasting for a very long time. As a result of the massive release of oil which occur in the Gulf area, several studies were undertaken to predict the impact of oil contamination on desalination plants on ships which were operating in the Gulf. The United States Navy [13] conducted a test program on an actual shipboard evaporator to determine the effects of oil pollution on the operation of the plant. In this experiments, the Navy demonstrated that the desalination plant would operate with 0.1 to 0.2 % (1000 to 2000 ppm) of fresh crude oil without adversely affecting heat transfer or overall operation. Unfortunately the Navy test data are not sufficiently definitive to establish that sea water oil concentration of 1000 to 2000 ppm will not result in thermal or mechanical problems in any thermal desalination plants. It is important to note that the properties of fresh oil can change dramatically as oil weathers. Therefore, the effect of weathered oil on a desalination plant may be significantly different from the effects of fresh oil. The studies did not address the effects of weathered oil on desalination plants, so further testing need to be conducted. Nakazawa et al. [14] have designed a computer simulation program using a mathematical model in order to study the behavior of hydrocarbons in the evaporator. In this study, some improvement were made to the actual conditioned of the subject plant. To establish the significance of particular constituents that may be carried over under practical conditions, it is necessary to know their concentration in the feed water and consequently their potential effects on human health. A comprehensive review of water quality standards was undertaken by the World Health Organization (WHO) [15] to determine the maximum allowable concentration of oil or hydrocarbons in drinking water which will not result in health risks. This study set a specific limit for oil contamination level in drinking water which is 50 ppb. There are basically two major process classifications of desalination plants namely thermal and reverse osmosis. This paper deals with thermal desalination system. The thermal process involves heating of the sea water to form steam and condensing the steam to form distilled product water.

In reviewing the literature, it was intended in this paper that results of experimentation would be used to determine the concentration and the properties of oil which would result in severe problems in a facility of a great importance such as sea water desalination processes. So, a wide range of fresh oil viscosity and oil concentration are employed. Also the present study addresses the adversely effects of fresh oil as well as weathered oil contamination in sea water used for desalination.

EXPERIMENTAL APPARATUS AND PROCEDURES

The experimental apparatus used for this investigation is shown in Figure 1. It was designed to enclose all of the individual parts in glass, so that they could be viewed completely at any time of the test. The aim of the laboratory technique is to simulate the conditions that are likely to occur in the field of the desalination processes, particularly in terms of sea water salt concentration, oil contamination type and oil concentration in the feed sea water. The test rig consisted mainly of a glass evaporator in which saline water is boiled. Heat is supplied to the evaporator using internal electric immersed heaters. The vapor rising from the saline water in the evaporator is then cooled in a transparent helical condenser using tap water as a coolant. The vapor is then converted to liquid water which is collected in a graduated vessel at the condenser outlet. The system is vented to remove the air and any other non condensable gases dissolved in saline water. The total salt concentration of sea water is an important parameter which is expressed in terms of salinity, which equals to the total amount of salt (in grams) per kilogram of sea water. In the open ocean the salinity lies between 33.6 to 36.8 parts per thousands [16], but in more isolated basin areas extreme deviations can occur. On the other hand, in Red sea saltiness up to 41 parts per thousands have been measured. In the present experiments, saline water is prepared by stirring 34 g of sea salt to dissolve in tap water to create 1000 g of saline water which is kept fixed throughout the whole experiments. Different fresh oil concentrations, are used to contaminates the 1000 g prepared saline water and then feed to the evaporator.

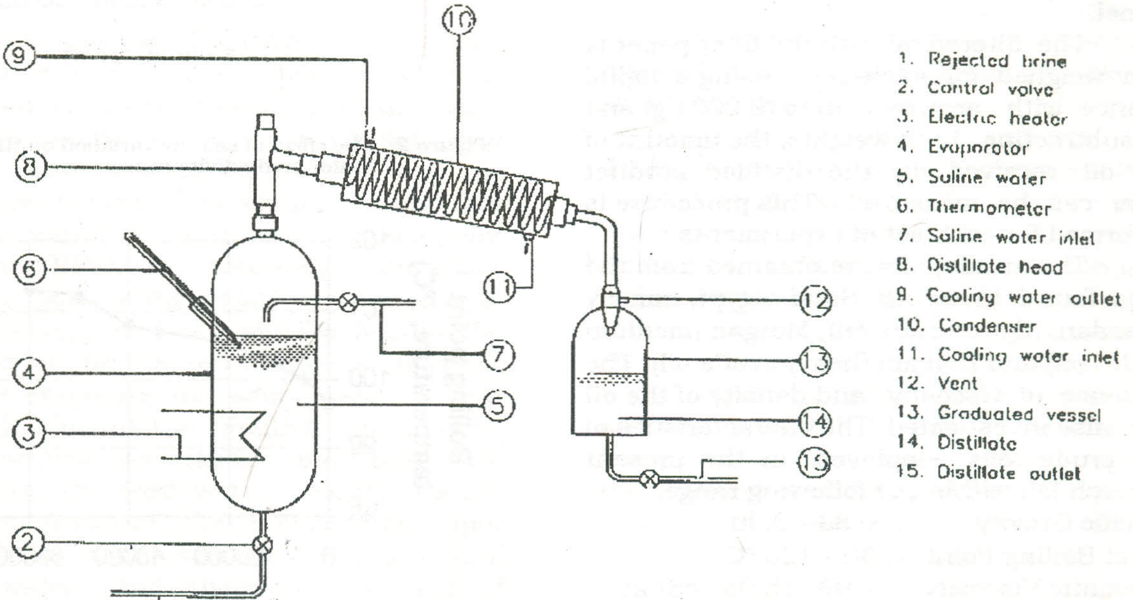

Figure1 Experimental apparatus

Oil concentration ranging from 5 g (5000 ppm) to 100 g (100000 ppm) are employed in the present study. As, seen in the literature, weathered oils are always found after fresh oil spill occurrence, so weathered oil was prepared with different concentration and different elapsed time after the oil being placed on the saline water surface. This was done by spilling fresh oil on the top of the saline water, prepared with the fixed salinity, for different periods of elapsed time up to 12 days in the ambient conditions indoor the laboratory in several marked pans. The kinematic viscosity for each employed oil in centistoke was measured directly using an Ubbelohde viscometer type. The method used is in accordance with ASTM standards. The boiling temperature measurements were done using Hg thermometer.

The distillate product received in the graduated vessel for each test was monitored, so to evaluate the amount of oil received by the distillate product. After each test, the distillate product is fed to oil separation unit which consists of oil separatory funnel, where the oil is removed from each distillate product using an oil filter paper located inside the separatory funnel.

The filtered oil with the filter paper is then weighed for each test using a digital balance with accuracy up to (0.0001 g) and by subtracting both weights, the amount of the oil received by the distilled product water can be measured. This procedure is performed for each set of experiments.

The crude oils are obtained from the fields found in South Sinai, Egypt, namely Ramadan (light crude oil), Morgan (medium crude oil) and Blaeam (heavy crude oil). The influence of viscosity and density of the oil was also investigated. The characteristics of the crude oils employed in the present research fall within the following range:

Specific Gravity : 0.83 - 0.90
Initial Boiling Point : 30 - 125 °C
Kinematic Viscosity : 7.93- 15.05 cSt at 40 °C
Wax % wt. : 5 - 12
Asphalt %wt. : 0.05 - 3.0

Also a commercially available refined lubricating oil is used with kinematic viscosity ranging from 220 to 320 cSt. at 40 °C.

RESULTS AND DISCUSSION

a) Effect of Salinity on the Desalination Process

The effect of feed water salinity on the distillate productivity ratio (kg of distillate/kg of feed saline water) and on the boiling point temperature are examined. Figure 2 shows the relationship between distillate productivity ratio versus different feed water salinity. It is clear that the distillate productivity ratio decreases about 20% as salinity is increased in the range from 0 to 60000 ppm. The effect of feed water salinity variation on the boiling point temperature is shown in Figure 3.

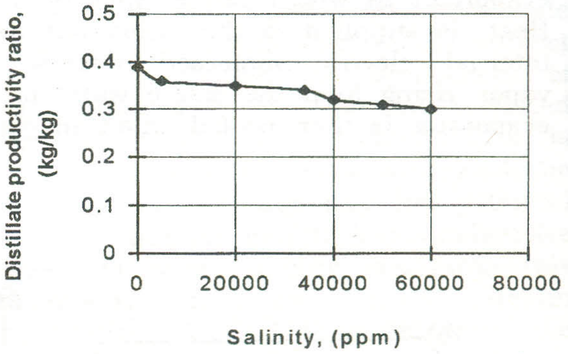

Figure 2 The effect of salinity variation on the distilled water productivity ratio.

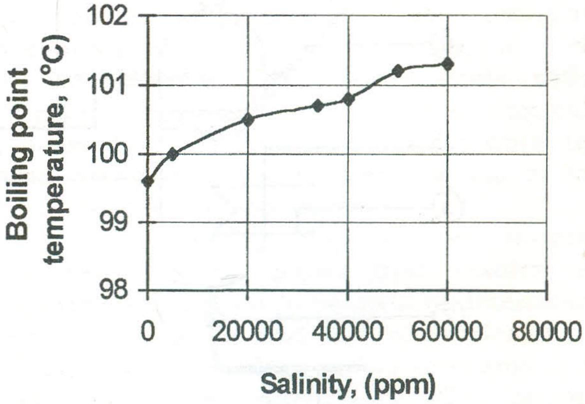

Figure 3 The effect of salinity variation on the boiling point temperature.

The explanation for the effects of feed water salinity variation on the boiling point temperature and consequently on the distillate productivity ratio can be clarified by considering the overall energy balance. In the distillation process in the present work, the saline water is made to evaporate by heating process under constant pressure process. The overall energy balance gives heat input by heating source, in terms of temperatures can be approximated as:

$$Q = M_d L_t + M_f c_p (T_v - T_f) \qquad (1)$$

Where:

M_d	Distillate mass rate
L_t	Latent heat of vaporization
M_f	Saline water feed mass rate
c_p	Specific heat under constant pressure
$(T_v - T_f)$	Temperature difference between the vapor and the saturated liquid

Or,

$$Q = M_d L_t + M_f c_p (\Delta t + \delta) \qquad (2)$$

Where: δ is the boiling point elevation.

In applying the above relation to the evaporator, Δt is related to the pure water at a certain pressure. However, at the same pressure saline water has a boiling point greater than that of pure water, and the difference between its boiling point and that of pure water is known as the boiling point elevation (BPE). So, according to the above relation, part of the steady heat added goes to the second term as a sensible heat on the expense of the first term which is the latent heat to evaporate the saline water. So that the reduction of the distillate productivity ratio occurs as (BPE) increases with increasing the feed water salinity. Also, at any temperature the equilibrium vapor pressure of saline water is less than that of pure water and therefore the rate of evaporation is less with increasing the feed water salinity. As the distillation proceeds in the evaporator, the salt concentration in the brine water increases.

This causes a further decrease in the equilibrium vapor pressure [17], as well as a further increase in the (BPE), which causes further reduction on the distillate productivity ratio.

b) Effect of Fresh Refined Oil

In this section the effects of fresh light refined oil and fresh medium refined oil, on both the desalination process and distillate water quality are investigated using various oil concentrations. The water salinity was kept constant throughout the whole experiments at 34000 ppm. Figure 4 illustrates the effect of contaminating the feed saline water with varying refined oil concentration on the water distillate productivity ratio, with light and medium refined oil range. The distillate productivity ratio decreases by increasing the refined oil concentration in the feed saline water (5000 ppm to 100000 ppm) for both types of oil. Figure 5 shows that the boiling point temperature increases as the refined oil concentration in the feed saline water is increased.

The effect of varying the oil concentration in the saline feed water on the distilled water contamination is clear as shown in Figure 6.

These curves indicate that desalination process would operate with low concentration of the refined oil in saline water without adverse affects. However, by raising the refined oil concentration in the saline feed water, the distillate productivity ratio is markedly affected with still not much oil carried over into the product water.

Typically, about 8% reduction in the distillate productivity ratio is reported and the estimated values of oil carried over with the distilled water varied from 15 ppm-123 ppm (0.1-0.5 percent of the refined oil contaminating the feed saline water).

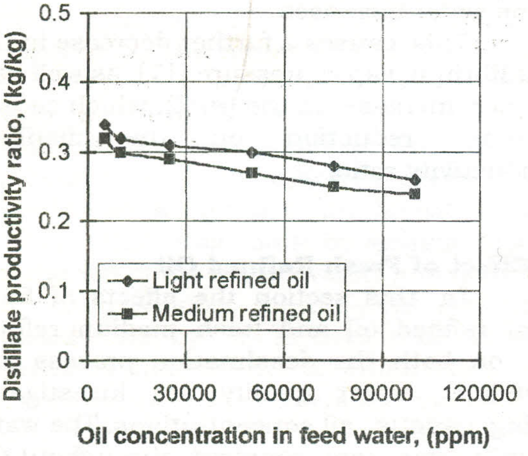

Figure 4 The effect of fresh refined oil concentration in the feed water on the distillate productivity ratio.

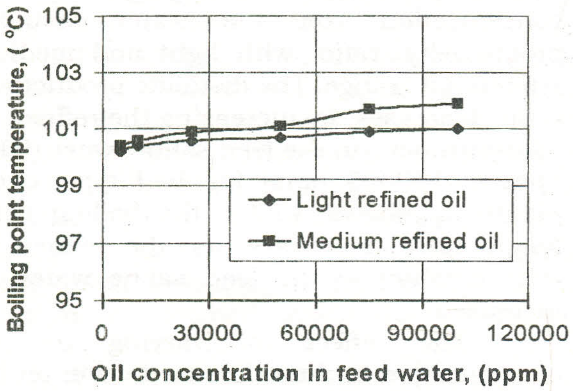

Figure 5 The effect of fresh refined oil concentration in the feed water on the boiling point temperature.

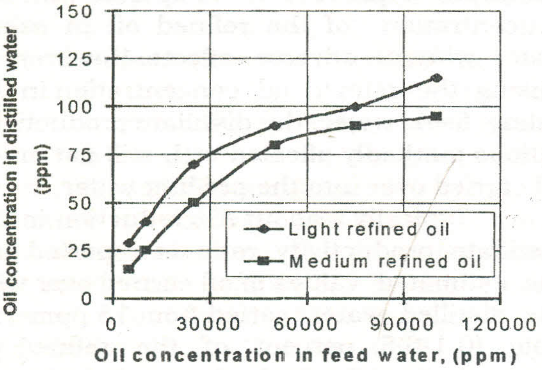

Figure 6 The effect of fresh refined oil concentration in the feed water on the oil concentration in distilled water.

The refined oil contains a wide range of additives, many of which are surface active compounds, which highly increases their viscosities as well as their boiling point range. Thus, consuming much of the steady heat supplied to the evaporator on the expense of the distillate evaporation rate.

The rate of evaporation of the given oil is undoubtedly proportional to the percentage of the light volatile components. These volatile fractions are too low in refined oil [18]. This likely seems to be the reasons for the low values of the oil concentration received by the distilled water. However, even the amount of oil carried over with the product water is too low, it is still has a serious risk if compared with the above-mentioned maximum allowable concentration of oil in drinking water.

c) Effect of Fresh Crude Oil

Tests were performed to examine the effects of contaminating saline feed water with fresh crude oils on the desalination performance and the findings are presented in this section. Figure 7 shows the effect of varying the fresh crude oil concentration in feed saline water on the distilled water productivity ratio. Tests being carried out with light crude oil (sp.gr.= 0.84 & ν=7.93 cSt at 40° C), medium crude oil (sp.gr.= 0.87 & ν=11.8 cSt at 40° C), and heavy crude oil (sp.gr.= 0.90 & ν=15.05 cSt at 40° C) with oil concentration in the saline feed water ranging from (5000 ppm to 100000 ppm). The distilled water productivity ratio decreases with the increase of the crude oil concentration in the saline feed water. The distilled water productivity ratio is decreased by about 20% when the crude oil concentration increased from 5000 ppm to 100000 ppm. Figure 8 illustrates the effect of the crude oil concentration variation in saline feed water on the boiling point temperature. It can be seen that the boiling point increases as the oil concentration in the feed saline water increases for the three types of crude oils studied.

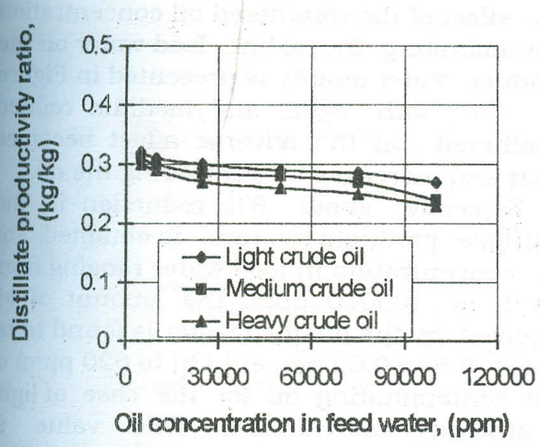

Figure 7 Relationship between distillate productivity ratio and feed water with fresh crude oil concentration.

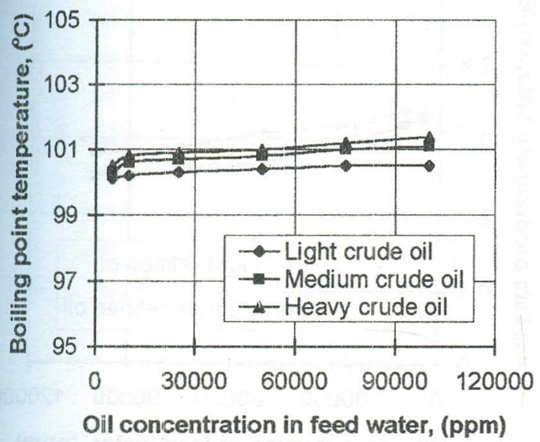

Figure 8 Relationship between boiling point temperature and feed water with various fresh crude oil concentration.

Figure 9 provides a picture of the oil concentration received by the distilled water versus the various fresh crude oil concentration in the saline feed water. The figure clearly indicates that the oil concentration in the distilled water is markedly increased as the crude oil concentration in the saline feed water increases. It is also interesting to notice that, with particularly the lighter crude oil , the oil concentration in the distilled water is found to raise sharply as the oil concentration polluting the saline feed water is increased.

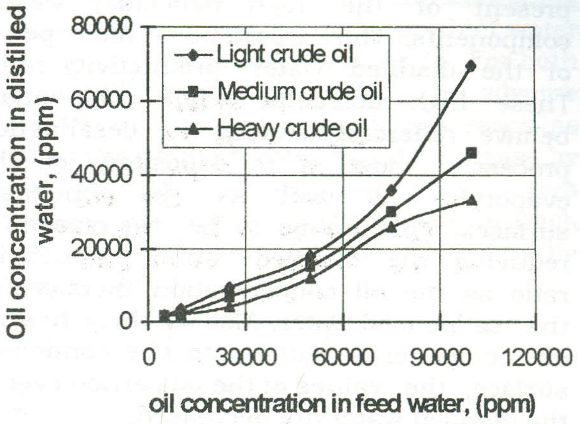

Figure 9 Relationship between oil concentration carried over in distilled water and feed water with various fresh crude oil concentration.

These curves indicate that about 30 to 60 percent (1666 to 60000 ppm) from the amount of contaminating oil will be carried over into the product water in the case of light crude oil. This value estimated for the other medium and heavy crude oil to be 28 to 48 percent (1420 to 48000 ppm) and 26 to 33 percent (1300 to 33000 ppm) respectively. According to the results presented here, it is clear that the low boiling point components of fresh crude oils evaporate easily even before the saline water itself, and so move readily to the distilled water. With regard to the relation between the vapor pressure and temperature of the fresh crude oil components, the vapor pressure of all the volatile components in the crude oil is higher than that of saline water. Therefore it consumes not much of the heat added to the evaporator, and then condensed with the product water especially with the fresh light crude oil as it contains much low molecular weight components. As the condensation process proceeds, and since the latent heat of condensation of the evaporated crude oil components is much smaller than that of saline water, therefore condensed amount of the evaporated oil is much higher than that of condensed water for the same cooling rate. However, with the case of fresh heavier crude oil, the amount of heat for evaporation increases due to the present of the high molecular weight components. This would be on the expense of the distilled water productivity ratio. These high molecular weight components behave differently during the desalination process, most of it deposited on the evaporator as well as the condenser surfaces. This seems to be the reasons of reducing the distilled water productivity ratio as the oil concentration increases in the saline feed water. Also as these heavier oil components adhere to the condenser surface, the values of the oil carried over to the distilled water are decreased.

d) Effect of Weathered Oil

As, seen in the literature, weathered oils are always encountered after any sort of fresh oil enters the sea water environment.

This section describes and discusses the experimental results of the effect of weathered refined oil as well as weathered crude oil on the desalination process. So weathered oil was prepared with different concentration and different elapsed time after the oil being placed on the free saline water surface. This is done by placing the oil in shallow dashes in the laboratory ambient conditions to simulate the outdoor sea water environment when contaminated with oil. The water salinity was kept constant throughout this group of experiments at 34000 ppm. Figure 10 shows the relationship between the distilled water productivity ratio and saline feed water contaminated with different weathered refined oil concentration after the oil had being placed on the water surface for 72 hours. Test being carried out with both weathered light and medium refined oil. It can be seen that the distilled water productivity ratio decreases as the weathered refined oil concentration increases.

Figure 11 shows the variation of the boiling point temperature versus saline feed water with different weathered refined oil concentration. The results indicate that the boiling point temperature increases slightly with the increasing of the weathered refined oil concentration in the saline feed water. The effect of the weathered oil concentration contaminating the saline feed water on the product water quality is presented in Figure 12. For both light and medium refined weathered oil the adverse affect becomes clear and increases by weathering the oil.

Typically, about 8% reduction in the distillate productivity ratio is obtained. For oil concentration in feed water ranging from 5000 to 100000 ppm, the amount of oil received by the distilled water is found to be about 0.6 to 0.62 percent (30 to 620 ppm) of the contaminating oil for the case of light weathered refined oil. This value is estimated for the other medium weathered refined oil to be 0.4 to 0.42 percent (20 to 420 ppm).

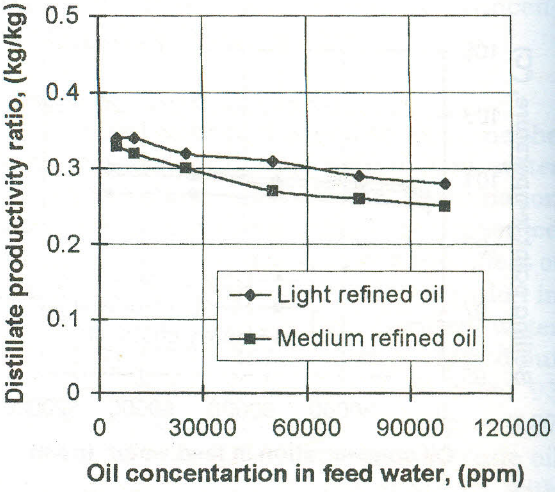

Figure 10 Relationship between distillate productivity ratio and feed water with various weathered refined oil concentration.

The volatile low molecular weight components in these particular refined oil are too low. However, the formation of oil-in-water emulsion is one of the most important process affecting that oil after certain period of time on the water surface. Emulsification causes the water content in the oil to grow and to lose the oil consistency. This increases the amount of the oil carried over with the distilled water. A fairly steep temperature profile exists in heating that emulsion causing a reduction on the water distilled productivity ratio.

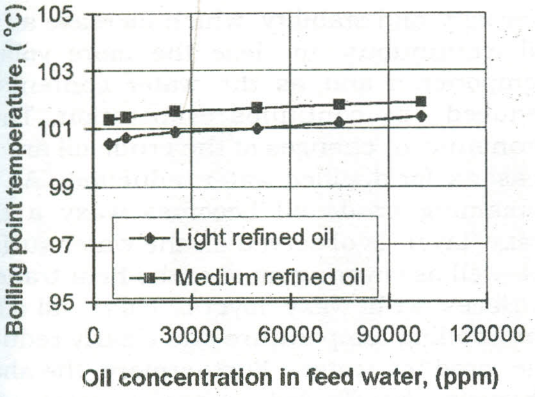

Figure 11 Relationship between boiling point temperature and feed water with various weathered refined oil concentration.

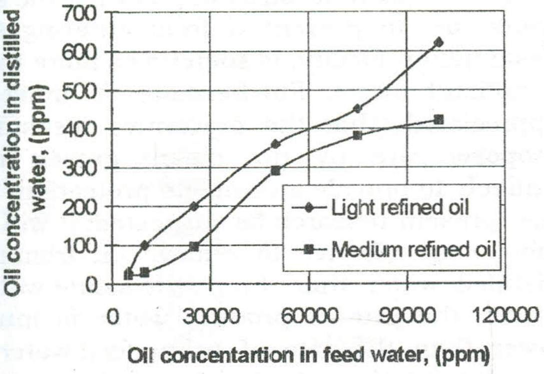

Figure 12 Relationship between oil carried over by distilled water and feed water with various weathered refined oil concentration.

The effect of contaminating the saline feed water with a fixed crude oil concentration (25000 ppm), that has been weathered for different elapsed time, on the distilled water productivity ratio is shown in Figure 13. It can be seen that the distilled water productivity ratio decreases by increasing the elapsed time. Figure 14 gives the variation of the boiling point temperature versus elapsed time of weathering the crude oils. The boiling point increases as the elapsed time increases. The effect of the weathered crude oils for different elapsed time that contaminating the saline feed water on the product water quality is presented in Figure 15. For both light and medium crude oil, the adverse impacts on the desalination processes as well as the product water quality increase by weathering the oil. In these curves zero elapsed time represents the results for fresh crude oil, which is immediately spilled to the water surface.

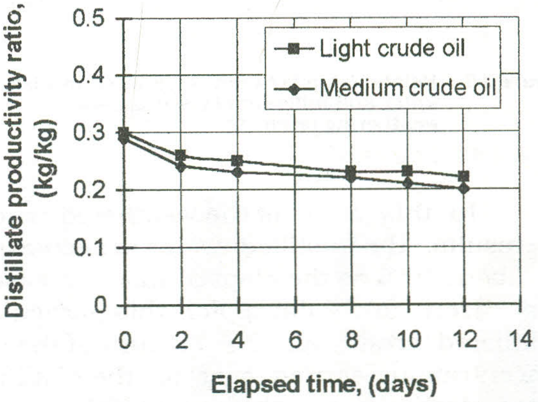

Figure 13 Relationship between distillate productivity ratio and different elapsed time of weathering crude oil.

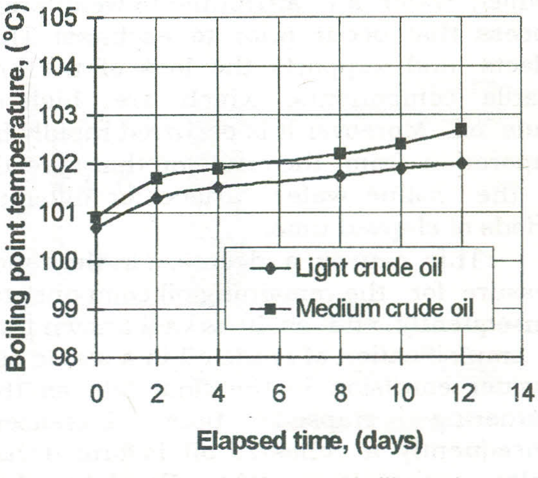

Figure 14 Relationship between boiling point temperature and the different elapsed time of weathering crude oil.

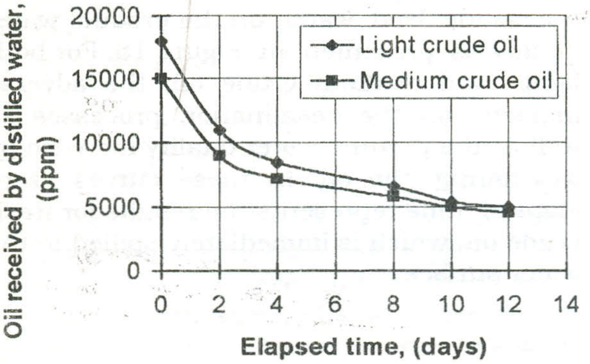

Figure 15 Relationship between oil received by distilled water and different elapsed time of weathering crude oil.

In this case of the weathered crude oil results, the distilled water is decreased by about 10% as the elapsed time increases from (zero to 12 days). For this particular weathered crude oil, the amount of the oil concentration, carried over to the distilled water, declined rapidly from 18000 ppm to 5000 ppm in the presence of light crude oil and from 15000 ppm to 4500 ppm in the presence of medium crude oil. The results show the much reduced of oil concentration carried over by distilled water with these weathered crude oil in comparison to the fresh crude oil.

The lowering concentration in distilled water are attributed to weathering process that occur prior to each test. This reflects and supports the loss of the low volatile components, which are high in crude oil. Moreover it is occurred rapidly by evaporation from the crude oil that spreads on the saline water surface for different periods of elapsed time.

This causes a decrease in the vapor pressure for the remaining oil components. Consequently and as it is well known that the emulsification of crude oil in a stable oil-in-water emulsion is the final fate as the weathering elapsed time increases. Consequently a cohesive oil is formed that finally resists evaporation. Emulsion that are formed in early time are high in entrained water content but of relatively low viscosity and stability, which increase as the oil continuous to lose the more volatile components and as the water contents is reduced by continuos evaporation. These pronounced changes of the crude oil are the reasons for distilled water reduction. As the remaining crude oil becomes waxy a thin waxy layer is observed on the water surface as well as covering most of the heat transfer surfaces with waxy layers. This will affect the boiling temperature and clearly reduces the product water. Furthermore, the above changes sharply reduce the amount of oil concentration in the distilled water. In this case also the heat required for evaporation is increased.

e) Protective Measures

To prevent oil from polluting the sea water or to prevent it from entering the desalination facility, is sometimes more than a difficult target. Furthermore, it must be appreciated that the preventive measures proposed are by no means proven and unlikely to provide a complete protection. In the present research as suggested, it will be more cost effective to remove oil from the distilled water than from the saline water, since the rate of product water is much lower than the rate of saline feed water to the desalination plant. So, in this section experiments being carried out to study the effect of oil contaminating the saline feed water as the desalination is progressively proceed in the subsequent desalination stages. Tests being carried out using fresh medium refined oil as well as fresh medium crude oil with a concentration of 25000 ppm in the saline feed water. To simulate the second stage experimentally, the rejected water from the evaporator was collected and then re-evaporated at the same test rig and the same has been done for the third stage.

Figures 16 and 17 illustrate the distilled productivity ratio produced from each evaporation stage as well as the amount of the oil carried over through each stage respectively, when the saline feed water to the evaporator is contaminated with medium refined oil.

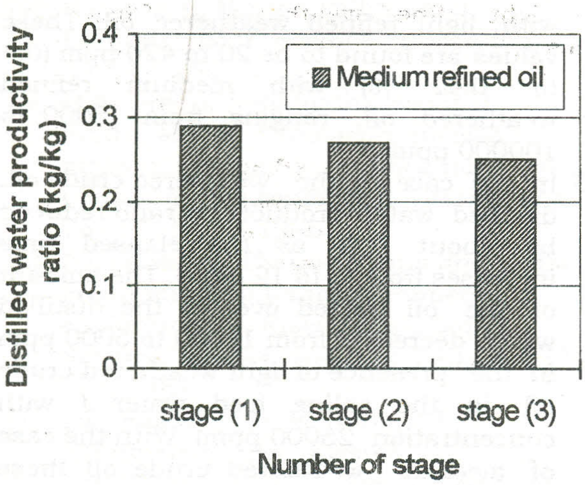

Figure 16 Distilled water productivity ratio at each evaporation stage.

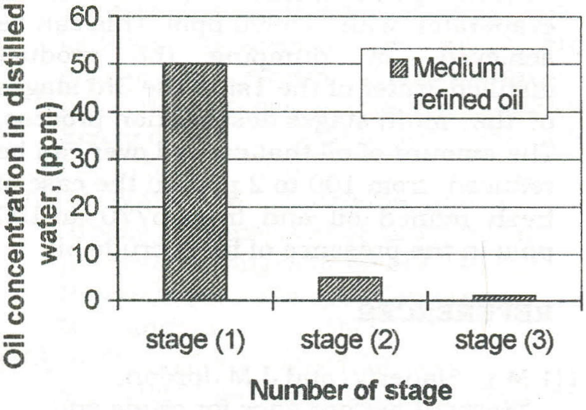

Figure 17 Oil concentration in distilled water at each evaporation stage.

Figures 18 and 19 illustrate the distilled productivity ratio produced from each evaporation stage as well as the amount of the oil carried over through each stage respectively with contaminating the saline feed water with medium fresh crude oil.

According to the obtained results, it is clear that up to 50 ppm refined oil is carried over to the first evaporation stage and about 2 ppm which is quite small amount of oil carried out with the distilled water in the third stage. However, with the presence of fresh crude oil in the feed saline water, the estimated value of oil in the distilled water is 6770 ppm in the first evaporation stage and sharply reduced to 100 ppm in the third evaporation stage. So, from the above results to ensure that the amount of oil transferred to the product water are in the standard limits which are approved by the (WHO), the product water up to stage three must be avoided. This can be achieved by dumping the product distilled water of the 1st to the 3rd stages outside the remaining multi stages desalination process.

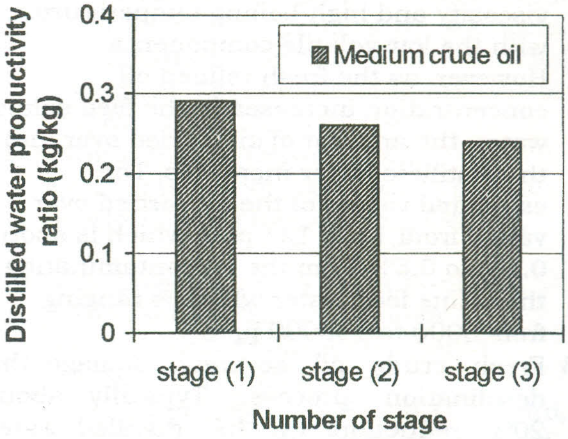

Figure 18 Distilled water productivity ratio at each evaporation stage.

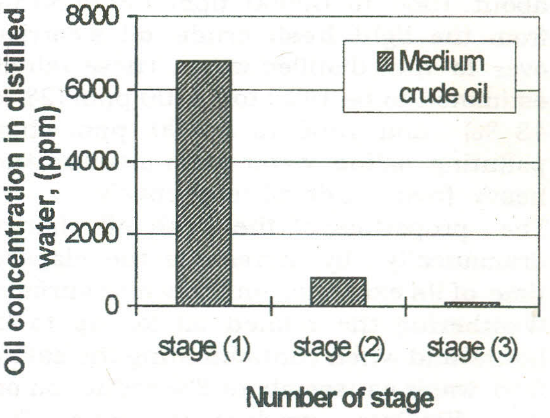

Figure 19 Oil concentration in distilled water at each evaporation stage.

CONCLUSIONS

The following conclusions can be drawn from the results obtained:

1. The reduction of water distillate productivity ratio caused by increasing the salinity could be considered to be the results of two competing phenomena, namely the increase of the boiling point elevation (BPE) and the decrease of the equilibrium vapor pressure.
2. According to the test data obtained, saline water contaminating with low fresh refined oil concentration up to 1000 ppm can have a small effect on desalination process due their high constituency, viscosity and high boiling temperature with the low volatile components. However, as the fresh refined oil concentration increases in the feed saline water, the amount of oil carried over into the distillate water increases. The estimated values of the oil carried over varied from 15 to 123 ppm which is about 0.1% to 0.5% from the oil contaminating the saline feed water which is ranging from 5000 to 100000 ppm.
3. Fresh crude oil severely damage the desalination process. Typically about 20% reduction in the distilled water productivity ratio is reported. The oil carried over with the distilled water raised sharply as the fresh crude oil concentration contaminating the saline feed water is increased. It was found that about 1666 to 60000 ppm (30 to 60 %) from the light fresh crude oil is carried over to the distilled water. These values estimated to be 1420 to 48000 ppm (28 to 48 %) and 1300 to 33000 ppm when polluting saline water with medium and heavy fresh crude oil respectively.
4. The properties of the fresh oil change dramatically by increasing the elapsed time of its existence on the water surface. Weathering the refined oil for up to 72 hours and when contaminating the saline feed water causes about 8% reduction on the distillate productivity ratio. The amount of oil received by the distilled water is found to be 30 to 620 ppm (0.6 to 0.62 %) when saline water is polluted with light refined weathered oil. These values are found to be 20 to 420 ppm (0.4 to 0.42 %) with medium refined weathered oil, ranging from (5000 to 100000 ppm).
5. In the case of the weathered crude oil, distilled water productivity ratio reduced by about 10% as the elapsed time increases from (0 to 12 days). The amount of the oil carried over in the distilled water decreases from 18000 to 5000 ppm in the presence of light weathered crude oil in the saline feed water (with concentration 25000 ppm). With the case of medium weathered crude oil these values are estimated to be from 15000 to 4500 ppm.
6. Extensive study has been made to minimize the oil contamination of the product distilled water, even in the case whereby polluted saline feed water to the evaporator with 25000 ppm. This can be achieved by dumping the product distilled water of the 1st to the 3rd stages of the multi stages desalination process. The amount of oil that carried over can be reduced from 100 to 2 ppm in the case of fresh refined oil and from 6770 to 100 ppm in the presence of fresh crude oil.

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