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ORIGINAL ARTICLE

Hydrogeochemical evolution of inland lakes' water: A study of major element geochemistry in the Wadi El Raiyan depression, Egypt

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ABSTRACT

Wadi El Raiyan is a great depression located southwest of Cairo in the Western Desert of Egypt. Lake Qarun, located north of the study area, is a closed basin with a high evaporation rate. The source of water in the lake is agricultural and municipal drainage from the El Faiyum province. In 1973, Wadi El Raiyan was connected with the agricultural wastewater drainage system of the Faiyum province and received water that exceeded the capacity of Lake Qarun. Two hydrogeological regimes have been established in the area: (i) higher cultivated land and (ii) lower Wadi El Raiyan depression lakes. The agricultural drainage water of the cultivated land has been collected in one main drain (El Wadi Drain) and directed toward the Wadi El Raiyan depression, forming two lakes at different elevations (upper and lower). In the summer of 2012, the major chemical components were studied using data from 36 stations distributed over both hydrogeological regimes in addition to one water sample collected from Bahr Youssef, the main source of freshwater for the Faiyum province. Chemical analyses were made collaboratively. The major ion geochemical evolution of the drainage water recharging the El Raiyan depression was examined. Geochemically, the Bahr Youssef sample is considered the starting point in the geochemical evolution of the studied surface water. In the cultivated area, major-ion chemistry is generally influenced by chemical weathering of rocks and minerals that are associated with anthropogenic inputs, as well as diffuse urban and/or agricultural drainage. In the depression lakes, the water chemistry generally exhibits an evaporation-dependent evolutionary trend that is further modified by cation exchange and precipitation of carbonate minerals.

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Introduction

The Wadi El Raiyan depression is located in the Western Desert, 40 km southwest of Faiyum Province, and has an estimated area of 703 km^2. It is situated between latitudes 28°45′ and 29°20′N and longitudes 30°15′ and 30°35′E. Since 1973,

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the depression has been used as a reservoir for agricultural drainage water. Approximately 200 million cubic meters of drainage water from cultivated lands are transported annually via El Wadi Drain to the Wadi El Raiyan lakes [1]. Two man-made lakes (i.e., upper and lower) joined by a channel were built at two different altitudes (Fig. 1). The upper lake covers an area of approximately 53 km^2 at an elevation of 10 m below sea level. The upper lake is completely filled with water and surrounded by dense vegetation [2]. The excess water of this lake flows to the lower lake via a shallow connecting channel [3]. The lower lake is larger than the upper lake and has an estimated area of approximately 110 km^2 at an elevation of 18 m below sea level [4]. The recorded maximum water depth in the lower lake is 33 m [5]. The inflow of water to the lower lake varied from 17.68×10^6 m^3 in March 1996 to 3.66×10^6 m^3 in July 1996, with a total annual inflow of 127.2×10^6 m^3/year [5]. The area between these two lakes is used for fish farming.

The major ionic composition of the surface water can reveal the type of weathering and a variety of other natural and anthropogenic processes on a hydrological basin-wide scale. Since the earlier works [6–9], the major element geochemistry of numerous major rivers has been studied, notably including the Amazon [10–13], Ganges–Brahmaputra [14–16], Lena [17–19], Makenzie [20], and Orinoco [21,22]. Studies have shown that there are a variety of processes that control the geochemical characteristics and variety of river water geochemistry. These processes include rainfall type, degree of evaporation, weathering of the bedrock, bedrock mineralogy, temperature, relief, vegetation and biological uptake.

To the authors' knowledge, there have been few published studies and insufficient data on the geochemical evolution of drainage water in the study area. Those studies include the works of Saleh [2], Sayed and Abdel-Satar [3], Saleh et al. [23,24]. This article addresses the water geochemistry of an integrated drainage system that drains through different sources of agricultural wastewater into an artificial inland depression (Figs. 1 and 2).

The area supports rich and varied desert wildlife and unique geological and geomorphological features [25]. Since 1973, the Wadi El Raiyan lakes have attracted large populations of birds, particularly waterfowl. The two lakes are currently among the most important Egyptian wetland areas and are likely to assume international importance for migrating waterfowl in the future.

The inorganic pollutants in the Wadi El Raiyan lakes were studied by Saleh et al. [23] in 2000. The study documented a significant improvement in the water quality of the Wadi El Raiyan lakes compared to 1988 as reported by Saleh et al. [24]. Mansour and Sidky [4] compared the major components of contamination between the Lake Qarun and Wadi El Raiyan wetlands, and they concluded that Lake Qarun was more polluted than the Wadi El-Raiyan lakes and that the lower lake of this wetland was relatively more contaminated than the upper lake.

Bedrock geology

El Faiyum Depression is a natural depression in the Western Desert of Egypt and extends over 12,000 km^2. Tablelands surround the Faiyum Depression on the east, west and south and separate it from neighboring depressions, the Nile Valley and Wadi El Raiyan. The Faiyum Depression is underlain by rocks of the Middle Eocene, which form the oldest exposed beds in the area and are composed essentially of gypsiferrous shale,

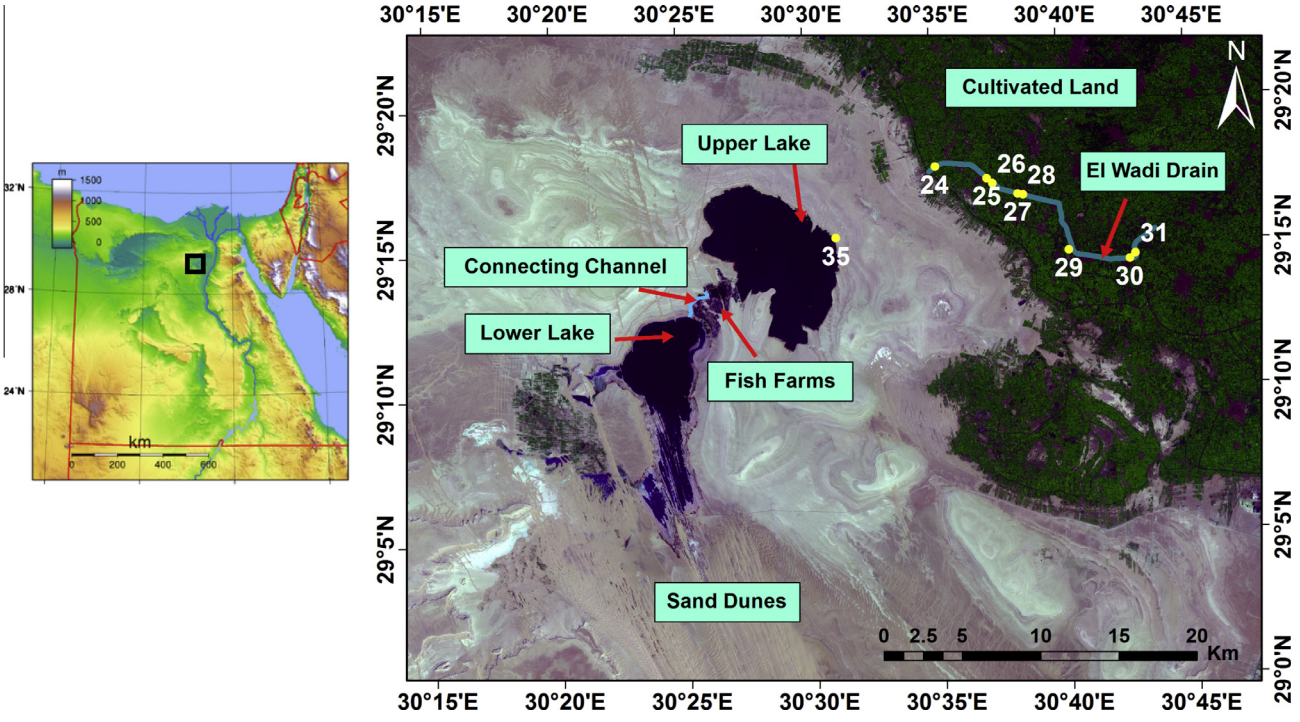

Fig. 1 Location map of the Wadi El Raiyan upper and lower lakes, El Wadi drain and location of collected water samples from the cultivated land "as shown in yellow circles".