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Water quality and discharge of the Lower Jordan River

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SUMMARY

The fresh surface water of the Lower Jordan River (LJR) has been limited in the past several decades due to damming of its main tributaries, which reduced the annual flow by 90%, leaving a mixed flow of polluted and saline sources. A monitoring and sampling hydrometric station was installed on the southern LJR to track the temporal variations of its discharge (Q) and hydrochemistry. In addition to manual water sampling, the station includes an automatic water sampler and cellular transmitting pressure and EC sensors, allowing real time observation. All samples were analyzed for major ions (Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl^-, SO_4^{2-}, NO_3^-, Br^-) and several samples were analyzed for selected isotopes ($^{34}S_{sulfate}$, $^{18}O_{sulfate}$, $^{15}N_{nitrate}$, $^{18}O_{nitrate}$, $^{2}H_{water}$, $^{18}O_{water}$) as tracers. A general inverse seasonal trend was found between EC and water level although extreme values relate to flood events during the wet period. High values of EC (up to 40.3 mS/cm), high concentration of major ions, and flood events characterized by clockwise EC–Q hysteretic relations likely relate to the dissolution of precipitated salts in the basin. Isotope analyses reveal lithology and sewage as the respective major contributors of salinity; they were used to identify events unrelated to runoff (i.e., to precipitation in the area). The continuous monitoring is an essential tool for understanding long term changes of such a dynamic system but is critical for identifying extreme events occurring rarely and rapidly, possibly having a drastic effect on fauna and flora.

1. Introduction

Water quality in many rivers worldwide has degraded due to anthropogenic activities. Municipal and industrial polluted wastewater, salinization and the control of water regime demonstrate some of the aspects damaging water quality. For example, saline agricultural return flows caused salinization in the Amu-Daria River in central Asia (Crosa et al., 2006), geomorphic changes caused by damming of the McKenzie river resulted in the reduction of the salmon population (Ligon et al., 1995), and the Rhine River became known as “the sewer of Europe” by the end of 1960s due to former severe industrial and municipal pollution, causing most flora and fauna to disappear (Wieriks and Schulte-Wulwer-Leidig, 1997).

The Lower Jordan River (LJR, Fig. 1a) runs through the Jordan Dead Sea Rift from the Sea of Galilee to the Dead Sea along an aerial distance of 105 km (220 km along its meanders; Nir, 1989) and is incised in two Pleistocene floodplain units. The current day floodplain of the former river Zor incised into the Samra formation (marl, sand, conglomerate, limestone and chalk), while the higher, ancient floodplain termed Ghor consists of the Lake Lisan formation (aragonite, marl, detrital sediments and gypsum; Nir, 1989; Farber et al., 2004). The LJR is located in a (semi-) arid region with high evapotranspiration (Farber, 2005).

The two major sources of the LJR, the Sea of Galilee and the Yarmouk River, were dammed during the 1960s to meet the water needs of the region’s growing population. Accordingly, flow volumes decreased dramatically, causing changes in the river’s physical and ecological characteristics, as well as in its water quality (Calvo and Ben-Zvi, 2005). Current water sources of the LJR – mainly diverted saline springs, agricultural return flows, partially treated waste water, discharge from fish ponds, ground water and storm water – contribute to varying salinity and pollution. Nevertheless, only few publications have addressed this issue, as most of the LJR is a trans-boundary river, sensitive politically and difficult to approach physically due to remaining land-mines along parts of its course (Knesset site, 2013). Farber et al. (2004) defined three distinct segments (northern, middle and southern) based on salinity and sources. Salinization trends could not be explained by a sole source; the groundwater component in the northern section contributes the largest volume of water, while in the southern section groundwater contributes a higher solute concentration (Farber et al., 2004). A drastic decrease in water discharge increased both

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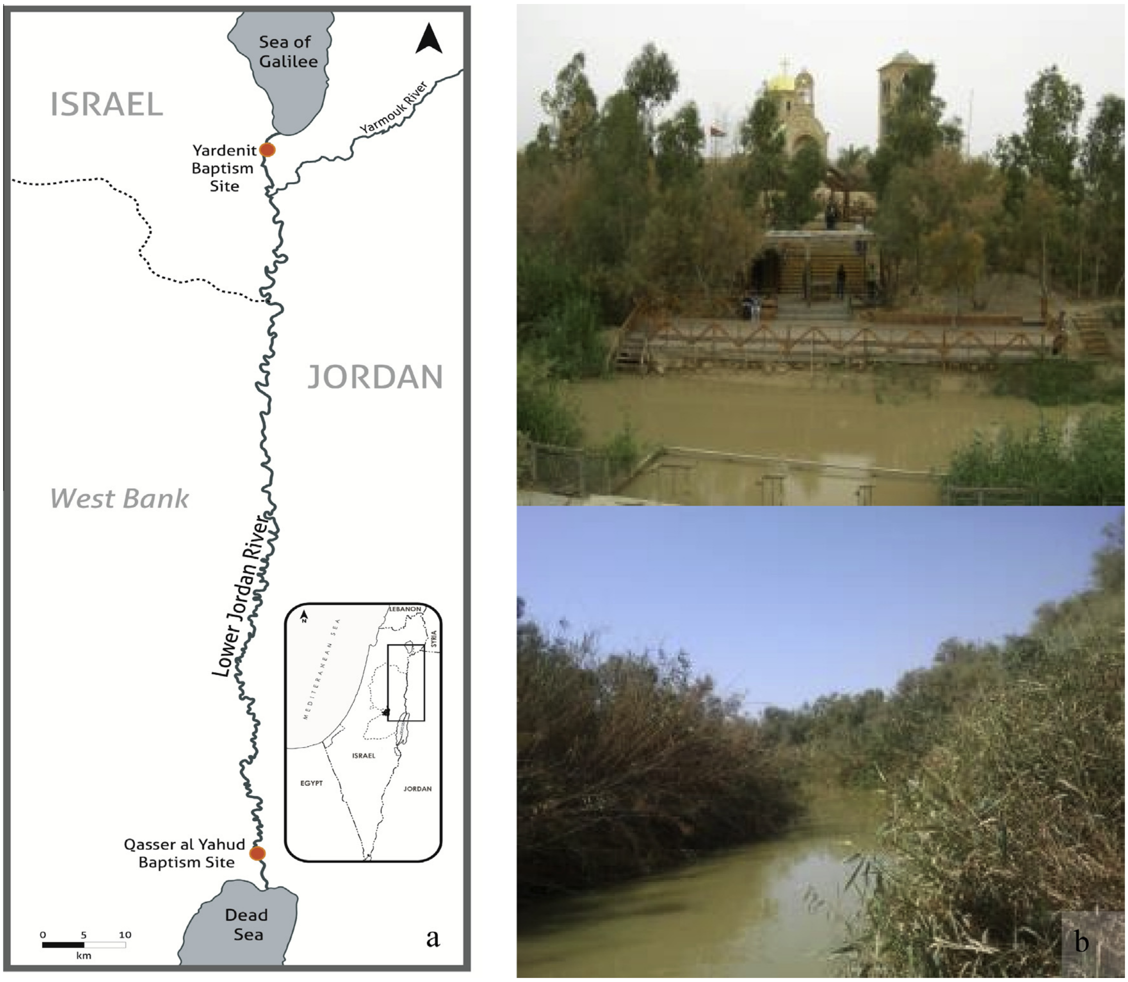

Fig. 1. (a) Map of the Lower Jordan River (LJR). (b) Qasser Al-Yahud.

the salinity and the organic pollution and the loss of natural habitats together with a 50% decrease in biodiversity (Gafny et al., 2010).

The water appendix in the Jordan–Israel peace agreement (26.10.1994) states the commitment of the parties to monitor water quality along the border within 3 years from the agreement. In addition, wastewater and saline water are to be treated before entering the LJR within 4 years. An initial monitoring scheme operated by state authorities began in July 2012 with two new hydrometric stations. A treatment plant aiming to treat waste and saline water has been constructed and is expected to start operating during 2015. Rehabilitation efforts were initiated in May 2013 with a daily allotment of 24,000 m^3 of treated water entering the LJR from the Sea of Galilee (Israel Water Authority, 2013).

The Jordan River is the largest continuous flowing source of water to the Dead Sea and its discharge is vital for the water balance of the dwindling Dead Sea (Calvo and Ben-Zvi, 2005). In addition, the LJR is intensely used for agriculture (Segal-Rozenhaimer et al., 2004). Apart from hydrologic and economic aspects, the Jordan River is of high importance to religious groups baptizing in its waters. The objectives of this research are (1) to address the causes of annual water quality changes by understanding the chemical composition of the water, using continuous water monitoring and high-frequency sampling combined with geochemical tools and (2) to quantify the relevant and temporally varying water discharge. Relations between water quality parameters should enable to further understand the characteristic behavior of the LJR at base flow and also in rain-fed and anthropogenically induced runoff events.

2. Methods

A hydrometric station was installed in February 2010 at the "Qasser al-Yahud" baptism site, 8 km north of the Dead Sea (Fig. 1a and b), including an automatic water sampler (Andress & Hauser Liquiport 2000), independent pressure sensors (Waterpilot FMX21, Schlumberger), EC-sensor (Condumax CLS12) and a turbidity sensor (TurbiMax WCUS41). High correlation ($r^2 = 0.93$) between data of the atmospherically corrected MicroDivers and the Waterpilot enabled interpolation of water level data. Information on precipitation events were obtained from the database of the Israel Water Authority internet site.

2.1. Water discharge

Water discharge (Q) was calculated using the continuity equation $Q = UA$, where A is the cross sectional area (m^2) and U is the mean water velocity (m/s). Velocity was measured by two non-contact methods using a Decatur Electronics portable surface velocity radar (SVR) with a 0.3–9.1 m/s range and 5% accuracy, and separately also by floats. As both surface velocity methods are not equivalent to average water velocity, results were multiplied by a coefficient (0.85) for SVR measurements (Yorozuya et al., 2010) and a lower coefficient (0.64) for floats (Marjang and Merkley,