Chemie der Erde 74 (2014) 735–747

Contents lists available at ScienceDirect

Chemie der Erde

journal homepage: www.elsevier.de/chemer

Natural salinity sources in the groundwaters of Jordan—Importance of sustainable aquifer management

Elias Salameh*, Marwan Alraggad, Arwa Tarawneh

University of Jordan, Faculty of Science, Amman 11942, Jordan

ARTICLE INFO

Article history:
Received 27 January 2014
Accepted 14 April 2014
Editorial handling - P. Möller

Keywords:
Deep aquifers
Exploitation
Saltwater mobilization
Salinization of aquifers

ABSTRACT

In recent years, voices in Jordan became lauder to exploit the fresh to brackish deep groundwater overlain by fresh groundwater bodies. In this article the implications of such a policy on the existing fresh water bodies are worked out through studying the sources of salinity in the different aquifer systems and the potentials of salinity mobilization by artificial changes in the hydrodynamic regimes. It is concluded that extracting the groundwater of deep aquifers overlain by fresh water bodies, whether the deep groundwater is fresh to brackish, brackish or salty, is equivalent to extracting groundwater from the overlying fresh groundwater bodies because of the hydraulic connections of the deep and the shallow aquifers' groundwaters. The consequences are even more complicated and severe because exploiting the deep groundwater containing brackish or salty water will lead to refilling by fresh groundwater leaking from the overlying aquifers. The leaking water becomes salinized as soon as it enters the pore spaces of the emptied deep aquifer matrix and by mixing with the deep aquifer brackish or saline groundwater. Therefore, the move to exploit the deep groundwater is misleading and damaging the aquifers and is unjust to future generation's rights in the natural wealth of Jordan or any other country with similar aquifers' set-up. In addition, desalination produces brines with high salinity which cannot easily be discharged in the highlands of Jordan (with only very limited access to the open sea) because they will on the long term percolate down into fresh water aquifers.

1. Introduction

Jordan relies to about 70% of its water supply on groundwater extractions of which around 40–50% come from non-renewable groundwater. During the last 3 decades overexploitation of the groundwater resource in defined areas has mobilized saline groundwater by which the salinity of some fresh groundwater bodies increased and other were damaged (Salameh, 2008, 2011). The groundwater in the different parts of the country is found in a variety of aquifers, overlying each other and separated from each other by aquicludes but none-the-less these different aquifers are hydraulically interconnected. Therefore, extracting water from the deep aquifers overlain by shallower ones is practically quasi an extraction from the shallower aquifers because the water in the shallow aquifer due to its hydraulic interconnection with the lower aquifer will increasingly leak downwards into the lower aquifer via joints, faults, fractures and other weakness zone within the aquicludes separating both aquifers. In general, the deep aquifers contain brackish to saline water and the shallower ones freshwater; therefore, extracting the brackish or saline water from deep aquifers will result in the salinization of the fresh groundwater leaking from the fresh shallow aquifer into the deep salinized one.

In this paper the sources of salinity in groundwaters of Jordan are discussed. The salinized groundwater bodies are defined and the consequences of overexploiting the fresh water aquifers and the mining of deep groundwater are considered.

2. Geology

Rocks of Precambrian to recent age build up the geology of the country. In its south western part the granitic basement crops out and extends in the underground of the country with a small dip angle of 2–3° towards the northeast (Quennell, 1959; Bender, 1968; NRA, 2012). Overlying this granitic basement follows a series of mainly sandstone formations of Cambrian to Silurian age (Fig. 1). Carboniferous deposits are not cropping out in Jordan but may be encountered at depth in the northeast. Triassic rocks crop out in the area along to the mid-latitude of the Dead Sea. Jurassic rocks occur

* Corresponding author. Tel.: +962 6 53 55000x22261; fax: +962 6 5300253.
E-mail addresses: salameli@ju.edu.jo (E. Salameh), mar_raggad@yahoo.com (M. Alraggad), aa.tarawneh@yahoo.com (A. Tarawneh).

http://dx.doi.org/10.1016/j.chemer.2014.04.007
0009-2819/

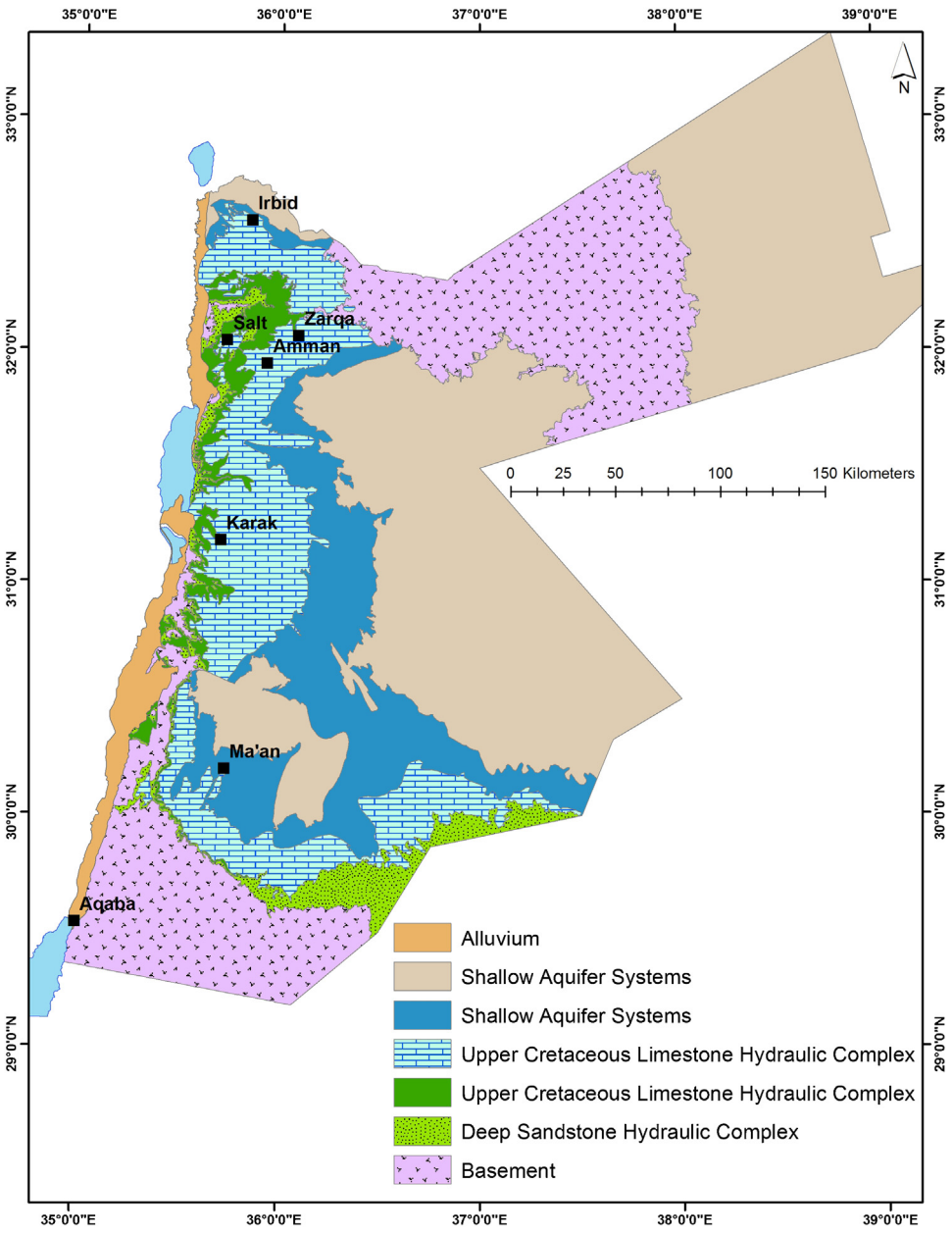

Fig. 1. Simplified geological map showing the general set-up of the hydrogeological system in Jordan and sampling points (NWMP, 2003).

along the northern shore of the Dead Sea (Bender, 1968; Bandel and Salameh, 2013).

Overlying the Cambrian to Silurian rocks in the southern part of Jordan and the Triassic and Jurassic rocks in the northern part is a series of sandstone of Lower Cretaceous age, which in turn is overlain by calcareous Upper Cretaceous rocks. Tertiary calcareous rocks partly cover the Upper Cretaceous rocks (Quennell, 1959; Bender, 1968; Bandel and Salameh, 2013).

Quaternary and recent sediments are restricted to wadi courses and cover most of the Jordan – Dead Sea Rift Valley. In addition, Quaternary basalts cover the most northeastern part of the country extending into Syria further north and Saudi Arabia further southeast (Fig. 1).

3. Aquifers

The above given short generalized account on the geology of Jordan allows subdivisions of the geologic formations in hydrogeologic terms of aquifers, aquicludes and aquitards as follows (Salameh and Bannayan, 1996).

3.1. Deep sandstone aquifer complex

This includes the packages of sandstone formations of Cambrian to Silurian which are directly overlain by Lower Cretaceous sandstones in the southern part of Jordan with a total thickness of more than 1000 m. Towards the north, parallel to the middle and northern latitudes of the Dead Sea, a wedge of Triassic and Jurassic sandstone, silt and limestone formations with evaporite residues starts to separate the underlying older Cambrian to Silurian sandstone from the overlying Lower Cretaceous sandstones. The whole rock package of Cambrian to Silurian, Triassic, Jurassic and Lower Cretaceous rocks, composed mainly of sandstones, build one aquifer complex is referred to as the deep sandstone aquifer complex (Fig. 2).