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Artificial neural network approach for predicting reverse osmosis desalination plants performance in the Gaza Strip

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HIGHLIGHTS

- Small and large scale desalination plants' performance evaluation
- Prediction of desalination plants' performance using artificial neural network technology.
- Recommending possible enhancements for desalination plants' performance.

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ABSTRACT

A rapidly growing technique for producing new water is desalination of seawater and brackish water. In the Gaza Strip the maximum amount of the drinking water is produced through small private desalination facilities. The present paper is concerned with using artificial neural network (ANN) technique to forecast reverse osmosis desalination plant's performance in the Gaza Strip through predicting the next week values of total dissolved solids (TDS) and permeate flowrate of the product water. Multilayer perceptron (MLP) and radial basis function (RBF) neural networks were trained and developed with reference to feed water parameters including: pressure, pH and conductivity to predict permeate flowrate next week values. MLP and RBF neural networks were used for predicting the next week TDS concentrations. Both networks are trained and developed with reference to product water quality variables including: water temperature, pH, conductivity and pressure. The prediction results showed that both types of neural networks are highly satisfactory for predicting TDS level in the product water quality and satisfactory for predicting permeate flowrate. Results of both developed networks were compared with the statistical model and found that ANN predictions are better than the conventional methods.
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1. Introduction

Gaza Strip suffering from depletion of accessible fresh water because of the groundwater over pumping which it is the only resource being used for domestic purposes. The problem came to be more serious with time as a result of seawater intrusion into the coastal aquifer, in addition to the infiltration of somewhat treated wastewater to the aquifer [1,2]. Water is essential for socioeconomic growth and environmental sustainability. The Gaza Strip is mostly in a catastrophic situation that needs urgent and serious actions to improve the water status on conditions of both quality and quantity. The desalination of brackish and seawater is at present a global motivation that has concerned overall governmental and public awareness not only in arid areas but also in other regions in the world. Desalination provides a mean of upgrading brackish water or seawater to produce potable water by the removal of salts and biological materials from seawater or brackish water. There are a number of desalination techniques that are commercially used such as vapor compression distillation, electro-dialysis, multi-stage flash distillation; and reverse osmosis [3].

The groundwater in the Gaza coastal aquifer is approximately brackish excluding some fresh water in the appearance of shallow lenses. Thus, the quantity of fresh groundwater is almost negligible and exists only in some areas in the Gaza Strip for example Beit Lahia. Desalination of brackish and seawater in the Gaza Strip appears to be promising, mainly in the absence of any other options. Though, utilizing desalination method as an alternative water supply denotes many challenges such as energy cost and environmental characteristics [4]. On one hand, depending on desalination as a source of water supply can solve the increasing issue of water shortage in the vicinity and overcome the worsening problem of water quality. However, the securing of potable water for drinking purpose to the community in the Gaza Strip is becoming an important goal to be implemented by the Palestinian Water Authority (PWA) [5]. The Palestinian Water Authority identifies water

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desalination as the standard approach to solve the water shortage problem and provide people in the Gaza Strip with acceptable water quality for drinking and other purposes [6]. The only technology applied in Gaza for brackish water desalination purpose is Reverse Osmosis (RO). The first RO plant in the Gaza Strip was built in 1991 with a capacity of 45 m^3/h and recovery of 75% in Deir Al Balah town of the Middle area governorate by EMS a subsidiary of Mekorot company. In the last two decades seven RO desalination plants were built including: six brackish water desalination plants and one seawater desalination plant [7]. Today, there are about 118 small private RO desalination units established and operated all over the Gaza Strip, and almost 30 units are licensed by PWA.

Artificial neural networks (ANNs) are flexible tools which are being used progressively to predict and forecast water resources variables. The neural network models must be developed according to the existing data and information about water quality parameters for several years of a particular area [8]. It is assumed that nonlinear approaches such as ANNs are adequate for predicting water quality parameters in the underground and fresh water bodies. Earlier studies showed that ANNs were successfully used to predict water quality parameters such as TDS, conductivity and flowrate in underground water, rivers and desalination plants. The ANNs were able to capture nonlinear relationships among input and output variables for modeling the performance of desalination plants [9–13].

Cordoba [14], developed ANN models to evaluate and predict some of drinking water quality parameters within a water distribution system. [15] have successfully developed an artificial neural network model for predicting the two important parameters of RO desalination plants including: salt rejection and permeate flowrate (flux). [16] used ANN technology to develop a model for predicting the performance of a reverse osmosis plant. The artificial neural network was fed with three inputs including: feed pressure, temperature and salt concentration to predict the water permeate flowrate. The developed network learned the input–output data mapping with accuracy. [17] applied artificial neural network method for the prediction of RO desalination plants' performance. The permeate flowrate and salt rejection at different conditions of the process were predicted using ANN based on the experimental water quality data. The model results were tested and compared with the observed data and then error percentage was calculated.

The main objective of this study is to predict the performance of RO desalination plants in the Gaza Strip using ANN technology. For this purpose the next one week total dissolved solids (TDS) content and the permeate flowrate are predicted using multilayer perceptron (MLP) and radial basis function (RBF) neural networks. The conventional method is used to compare the predicted results obtained from both developed neural networks. Due to the tough and crucial circumstances in the Gaza Strip, it was extremely challenging to generate and collect more experimental data. However, this study used limited data sets for the development of ANN models for predicting RO desalination plants' performance. As a first case study for predicting the performance of desalination plants in the Gaza Strip, it is expected that the developed approach may prove helpful in improving plants' performance and potentially increase their water production. In addition it may be used as a new tool to improve current drinking water quality management practices in Gaza.

2. Materials and methods

2.1. Study area

The Gaza Strip is a narrow strip of land on the eastern coast of the Mediterranean sea, situated in the middle east at latitudes [31°16″ and 31°45″N] and longitudes [34°20″ and 34°25″E] bordered by the Mediterranean sea in the west and the Negev desert and Egyptian Sinai headland in the south with a total area of 365 km^2 [18]. Most of the Gaza Strip topographical area is described as flat area gradually sloping with a range from 0 to 5%, westward toward the sea allowing for surface runoff. The landscape is essentially a foreshore plain. A sandy beach stretches along the coast, bound in the east by a bridge of sand dunes up to 40 m high. Land surface elevations range from mean sea level (MSL) to about 110 MSL in the eastern parts. Gaza's water resources are essentially limited to that part of the coastal aquifer that underlies its area [19].

Five large and small scale brackish water desalination plants in the Gaza Strip were selected for this study. These plants were selected to develop ANN models for predicting the performance of RO desalination plants in the Gaza Strip. The water quality data were generated from the selected five plants from southern, middle area, Gaza city and northern area. They are named Al-Salam plant (Rafah), Al-Sharqia plant (Khanyounis), Al-Balad plant (Dier Al Balah), Hanneaf plant (Gaza) and Al-Radwan plant (Beit-Lahia). The selected desalination plants are shown in Fig. 1.

2.2. Collection, processing and analysis of water samples

A 500-ml and one liter polyethylene bottles were used for collecting water samples. The water samples were collected once every week for a period of six months from March to September 2013. The selected parameters for this study include: temperature, pressure, flowrate, TDS, pH and electrical conductivity (EC). The samples were collected from the feeding wells and desalination plants' product water. Samples were analyzed in laboratories of Palestinian Ministry of National Economy and Water and Environment institute at Al-Azhar University-Gaza, Palestine. Electrical conductivity and pH were measured directly in the field using a portable instrument called Electrochemistry made by CIBA-CORNING. The pressure was measured in (bars) with high precision and accurate pressure gages, while temperature was measured in degrees Celsius (°C) using a digital thermometer. The total dissolved solids were measured by using the Oven method. The permeate rotameter was used to measure the flowrate of permeate water (m^3/h).

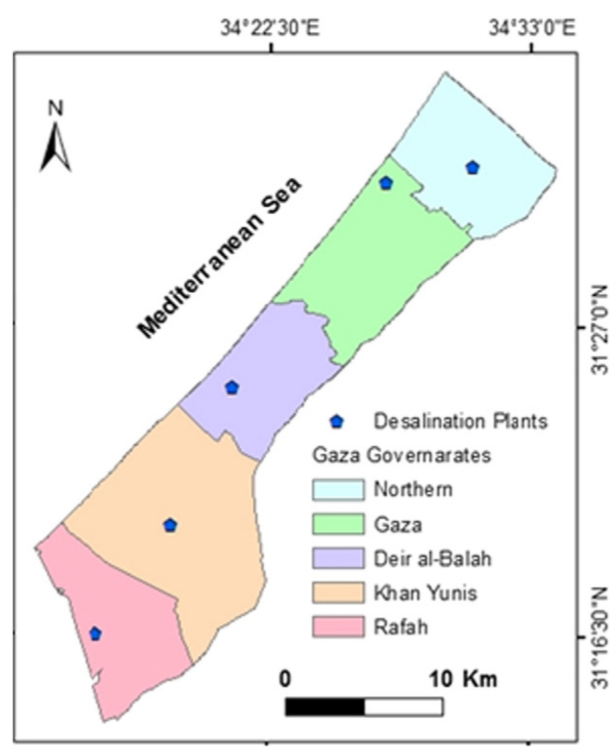

Fig. 1. Map shows the selected desalination plants.

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