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Hydrochemical identification and salinity problem of ground-water in Wadi Yalamlam basin, Western Saudi Arabia

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Abstract

Wadi Yalamlam, located in the western province of Saudi Arabia, lies within a typical arid to semi-arid area. Within its drainage area of about 1600 km^2, the ground-water of its shallow alluvial aquifer is relatively high in salinity. The present study integrates hydrochemical, hydrogeological, and recharge estimation analyses to identify the process/processes, that led to the aquifer salinity. The results of chemical analysis indicate that the ground-water salinity is highly variable and inconsistent along the course of the wadi. This variability is probably due to the local hydrogeological conditions and to the intensive evaporation of effluent surface irrigation water that led to the precipitation of evaporites, e.g. calcite, dolomite and gypsum, especially affecting the ground-water at shallow depths. The recharge rate of approximately 20 mm $year^{-1}$—also plays a role in determining the risk of ground-water salinity in this aquifer.

Keywords: Arid region; Ground-water; Saturation index; Salinity; Saudi Arabia

1. Introduction

The Arabian Shield in Western Saudi Arabia is considered the most important recharge zone for the alluvial aquifers. Traversing the Shield are several wadis which are ephemeral in nature and have direct response to the

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sporadic rainfall. In such arid and semi-arid environments of limited water resources, ground-water constitutes a significant part of these resources. Further, in such environments, the ground-water chemistry evolves rapidly and the salinity goes up considerably, leading to restrictions in its utilization and limitations on the development and management of unconfined alluvial aquifers. Several factors cause the increase in ground-water salinity. Some of these factors are local, such as hydrogeological conditions, rate of natural recharge and irrigation, while others are regional in nature, including the aridity of the environment and the irregular and unpredictable occurence of rainfall (Eagelson, 1978, 1979).

Wadi Yalamlam is one of the important wadis in Western Saudi Arabia. While it receives more than 200 mm of annual rainfall, the aquifer in the wadi still has a ground-water salinity problem. This wadi is a part of the Arabian Shield, which is an extensive occurrence of Precambrian igneous and metamorphic rocks. These rocks contain appreciable amounts of minerals such as feldspars and micas which are thermodynamically unstable and tend to dissolve when in contact with water. These environments reflect the heterogeneities in recharge estimation and water quality assessment in time, as well as in space.

The purpose of the present study is to identify and discriminate among the local and regional causes of ground-water salinity, as well as to hydrochemically and hydrogeologically characterize the unconfined alluvial aquifer of Wadi Yalamlam in Western Saudi Arabia.

2. Methods

2.1. Topography and geology

The study area of Wadi Yalamlam is bound by latitudes $20^\circ 30'$ and $21^\circ 10'$N and longitudes $39^\circ 45'$ and $40^\circ 30'$E., lying about 125 km south-east of the city of Jeddah, and 70 km south of the city of Makkah (Fig. 1).

Geologically, this wadi is a part of the Arabian Shield extending from north to south parallel to the Red Sea (Fig. 2). This escarpment is one of the outstanding landscape features of Saudi Arabia. The Shield is composed of Precambrian crystalline, metamorphic and metavolcanic sedimentary rocks, with local Tertiary and Quaternary basalt flows. These rocks form the mountain ranges east of the Red Sea coastal plain (Brown et al., 1963; Wier and Hadley, 1975; Pallister, 1982; Moore and Al-Rehaili, 1989).

Loose Quaternary sediments fill the Wadi Yalamlam basin with a thickness ranging form 5 to 10 m in the upstream to more than 50 m in the downstream. These sediments consist of alternating layers of sand, gravel and clayey sand driven from the host rocks and constituting an ideal place for ground-water accumulation. In addition to this alluvial aquifer, field studies indicated that the bedrock of the basin is highly weathered and fractured also providing an ideal host for ground-water preservation (Subyani and Bayumi, 2001).