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Soil deterioration as influenced by land disposal of reject brine from Salbukh water desalination plant at Riyadh, Saudi Arabia

H. Al-Faifi [a], A.M. Al-Omran [b,*], M. Nadeem [b], A. El-Eter [b], H.A. Khater [b], S.E. El-Maghraby [b]

[a] Natural Resources and Environment Research Institute, KACST. P.O. Box 6086, Riyadh 11442, Saudi Arabia
[b] Department of Soil Science, Faculty of Food & Agricultural Sciences, King Saud University P.O. Box 2460, Riyadh 11451, Saudi Arabia

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ABSTRACT

Impact of reject brine chemical composition on soils in Riyadh Saudi Arabia, was evaluated. Soil samples at three depths along transect on both sides of the pond were taken, in addition to, water samples from feed, product, reject and pond. Results showed that, the salinity of the brine reached up to, 5500 mg l^{-1}. The concentrations of soluble ions were exceeding the allowable limits in most water samples. The ratio of major ions and concentration factor was higher. The concentrations of heavy metals were in the allowable limits for drinking water standards especially, in the feed, and product waters. Results pertaining soil properties indicated that the soil pH, EC_e values and, the concentrations of soluble ions were higher in soils closed to the pond. Also, the concentrations of heavy metals were negatively correlated with $CaCO_3$ content and soil pH (expect for Pb; Zn; Cd and Cr), while it was highly correlated with clay content of the soil. Generally, higher ESP and EC_e values in the studied soils can lead to lower permeability, poor aeration and consequently soil deterioration.

1. Introduction

The last 20 years have seen rapid growth in the number of desalination plants for producing drinking water in many parts of the world [1]. The Gulf countries, by necessity, have become the world leader in desalination of sea and brackish water, and currently have more than 65% of the world's total capacity [2,3]. The strategy of Saudi Arabia to meet present and future demands for water resources has shifted attention to the role of desalination technology in alleviating water shortages using sea and brackish water as feed. Reject brine, is a byproduct of desalination process. Brine discharged is more concentrated than the brackish water and contains inorganic salts and other chemicals, and other substances [4]. The reject brine from the seawater desalination is generally discharged to sea, while in the inland desalination plants of brackish water are the feed source and reject brine is disposed using evaporation ponds, discharged to the surface, etc. [5]. Consequently this may cause soil and groundwater contaminations with chemical constituents from various sources (i.e. reject brine, pretreatment waste and cleaning waste of desalination plants). Unfortunately, the environmental implications associated with the discharge of concentrate from desalination plants have not received adequate considerations by concerned authorities [1,6–8]. A high salinity of the reject brine can deteriorate the soil structure. This happens when calcium ions are replaced by sodium ions in the exchangeable ion complex. As a consequence, the infiltration rate of water and the soil aeration is reduced. This will only occur in extreme cases of salinity as a result the soils are degraded by the problems of salinity and sodicity [9]. However there is a shortage in the information towards the environmental impacts of the reject brine from desalination on the soil properties under Saudi Arabia conditions. Therefore, the objectives of the present work are: (1) to determine the composition of feed or raw water, product, reject brine, and pond water of Salbukh station for water desalination at Riyadh, Saudi Arabia; (2) to further evaluate possible hazards that might arise from the rejected brine, of such station. As well as (3) the changes in soil chemical and physical properties as affected by land disposal of reject brine from such station will be evaluated.

2. Materials and methods

2.1. In-place soil samples

The soil samples used for this study (90 soil samples e.g. 5 distances × 2 sites × 3 depths × 3 replicates) were collected in 2008 from the surrounding area of Salbukh station for water desalinization at Riyadh, Saudi Arabia (25°03′39.8″ N; 46°27′13.7″ E). Soil samples were taken from both right (45 samples) and left (45 sample) sides of the reject brine pond (Fig. 1) at intervals of 0, 10, 50,100 and 500 m

* Corresponding author.
E-mail addresses: halfaifi@kacst.edu.sa (H. Al-Faifi), rasoul@ksu.edu.sa (A.M. Al-Omran).

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Fig. 1. The brine disposal site at Salbukh.

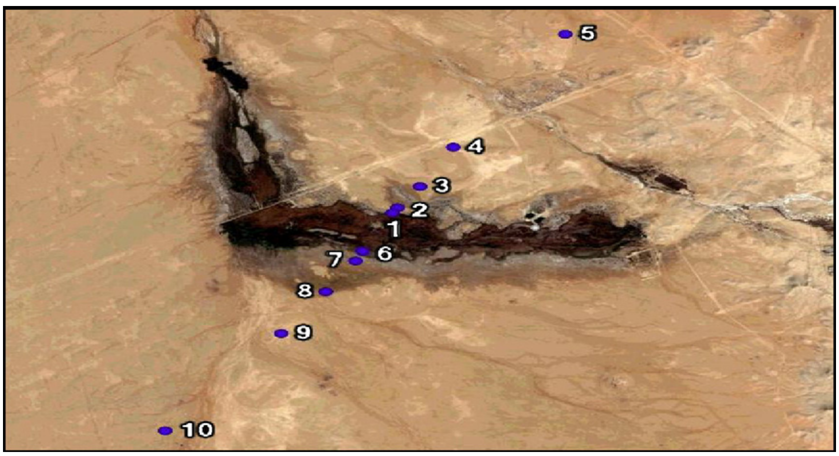

Fig. 2. Soil sampling location in the studying area at Salbukh.

(Fig. 2). Also, three soil depths (0–15, 15–30, and >30 cm.), were sampled at each point to assess the vertical distribution of soil parameters. Soil samples were air dried at room temperature and thoroughly mixed and gently ground to pass through a 2 mm sieve and stored for the physical and chemical analysis.

2.2. Chemical and physical analysis of the soil samples

Soil pH values were measured in soil paste after equilibration for 24 h [10,11]. While the soil EC_e values as well as the concentrations of soluble cations and anions (e.g. Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, CO_3^{2-} Cl^-, and SO_4^{2-}) were determined in soil paste extracts [12,13]. Particle size distribution was determined by the hydrometer method [14]. Content of $CaCO_3$ was determined by calcimeter method [15]. Also, soil samples were digested with HNO_3, $HClO_4$ and HF [16] for the determination of the total concentrations of Al, Ni, Fe, Cu, Mn, Cd, Cr, Pb and Zn using ICP-AES (Perkin Elmer, 4300 DV).

2.3. Collection and analysis of water samples

Representative discharge effluents from the inland desalination plant along with feed, reject brine, product and pond water of Salbukh station for water desalinization plant were collected and analyzed. The pH, EC_w, TDS, soluble cations (Ca^{2+}, Mg^{2+},Na^+, and K^+), soluble anions (CO_3^{2-}, HCO_3^-, CL^-, SO_4^{2-} and NO_3^-) and B were determined according to standard methods [17]. Also, concentrations of Al, Ni, Fe, Cu, Mn, Cd, Cr, Pb and Zn in the collected water samples were measured by ICP-AES (Perkin Elmer, 4300 DV).

Table 1
Mean values for the chemical composition of the feed, product, reject and pond water samples.

Sampling source	pH	EC_w (dS m^{-1})	TDS (mg l^{-1})	Soluble cations (meq l^{-1})				Soluble anions (meq l^{-1})					B mg l^{-1}	SAR
				Ca^{++}	Mg^{++}	K^+	Na^+	CO_3^-	HCO_3^-	Cl^-	SO_4^{--}	NO_3^-		
Feed	7.9	2.1	1357.2	8.5	6.6	0.9	7.5	0.0	3.1	9.8	6.8.0	0.00	0.2	2.8
Product	6.9	0.6	407.2	2.0	2.0	0.2	1.9	0.0	1.1	2.8	4.3.0	0.00	0.1	1.4
Reject	7.2	7.9	5030.4	19.1	14.4	1.7	17.0	0.0	4.0	20.4	18.9	0.00	0.3	4.2
Pond	8.3	12.5	8009.2	52.0	48.1	5.8	57.4	2.3	7.45	73.2	63.9	0.85	0.85	8.3
Ratio[a]	0.9	3.8	3.7	2.25	2.2	1. 9	2.3	0.0	1.3	2.1	2.8	0.00	1.5	1.5
C.F[b]	1.15	1.58	1.59	2.7	3.3	3.4	3.4	0.0	1.86	3.6	3.4	0.00	2.8	1.96

[a] Ratio of major ions of feed and reject brine.
[b] Concentration factor (C.F.) = Pond water/Reject water.