EVALUATION OF GROUNDWATER QUALITY IN THE EASTERN DISTRICT OF ABU DHABI EMIRATE, UAE

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ABSTRACT

In this paper, chemical data (major ions) have been used to improve the understanding of the ground water salinity, and in particular, to evaluate the ground water quality in the shallow unconfined alluvial aquifer beneath the city of Al Ain (northeastern part of Abu Dhabi Emirate). Ground water samples were collected for chemical data from 28 wells in 2012. The chemical monitoring revealed high spatial variability in chemical parameters as influenced by climate, matrix aquifer changes in geological formations, water table depth, and the under Jabal Hafit limestone aquifer. Results show that changes in ground water chemistry in the aquifer is mainly controlled by evaporation, silicate mineral dissolution, evaporite dissolution, cation exchange, and mixing by upward leakage from Jabal Hafit limestone aquifer. The concentration increases were accounted for primarily by dissolved sodium, chloride, and sulphate. The high total dissolved solids (TDS) of shallow ground water beneath the city of Al Ain (up to 5640 mg/L) is mainly controlled by evaporation. In general, the ground water quality was good. Many of the chemical constituents analysed in each sample are within the primary drinking water standards. Ground water south of the study area (northern edge of Jabal Hafit) shows a poorer quality than the northeast and the east areas (near Oman Mountains).

Keywords: Groundwater quality, Arid region, UAE.

1. Introduction

Abu Dhabi Emirate is one of the seven Emirates which comprise the United Arab Emirates (UAE) and occupies an area of 67,340 km² or about 80% of the total area of the UAE. The Emirate has an arid climate with less than 100 mm/yr average rainfall, a very high evaporation rate (2-3m/yr), and no reliable surface water resources. Groundwater is the only conventional source of water in the Emirate of Abu Dhabi. Its share to the total fresh water supply in the Emirate is about 80%. Other unconventional sources of fresh water in the Emirate are desalination plants (17%) and wastewater reuse (3%). The current share of groundwater is estimated based on the estimated water demand in the Emirate and available production of the desalination plants. The sustainable yield of a groundwater aquifer, however, depends mainly on how fast this aquifer is replenished. Yet, the continuously increasing demand puts more pressure on this already scarce source and threatens its quality. In order to attain security in the vital groundwater source, it is essential to accurately evaluate the quality of the groundwater in the Emirate.

The most important problems faced by water resources in the United Arab Emirates are the depletion of aquifers in several areas, such as at Al Ain and Al Dhaib; saline water intrusion, and water quality degradation, such as that associated with the oil industry and agricultural activities (Rizk and Alsharhan, 2003). Many studies have been already done on the groundwater quality in parts of the Abu Dhabi Emirate. Groundwater is mostly brackish and nonrenewable (Al Katheeri, 2008). Previous studies have been based on chemical and isotopic tools to provide a general of geological, hydrogeological, and water quality characterization of the aquifer. These studies have focused on the Jabal Hafit Limestones aquifer (Murad *et al*., 2012) where groundwater exhibit specific chemical composition with high SO42-, and other elements concentrations (Cl-, Na+, Ca2+, Mg2+) which could reflect the influence of carbonates and evaporite sediments, and the Al Jaww plain (Ahmad, 2010). Howari (2004) studied the impact of urbanization on soil in the vicinity of Al Ain landfill through sixty four surface soil samples by analyzing heavy metals (cadmium, chromium, copper, nickel, lead and zinc). Results show that soils are contaminated by copper due to urbanization.

Hydrochemistry Assessment has been used to evaluate the groundwater quality in the shallow unconfined alluvial aquifer beneath the city of Al Ain (north-eastern part of Abu Dhabi Emirate).The aims of this work are (1) to understand the groundwater chemistry of the unconfined alluvial aquifer and (2) to evaluate the groundwater quality. The methodology exposed in this article is useful for differentiating between processes affecting groundwater. This is of high importance in aquifer conservation because conservation efforts are mainly addressed to the processes.

2. Study area

Al Ain basin is surrounded by three main geomorphological provinces: (a) Al Jaww plain and the Omani Mountains to the east, (b) the hilly area where bedrocks crop out to the south-east, and (c) the dune covered scarps to the north and south (El-Ghawaby and El-Sayed, 1997). The study area (Al Ain depression) is bounded by relatively high relief aeolian dune-covered landforms to the north and south, Al Jaww plain to the east, Jabal Hafit to the south, and Oman Mountains to the east. The topographic surface contour map of Al Ain area depicts a generally low relief surface containing a westerly directed trough axis (El-Ghawaby and El-Sayed, 1997). The geological formations are described according to El-Ghawaby and El Sayed, (1997). The Quaternary-Holocene deposits in Al Ain area consist of near-surface and surficial sediments of alluvial, aeolian and local sabkha origin. Sabkha deposits are well described by Wood *et al*. (2005) and Wood and Sanford (2007). The Quaternary–Holocene alluvial deposits overlie the Tertiary section in Al-Ain depression itself. These alluvial deposits range, size-wise, from cobbles, boulders and pebbles at the eastern part, where valleys debouch from Al Jaww plain, to pebbles and coarse sand where the main valleys become masked by the sand dunes to the west of Al-Ain town. The grain size distribution of gravel sediments shows a wide spectrum from pebbles to cobbles. The cementation of these gravels is mainly by calcium carbonate, calcium magnesium carbonate or gypsum. The bulk of the alluvium has been deposited after transport within the wadi network draining westward and northward from the ophiolitic and carbonate source rocks of the Oman Mountains and Jabal Hafit, respectively. The Jabal Hafit rocks are well bedded massive limestone which have been locally dolomitized (Zaineldeen, 2011). The Al-Ain depression is mostly composed of alluvial gravel deposits indicating old courses of buried paleo channels in other places than the presently active valleys. The Quaternary–Holocene deposits vary greatly in thickness due to the influence of subsurface faults and tilting undulations. The Quaternary–Holocene alluvium has been detected in the inter-dune trough zone for a thickness of 10 to 30 m, but is missing or is very thin in dune ridges (El-Ghawaby and El-Sayed, 1997).

On the hydrogeological hand, the main aquifers in the United Arab Emirates include the limestone aquifers in the north and east, fractured ophiolite rocks in the east, gravel aquifers flanking the eastern mountain ranges on the east and west and sand dune aquifers in the south and west (Rizk and Alsharhan, 2003). Two important limestone aquifers exist in the United Arab Emirates; the northern limestone aquifer (or Wadi Al Bih Aquifer) in Ras Al Khaimah area and Jabal Hafit limestone aquifer, south of Al Ain city (Rizk and Alsharhan, 2003). In this paper, only the Jabal Hafit limestone aquifer will be described. Jabal Hafit is composed of a 1500 m thick sequence of interbedded limestone and marl with gypsum and dolomite, and evaporite formations of Lower

Eocene to Miocene age. Limestone of the middle Eocene Dammam Formation constitutes an aquifer in the Jabal Hafit area. The aquifer is characterized by extensive dolomitisation and is affected by numerous faults and fractures. The aquifer formation has a secondary porosity. In the northern end of Jabal Hafit, groundwater is of thermal brackish. Because of its high salinity, the groundwater from Jabal Hafit aquifer is not suitable for human consumption. The temperature and conductivity logs indicate the possibility of a confined-flow carbonate system. High temperatures (between 36.5 and 51.4°C) occur in this aquifer at the depths range between 93 and 102 m (Khalifa, 1997). Groundwater is slightly alkaline, sodium chloride rich, and has a total dissolved solids (TDS) content between 3900 and 6900 mg/L (Khalifa, 1997). Results of chemical analyses indicated two geochemically different water types. The first type is relatively low in temperature and TDS, and the second type is relatively high in temperature and TDS. In both types, sodium is the dominant cation and chloride is the dominant anion. The environmental isotopes (18O, 2H, and 3H) in Jabal Hafit thermal water indicate that recent recharge occurs at high elevation (Khalifa, 1997). The largest reserve of fresh groundwater in the United Arab Emirates occurs in the alluvial deposits of the piedmont plains bounding the eastern mountains from the east and west. Two aquifers can be distinguished. These are the eastern gravel aquifer and the western gravel aquifer. Al Ain is located on the western gravel aquifer. Earlier studies show that the surficial aquifer near Al Ain is one of the main sources of fresh groundwater of Abu Dabi Emirate, but this aquifer may have limited natural recharge and can be affected by excessive groundwater pumping (Hydroconsult 1978). The eastern gravel aquifer is composed of a series of alluvial formations between promontories of rock spurs extending into the Gulf of Oman. The aquifer contains fresh groundwater that drains from the wadi towards the sea. The low chloride concentrations suggest younger water.

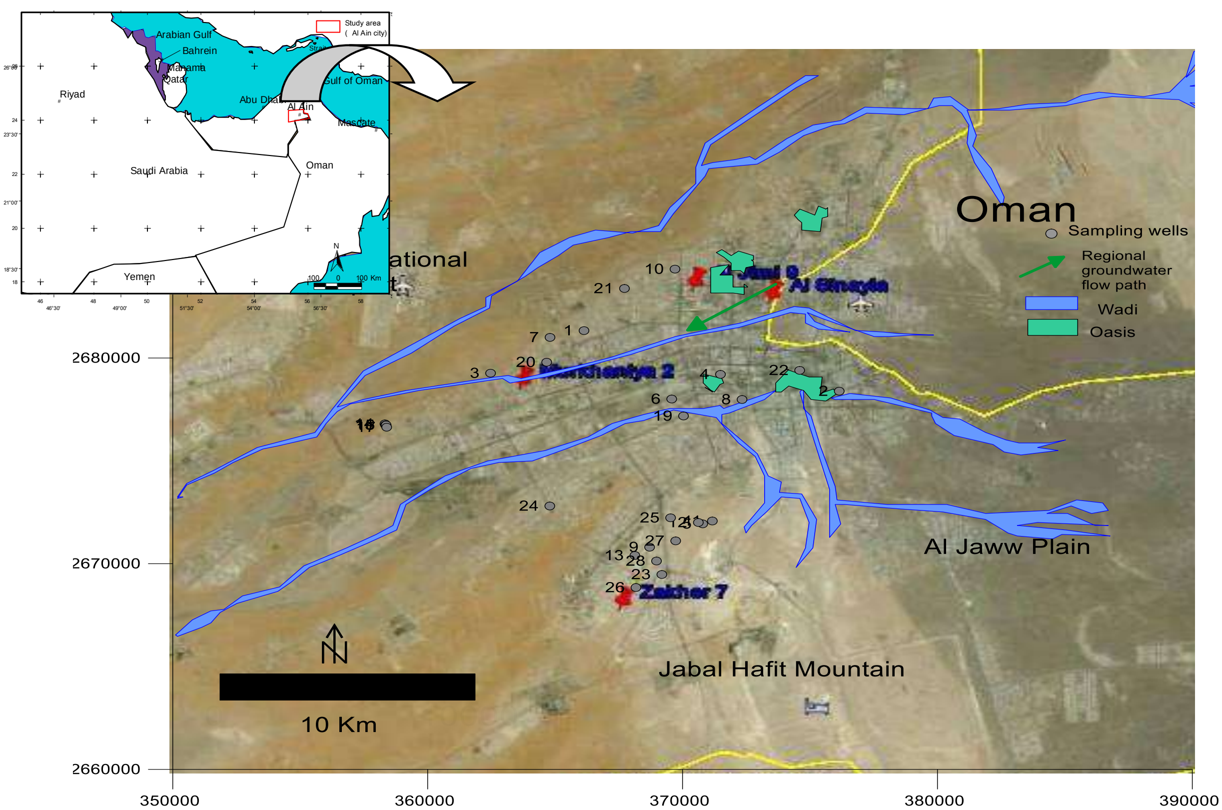

Figure 1: The study area with groundwater sample locations.

3. Sampling and analysis

Understanding the groundwater chemistry is based on sampling and analysis of water from twenty eight wells localized in the shallow unconfined aquifer. The locations of the sampled wells are shown in Fig. 1. The analytical work of this study was performed at the United Arab Emirates University in Al Ain. The pH was measured in the laboratory with a pH meter Orion 420. The electrical conductivity (EC) was measured with a conductivity meter Orion 150 in the laboratory. Cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) analyses were performed using a flam photometer 416. Samples were analyzed with ICS-200 Dionex ion chromatography and spectrophotometer Cary 50 UV visible Varian for anions (Cl^-, NO_3^-, F^-). The measurement of bicarbonate was done by titration at the laboratory. Charge balance errors for the groundwater range from -9% to 6% (standard deviation = 3). Only three samples have errors more than ±5%.

4. Results and discussions

The groundwater samples are characterized by major ions patterns $Na^+ >> Ca^{2+} > Mg^{2+} > K^+$ for cations and $Cl^- > SO_4^{2-} >> HCO_3^-$ for anions. Major dissolved ion contents are plotted on a Piper diagram (Fig. 2) showing that the chemical composition of the groundwater is predominantly Na-Cl-SO_4 type (82% of the samples). Two other hydrochemical facies appeared in the Piper plot: Ca-Mg–Cl-SO_4 type (14% of the samples), and Mg-Cl type (only one sample). The trilinear diagram of cations shows that in 82% of the samples Na^{2+} is the dominant cation and Cl^- is the dominant anion in 93% of the samples. Ca^{2+}, Mg^{2+} and HCO_3^- are never predominant. Only one sample shows Mg^{2+} as a dominant cation (well number 21 at Eidan Al Ridda, Al Towwaya). SO_4^{2-} is predominant in only 4 samples. In approximatly 93% of the samples, (Na^++K^+) represented 41 (well number 8, Al Dafeinah-Asharej) to 88% (well number 14, Al Ghadeer-Al Bateen) of the sum of cations, and Cl^- represented 44 (well number 28, Al Grayyeh-Zakhir) to 74% (well number 8x, Al Dafeinah-Asharej) of the sum of anions. The chemical facies Na-Cl reflect a low flow in the aquifer. This allow the predominance of Na (ion exchange processes) against Ca. The high concentrations of chloride in all samples can be linked to evaporation (arid zone) in the shallow aquifer (depths of water table range from 3 m to 15.25 m).

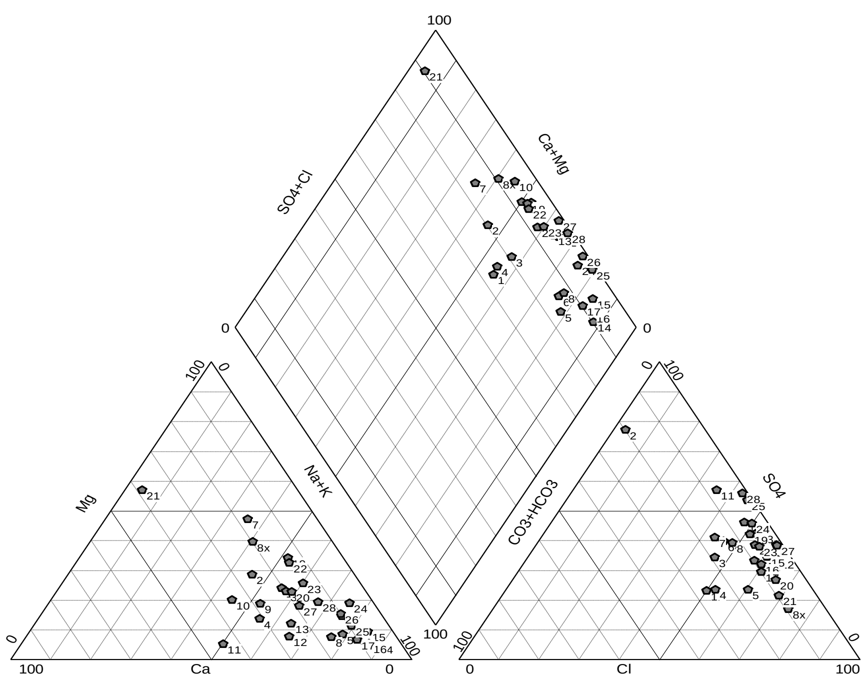

Figure 2: Piper diagram of the groundwater samples collected from the study area.

5. Summary and conclusions

A hydrochemical study was conducted on the shallow unconfined alluvial aquifer of the city of Al Ain (northeastern of Abu Dhabi Emirate). Groundwater is generally, with some variations, Na-Cl-SO4 type. Major solutes in groundwater appear to be derived primarily from silicate weathering and evaporite dissolution. In addition, cation exchange has provided some of the solutes in the groundwater. Evaporation-driven salinization of shallow groundwater in arid zone results in relatively high groundwater salinity values. Major ion concentrations exhibited increases in depth and space because of evaporation process, water-rock interactions (e.g. mineral dissolution, ion exchange reactions), leaching of ions by upward and downward leakage from respectively, Jabal Hafit limestone aquifer and sabka deposits, and leaching of ions from potential pollutant sources.

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