

Extent of the Desalination of Sea Water by using Simple Distillation, Freezing and Ion-Exchange Techniques

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Abstract

A severe water shortage resulting from extended period of drought occurred at Hambantota area in the last few years. In a continuation of our work for finding an inexpensive solution for such severe water shortages in future the study presented here was carried out. The main objective of the study was to find a low cost method for desalination of seawater. In this regard, our attention was first focused on the detection of desalination capacity by using ion-exchange, distillation and freezing techniques. Normal laboratory distillation and freezing procedures were followed to determine the extent of desalination of seawater and its applicability for drinking and cleaning purposes. The capacity of a resin to desalinate seawater was determined by filtering seawater through artificial resins, Amberlite IR-120(H)/ IR-45(OH) and the results obtained from the three methods are compared. Conductivity, hardness (Ca^{2+} and Mg^{2+} concentrations), pH, concentrations of Na^+ , K^+ , and Cl^- were used as parameters for estimating the extent of desalination. Titrimetric methods were used to detect the hardness and the concentrations of other ions were determined using a flame photometer, conductivity meter and a pH meter. Measurements indicated a remarkable decrease in salinity in seawater after freezing followed by distillation. The hardness of distilled and frozen seawater was found to be in acceptable limits (< 500 ppm) for drinking purposes. It has also been found that an ion-exchange resin like Amberlite IR-120(H)/ IR-45(OH), when using slower flow rates, has an outstanding capacity to decrease the hardness of seawater compared to the distillation.

Introduction

Desalination of seawater has received a significant attention nowadays in all over the world in finding solutions to the severe water shortages resulting from extended period of drought in many areas of the world. Such shortage occurred at Hambantota, Sri Lanka, in last few years. The methods for desalination include hydrate formation, reverse osmosis, the use of various chemicals, electro dialysis, etc and each of these methods is highly expensive and not suitable to a developing country like Sri Lanka. Therefore finding an inexpensive method for this process is

very essential and important to solve the water shortage problem in some arid areas of Sri Lanka. General home appliances such as boilers and refrigerators can be simply modified to obtain fresh water from sea water if the extent of desalination by distillation and freezing is in standard levels for normal use. However, the extent of the desalination of seawater by applying these techniques should be detected first. For this purpose, a study was carried out to determine the salinity of seawater after distillation, freezing and passing it through ion-exchange resins. Fresh water is commonly defined as water containing less than 1000 ppm of dissolved salts. Drinking water, according to the U.S Public Health Service standards, should have no more than 1000, preferably less than 500 ppm (Behrman, 1968). The paper presented here describes the very interesting results obtained after freezing followed by distillation and passing seawater through an ion-exchange resin, Amberlite IR-120 (H)/ IR-45(OH).

Methodology

Ion-Exchange Columns (50 cm height and 2.5 cm diameter) were prepared. Amberlite IR-120(H)/ IR-45(OH) resin (50 g) was mixed with deionized water and poured in to a column about 40 cm height. The column was washed with either 1M HCl (20 mL) or NaOH (40 mL) as required for activating the column. Then it was washed with deionized water until the acidity/basicity removes from the effluent (Duce 1980). Activated carbon (10 g) was added to a beaker and made slurry. Seawater sample (~200 mL) was treated with the activated carbon sample for 5 hours. Then the water sample was filtered, and passed through the cation exchange column. The effluent was collected at different rates. The effluent was then passed through the anion exchange column. The effluent was treated with activated carbon again and the ion exchange procedure was repeated several times.

The pH of the water sample was measured using pH KENT EIL 7020 and HORIBA M-8 pH meter was used to measure pH. Na^+ and K^+ concentration of the standard solutions and seawater samples (after and before passing through columns) was measured using JENWAY pfp7 flame photometer was used to detect K^+ and Na^+ ions. The results of the standard NaCl and KCl solutions were used to make calibration curves. Cl^- concentration was measured using standard AgNO_3 solution in the presence of Morh indicator. Complexometric titration with EDTA solution (0.1000 M), in the presence of EBT indicator and a buffer (aq. $\text{NH}_3/\text{NH}_4\text{Cl}$, pH =10), was done for the determination of hardness. Philips Haris conductivity meter with cell constant 0.99 was used to measure the conductivity. Simple distillation apparatus and the refrigerator were used to distill and freeze water samples. The

distilled water samples were tested for pH, conductivity, hardness, K⁺ and Na⁺ ions by following the similar procedure mentioned above. The procedure was repeated for the frozen samples after distillation.

Results

Measurements of pH, conductivity and estimated salt concentrations of sea water before and after the treatments mentioned above are shown in the table given below. The pH of seawater, after freezing followed by distillation, has been decreased approximately by two units. The same trend in pH is observed for the water samples passed through the ion-exchange column and it is independent of the flow rate. Hundred-fold decrease in conductivity can be seen in seawater processed by distillation, freezing and ion-exchange resin. However, the conductivity is slightly higher in seawater processed by distillation and freezing than in seawater processed by the ion-exchange resin. In contrast to the trends in pH, the conductivity is inversely proportional to the flow rate. Remarkable decrease in the volumes of EDTA and AgNO₃ required to react with Ca²⁺, Mg²⁺ and Cl⁻ can be seen for processed sea water and the estimated data for the hardness and Cl⁻ concentrations are tabulated in the table 1. Flame photometric measurements for both Na⁺ and K⁺ ions are low in seawater passed by all the methods mentioned above.

Table 1 - Summary of the measurements

Parameter	Seawater	Sea water after distillation	Sea water after freezing followed by distillation	Sea water passed through Amberlite IR columns	
				Flow rate, 13.75 mL/min, for the 1 st and 2 nd cycles respectively	Flow rate, 27.50 mL/min for the 1 st and 2 nd cycles respectively
Conductivity (Scm ⁻¹)	1.782 × 10 ⁻²	3.9 × 10 ⁻⁴	3.7 × 10 ⁻⁴	2.376 × 10 ⁻⁴ 1.584 × 10 ⁻⁴	3.861 × 10 ⁻³ 2.77 × 10 ⁻⁴
pH	8.5	6.17	6.50	6.7 6.7	6.9 6.8
Hardness (ppm)	3206.32	124	120	1326 10	2630 11.36
Na ⁺ (ppm)	11600	3260	2717	7000 3700	7000 3700
K ⁺ (ppm)	551	14.88	13.79	3.57 × 10 ⁻³	8.81 × 10 ⁻³
Cl ⁻ (ppm)	19503.68	—	—	5299.9 4202.78	6004.70 4202.78

Discussion

Considering all the results together, a remarkable decrease in conductivity, pH, hardness, Na⁺, K⁺ and Cl⁻ ions can be seen in seawater after distillation and freezing. The decrease in hardness of seawater less than 500 ppm after freezing and distillation is indicative of its suitability for desalination of seawater for drinking purposes. Though the large-scale distillation and freezing procedures are highly expensive and not acceptable for a country like Sri Lanka, the basic idea behind these observations can be taken for the invention of small-scale procedures applicable for individual use. Even a village person can distill seawater in a pot of his kitchen. However, a method should be arranged to collect the steam coming out after boiling sea water in a pot. If further desalination is essential his own refrigerator, if available, can be used to do so. Similar decrease can be observed in seawater after passing it through Amberlite IR-120 (H) and Amberlite IR-45 (OH) columns (table 1). This reflects the capability of a cation and anion exchange resins to desalinate seawater to some considerable amount. These results clearly focus our attention to use a naturally available resin such as clay minerals to desalinate seawater for drinking and cleaning purposes. An extension of the research towards that end is our next target and some studies regarding that are underway.

References

- Behrman AS. 1968 The Chemistry of water purification, Doubleday and company Inc.
 Duce ER. 1980 Biodegradation process to making drinking water biologically stable, Water. 257-261 pp.