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Environmental impact of RO units installation in main water treatment plants of Basrah city/south of Iraq

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HIGHLIGHTS

- The impact of brine water discharge is clear in the upstream reach of the study area.
- When RO units have 85% recovery percent, the max TDS increase is 5.9 % that exceeds the allowed salinity limit.
- When RO units have 50% recovery percent of, the max TDS increase is 2.7% that is less than the allowed salinity limit.
- The TDS increase values vary over the range (8.8-226.3 mg/l) which are < 4ppt (the regulation criteria limit).

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ABSTRACT

The citizens of Basrah city are suffering from the problem of high salinity water supply. This problem is proposed to be solved by installing RO units in 16 water treatment plants of Basrah city. RO units produce high-salinity brine water. The aim of this study is to predict the environmental impact of RO units installation measured in terms of TDS increase of Shatt Al-Arab River water. The TDS increase was predicted using HEC-RAS software. The software was applied to simulate twelve cases of TDS distribution in water of Shatt Al-Arab River. During each of the twelve simulation cases, the proposed RO units were assumed to have recovery percent (RP) of 50% and 85%. The simulation results indicated that when the proposed RO units have RP of 85%, the max percentage of TDS increase is 5.9%. While, when the proposed RO units have RP of 50%, the max percentage of TDS is 2.7%. The comparison of these results with the regulation criteria of brine water discharge shows that; when the installed RO units have RP of 85%, the percentages of TDS increase will exceed the salinity limit of most regulation criteria (5%).

1. Introduction

In south of Iraq, Basrah city is depending on Shatt Al Arab River as a main source of water supply. Until the year 2006, this river received fresh water from three main sources; Tigris, Euphrates and Al Karun Rivers. However, now it is receiving fresh water from Tigris River only. The downstream end of Shatt Al Arab River is affecting by tide phenomenon from the north west of the Arabian Gulf. The decrease of fresh water flow causes the increase of salt intrusion into Shatt Al Arab River during tide period, which led to increase the salinity level of its water. In addition, Basrah city is supplying with potable water of low salinity by Sweet Water Canal (SWC). The SWC has suffered numerous failures since it was commissioned and requires continuous maintenance and monitoring. Several long sections of the canal embankment are structurally unstable, resulting in steadily worsening performance and an increasing rate of failure [1].

All the above circumstances led to supply Basrah city citizens with high salinity water. Many workshops have held in Basrah city to put solutions to the problem of high salinity water supply. One of these workshops was held on 15–16/Feb./2014, which is titled "Basrah Water Crises and Shatt Al Arab Salinity Increase: Measures to Control". During the workshop, a paper was submitted titled "Practical Solutions for Water Supply Problem of Basrah City". The paper suggested the installation of reverse osmosis (RO) units in main water treatment plants of Basrah City to desalinate their product water and subsequently enhance the quality of water supply. After the submission of this paper, a question was asked about the environmental impact of RO units installation on water salinity of Shatt Al Arab River. This question is behind the performance of this study and its results will give the answer.

Desalination process cannot be accomplished without environmental and ecological inferences [2]. There are many environmental impacts depending on type of the applied desalination technology, such as

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energy consumption, land use, produced the emission of regular fuel combustion products, and discharge brine during regular operation. The most important environmental impact produced by desalination plants is the discharge of brine water [3,4,5]. The characteristics of reject brine water depend on feed water quality, type and recovery percent of desalination process and the chemical additives used [6]. Brine water might adversely affect water and sediment quality, reduce biodiversity, impairs marine biota or the vital functions of coastal ecosystems [7].

An increased awareness of the environmental impact of discharging the brine water of desalination plants into the surface waters has prompted environmental studies in existing plants as well as increased attention to this issue in both the design and siting of new plants and plants now in the planning stage [8]. Generally, the first paper to note that the brine and chemical discharges from desalination plants may impair the marine environment probably appeared in 1979 (cited in [9]). However, it took until the 1990s before the scientific interest in the marine environmental concerns of desalination plants became more pronounced, as reflected in the large published number of studies. Examples of these studies include those conducted by; Höpner and Windelberg [10], Morton et al. [11], Oldfield and Todd [12], Höpner and Lattemann [13], El-Samanoudi et al. [14], El-Gamal and Abdrabbo [5], Elabbar and Elmabrouk [8], Medeazza [15], Tularam and Ilahee [16], Lattemann and Höpner [7,17], Münk [18], Abo Qdais [19], Fernández-Torquemada et al. [20], Al-Dousari [21], Dupavillon and Gillanders [2], Ahmed and Anwar [22], Dawoud and Al Mulla [23], Darwish et al. [24], Naser [25], Fernández-Torquemada et al. [26] and Hu [6]. The review of these studies shows that; most of them either examined and compared the environmental impacts of MSF and RO desalination processes or conducted by collecting field data from existing desalination plants.

With regard to the use of modeling techniques (which is the tool used in this study) in studying the environmental impact of desalination plants, the review of previous studies shows that there are three commercial numerical softwares (CORMIX, VISUAL PLUMES, and VISJET) for modeling brine jet discharge. Palomar et al. [27] analyzed and validated these softwares and indicated that they are limited to near field region modeling and CORMIX is a steady-state model. In addition, Purnama et al. [28] developed a one-dimensional tidally averaged mathematical model to assess the impact of seawater desalination plants on water salinity of the Arabian Gulf and the Red Sea. They modeled each of the Arabian Gulf and the Red Sea as a semi-enclosed sea with simple depth topography, parabolic cross sections, and its valley bottom is uniformly descending. Also, Al-Barwani and Purnama [29] developed a model to simulate the long-time (or far field) brine plumes steadily discharged into the seawaters using a two-dimensional advection-diffusion equation. The model considered the effect of a tidally oscillating flow on the long-time brine plume assuming a highly simplified vertical beach profile, and vertically well-mixed (over the water depth) brine plume.

2. Regulatory criteria for brine water discharge

Brine water discharge alternatives include [5]; surface water discharge, disposal to sewage treatment plants, deep well disposal, land applications, evaporation ponds and brine concentrators. Surface water discharge is the most used brine disposal method. Since the most direct waste product of desalination plants is the concentrated salt brine discharge, all the regulatory criteria of surface water discharge are concerning the impact of increasing the salinity of the receiving stream. Jenkins et al. [30] reviewed the regulations or guidelines for brine discharges around the world as listed in Table 1.

Table 1 shows the variation in the putting regulations, however, nearly all have two common elements; a salinity limit and a boundary of mixing zone. The salinity limit is defined as an increment of no more than 1 to 4 ppt or 5% percent relative to ambient.

3. Overview on Basrah City water supply system

Basrah governorate is supplied with water by 37 main water treatment plants (WTPs), out of which 20 WTPs are located in Basrah city and its surrounding area, to which the raw water is fed from Shatt Al Arab River and SWC. The rest is located outside of Basrah city. Table 2 shows the source of water and the design capacity of Basrah city WTPs and Fig. 1 shows their locations.

All of the WTPs of Basrah city apply conventional water treatment processes which include; pretreatment, chemical coagulation, rapid mixing, flocculation, sedimentation, filtration and disinfection. Thus, these WTPs are not provided with facilities for reducing the TDS of water. To highlight the problem of high TDS water produced by WTPs in Basrah city, the readings of TDS in treated water were analyzed for the number of readings that satisfy the Iraqi standards for drinking water (max. TDS of 1000 mg/l). These readings were monthly taken during the years (2011–2014) by the staff of Central Laboratory of Water Analysis/ Basrah Water Administration. The results of analysis shows that; 735 out of 4477 readings satisfy the Iraqi standards and the max TDS of water supply in Basrah city is 9400 mg/l. These results indicate the urgent need for installing desalination units in WTPs of Basrah city.

Table 2 shows that WTPs No. 17, 18, 19 and 20 (indicated with yellow color in Fig. 1) are receiving water from SWC only. When the available raw water from the SWC is reduced, the water is conveyed to these WTPs as a priority and the other plants use the water of Shatt Al Arab River. Therefore, the water of these treatment plants has low TDS and there is no need for installing RO units in them. Thus, these WTPs shall not be considered in this study, i.e., the RO units are proposed to be installed in WTPs No. 1 through 16.

4. Water desalination using reverse osmosis

RO process is used to produce freshwater by removing dissolved salts from seawater and brackish water, helping to overcome the problem of freshwater shortage. RO plant consists of pre-treatment, high-pressure pump units and membranes, Fig. 2. The membranes are set in series within a pressure vessel. A pretreatment must be provide for feed water in order to remove inorganic solids and suspended solid, and for save the membranes from damage and fouling. The process starts by pumping the feed water (brackish water or seawater) under the forces of a pressure head that exceeds the osmotic pressure of the solution through the pressure vessel. As shown in Fig. 2, the fresh water permeates through the membranes, while, the brine water (high concentrated solution) is left behind [17]. The main design parameters of RO plants are; recovery percent, feed and osmotic pressures.

Table 1
Regulations for selected desalination brine discharges [30].

Region/authority	Salinity limit
US EPA	
Increment ≤ 4 ppt	
Carlsbad, California	
Absolute ≤ 40 ppt	
Huntington Beach, California	
Absolute ≤ 40 ppt	
Western Australia guidelines	Increment < 5%
Oakajee Port, Western Australia	
Increment ≤ 1 ppt	
Sydney, Australia	
Increment ≤ 1 ppt	
Gold Coast, Australia	
Increment ≤ 2 ppt	
Okinawa, Japan	
Increment ≤ 1 ppt	
Abu Dhabi	Increment ≤ 5%