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OPTIMIZING OF A BEACH WELL DESIGN FOR REVERSE OSMOSIS WATER HARVESTING

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ABSTRACT

The main objective of this paper is to design, construct and assess the quality and the quantity of beach groundwater well to feed the reverse osmosis (RO) units that is producing Kadhmah bottled water in Doha area of Kuwait. This well will be used as a backup for the existing single well in case of maintenance or stoppage.
A permanent production well was designed and constructed 35 meter apart from an existing production well. It was used to collect representative soil and groundwater samples, and to conduct pumping test. Water samples collected from the drilled well were analyzed in the appropriate laboratories for physical, chemical, biological and isotopic analyses.
It was found that the quality of the pumped groundwater is similar to sea water, having about 42000 mg/l of total dissolved solids (TDS) and is free of hydrogen sulfide. The chemical and biological analyses supported by the enriched values of the stable isotopes oxygen-18 and the deuterium confirmed the similarity of the pumped groundwater and the sea water. The pumped water is of a very good quality for the production of clean sea water to feed Kadhmah production reverse osmosis units in Doha area.
It was recommended to use the existing and the new well alternatively on weekly basis to produce 50 m^3/h to avoid the interaction of the drawdown in the wells.
If future plans required more quantities of similar quality of groundwater, it is recommended to locate new wells at least 500 m apart from each other and to follow the same design used in this study to assure the isolation of the upper 20 m of ferric layers that may clogs the RO membranes.

INTRODUCTION

Since the late 1980s of the past century and through today, bottled water is becoming a more mainstream activity. Today, millions of people rely upon bottled water as an alternative or substitute for tap water. In Kuwait, Kadhmah Bottled Water is the clear choice for healthy, very high quality and light with well balance mineral blend. It comes from deep, clean and naturally filtered beach well water. Kadhmah Bottled Water is the product of multi-discipline scientists of the Kuwait Institute for Scientific Research KISR to bring about remarkable purity and freshness of water utilizing advanced technologies. This quality is tested regularly to verify that it is extremely

pure. The ultimate target of this study is to construct a new production beach well that will be used to feed the reverse osmosis units that is producing Kadhmah bottled water. This well will be used as a backup for the existing single well in case of maintenance or any other stop or shortage reasons. This well is essential to keep the Kadhmah water production continuous. Based on the available hydrological and geological data and the existing well's (DO-01) specifications, the design of and location for the new well (DO-02) were identified, taking into consideration the total depth to be investigated and the groundwater screening depths intervals.

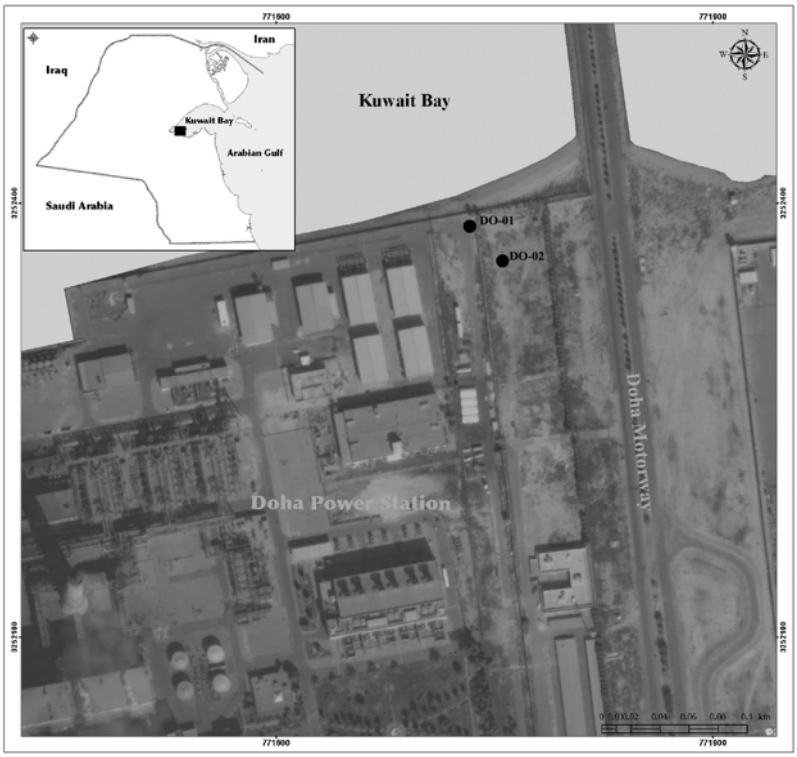

Figure 1. Well location in Doha area.

METHODOLOGY

Groundwater Sampling and In-Situ Analysis

Following the completion of the well development and measurement, and recording of the water level, an electric submersible pump was used to purge the well to enable the collection of representative groundwater samples, in accordance with the United States Environmental Protection Agency (USEPA) sampling guidelines (USEPA, 1996).

A number of portable instruments were used for the sampling. PH, temperature, electrical conductivity (EC), and dissolved oxygen (DO) of the collected samples were measured on site. These measurements were taken to ensure that purging would remove a sufficient quantity of water; to provide valid on-site measurements of

unstable parameters, such as temperature; and for comparison with laboratory measurements in order to check for changes due to holding time and transport. When field measurements indicated that physical parameters had stabilized, collection of groundwater samples commenced. The collected samples were chilled with ice bricks in an icebox before they were transported to the laboratory to keep the temperature of the samples at 4°C (APHA, 1998).

Soil Sampling

A total of 55 drill cutting samples, 500 g each, were collected at 1-m intervals while drilling at the well. The samples were dried, labeled, packed in plastic bags and were transported to the laboratory for further analysis. The samples were megascopically tested on site for the design of the well and further studied in the laboratory to construct a conceptual lithological model of the study area. Grain size analyses of selected drill cutting samples were carried out to help in their textural classification.

Well Testing

A 24-h pumping test was performed. Necessary equipment with a throttling device, variable speed and continuous power source to discharge a variable rate of about 50 m^3/h of water from a maximum depth of 48 m below the ground as installed. The test was conducted in the newly drilled well (DO-02) while the existing well (DO-01) was not in operation. The test lasted for 24 h with a discharge rate of 50 m^3/h and a semi-steady state was obtained after 6 h.

A 25- mm PVC pipe was installed inside the pumping well permanently to measure water level to a depth of 2 m above the pump intake. Groundwater samples were collected and the pumping rate was measured regularly during the test regularly

Analysis of Soil and Water Samples

The groundwater samples collected from the drilled well were analyzed for a total of 27 physical, chemical and biological parameters including pH, EC, DO, sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), total hardness (TH), chloride (Cl), sulphate (SO_4), bicarbonate (HCO_3), carbonate (CO_3), phosphate (PO_4), ammonia (NH_3), nitrate (NO_3), iron (Fe), boron (B) dissolved sulphide (S^{-2}), hydrogen sulphide (H_2S), total dissolved solids (TDS), total organic carbon (TOC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total petroleum hydrocarbon (TPH). Total coliform, fecal coliform, *Escherichia* coli, Fecal Streptococci, salmonella and isotopic components. Table 4 presents the measured parameters, instruments and methods used for the analysis. Stable isotopes (oxygen-18 and deuterium) were measured using off-axis integrated cavity output spectroscopy by means of a water isotope analyzer (Los Gatos model 908-0008).

Grain size analyses of selected drill cutting samples were carried out to help in their textural classification and for use in the interpretation of the lithological sequencing.

RESULTS AND DISCUSSIONS

Lithostratigraphy

The penetrated sequence is composed of an undifferentiated fluviatile and beach clastic sequence of The Kuwait Group aquifer. Lithological zonation of the sediment sequence in the study area was carried out on the basis of megascopic descriptions of the drill cuttings, supported by grain size analyses. The investigations indicated the occurrence of thick topsoil, shelly beach sand, reddish ferric silty and gravelly sand, gravelly sand, slightly calcretized gravelly sand and a one-meter mud layer. These lithological types were identified on the basis of the relative abundance of gravel, sand and mud following Folk's classification (Folk, 1974). No thick mud layers or hard calcretized layers were identified within the penetrated sequence; however, the precipitation of the authigenic calcite within the pore spaces (Al-Senafy and Al-Fahad, 2000) was responsible for the slight consolidation of the originally friable gravelly sand at depths between 23 and 29 m.

Gravelly sand is the most common lithological type within the studied sequence. The lower part of these sediments is the main water-bearing zone within the Kuwait Group aquifer in the study area. It is poorly sorted, and composed of pebbles and sand. The sediments at depths of 5 to 20 m are rich in ferric materials.

Groundwater Table

The penetrated aquifer is an unconfined aquifer. The static measured water table was between 2.5 and 3.0 m below the ground's surface depending on the seawater level.

Groundwater Quality

The statistics for of the collected groundwater samples are presented in Table 1. The main characteristic of the groundwater of the study area is that it is of the NaCl type with high contents of the major cations and anions, and as a result, it has a high TDS content. The TDS value, which is considered as a collective indicator of the aforementioned parameters is about 42000 mg/l indicating the similarity of the quality of produced groundwater and the beach water. Moreover, the concentration of magnesium is higher than that of calcium, indicating a characteristic of seawater. No traces of hydrogen sulphide, ammonia, or phosphate were detected in the pumped groundwater.

The presence of the total coliform bacteria and the fecal coliform bacteria is attributed to contaminated seawater, whereas other bacteriological parameters like E. coli, fecal streptococci, and salmonella were not detected.

The enriched values of oxygen-18 and deuterium, i.e., 0.72 and 0.31% respectively, indicated the similarity of the pumped water and the seawater.

Table 1. Results of the Analysis of Groundwater from the Newly Drilled Well

Parameters	Well DO-02
pH	7.27
EC (µs/cm)	55500
TDS (mg/l)	42029
Alkalinity (mg/l)	135
Bicarbonate (mg/l)	135
Carbonate (mg/l)	<0.1
Hardness (mg/l)	8000
Calcium (mg/l)	1080
Magnesium (mg/l)	1294.2
Sodium (mg/l)	11650
Potassium (mg/l)	480
Chloride (mg/l)	21000
Nitrate (mg/l)	10.12
Ammonia (mg/l)	<0.1
Boron (mg/l)	6.8
Iron (mg/l)	0.002
Phosphate (mg/l)	<0.1
Sulfide (mg/l)	<0.1
Sulphate (mg/l)	3700
TOC (mg/l)	0.598
TPH (mg/l)	0.185
BOD (mg/l)	<1.0
Total Coliform MPN/100)	1660
Fecal Coliform (MPN/100)	22
E. coli (MPN/100)	0
Fecal streptococci (cfu/100 ml)	0
Salmonella (cfu/100 ml)	0

CONCLUSIONS AND RECOMMENDATIONS

The newly designed and drilled backup groundwater production well has a depth of 50 m. It is a production beach well screened in the Kuwait Group aquifer. It can be used as a production well to produce 50 m^3/h from a depth of about 50 m with a reasonable drawdown. This well can be used as a backup for the existing well in case of maintenance for or other stoppages or shortages with the existing well. This well is essential to keep the Kadhmah water production unit running continuously.

The quality of the pumped groundwater is similar to that of seawater, having about 42000 mg/l of TDS and is free of hydrogen sulphide. The enriched values of the

oxygen-18 and deuterium confirmed the similarity of the pumped water and seawater, indicating the existence of sea water intrusion in the study area.
The chemical and biological characteristics make this groundwater unsuitable for human consumption unless treated. However, the pumped water is of a very good quality for the production of clean seawater to feed the Kadhmah production RO units in the Doha area for fresh water harvesting.
Given the quality of and the absence of H_2S in the pumped groundwater, the distance between the existing and the new production wells, and the characteristics of the Kuwait Group aquifer in the vicinity of the study area, each of the two production groundwater wells can produce 50 m^3/h provided that only one of the two is in operation at a given time to avoid the interaction of the drawdown in the wells. It is recommended that the two wells be operated alternatively on a weekly basis.
In case future plans require greater quantities of a similar quality of groundwater, it is recommended that new wells be located at least 500 m apart from each other in order to avoid interference between them. These wells should follow the same technical specifications and design used to construct the new well in order to ensure the isolation of the upper 20 m, which has a ferric composition, which was encountered in old wells causing the interlocking of the membrane pores.

REFERENCES

1.Al-Senafy, M., and K. Al-Fahad. 2000. Petrography of calcretes and their effects on the hydrology of Kuwait Group aquifer. Proceedings, First International Conference on Geotechnical, Geo Environmental Engineering and Management in Arid Lands, Al-Ain, UAE, pp. 481-484.

2.APHA. 1998. Standard Method for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C., USA.
Folk, R. 1974. Petrology of Sedimentary Rocks. Austin: Hemphill.

3.USEPA. 1996. Field Methods Compendium (FRC), draft. United States Environmental Protection Agency. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Analytical Operation Branch, Washington DC, USA.