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The impacts of a linear wastewater reservoir on groundwater recharge and geochemical evolution in a semi-arid area of the Lake Baiyangdian watershed, North China Plain

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HIGHLIGHTS

- An unlined wastewater reservoir caused the deterioration of groundwater quality.
- An evaporation fraction was estimated by Rayleigh distillation theory of isotopes.
- 73.5% of wastewater recharge to groundwater by leakage and irrigation infiltration.
- The region influenced by wastewater was divided into four subzones.
- Mixing, ion exchange, and carbonate precipitation are major geochemical processes.

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ABSTRACT

Sewage leakage has become an important source of groundwater recharge in urban areas. Large linear wastewater ponds that lack anti-seepage measures can act as river channels that cause the deterioration of groundwater quality. This study investigated the groundwater recharge by leakage of the Tanghe Wastewater Reservoir, which is the largest industrial wastewater channel on the North China Plain. Additionally, water quality evolution was investigated using a combination of multivariate statistical methods, multi-tracers and geochemical methods. Stable isotopes of hydrogen and oxygen indicated high levels of wastewater evaporation. Based on the assumption that the wastewater was under an open system and fully mixed, an evaporation model was established to estimate the evaporation of the wastewater based on isotope enrichments of the Rayleigh distillation theory using the average isotope values for dry and rainy seasons. Using an average evaporation loss of 26.5% for the input wastewater, the estimated recharge fraction of wastewater leakage and irrigation was 73.5% of the total input of wastewater. The lateral regional groundwater inflow was considered to be another recharge source. Combing the two end-members mix model and cluster analysis revealed that the mixture percentage of the wastewater decreased from the Highly Affected Zone (76%) to the Transition Zone (5%). Ion exchange and redox reaction were the dominant geochemical processes when wastewater entered the aquifer. Carbonate precipitation was also a major process affecting evolution of groundwater quality along groundwater flow paths.

1. Introduction

With industrialization and accelerated urbanization, municipal sewage leakage has become an important source of groundwater recharge, resulting in adverse effects on groundwater quality (McArthur et al., 2012; Schirmer et al., 2013). This is especially true for aquifers located in arid/semi-arid climate regions in which global warming and anthropogenic activities have led to decreased runoff, drying of rivers and declining groundwater levels. The major non-agricultural sources of groundwater contamination include leakage from water supply and disposal networks such as evaporation ponds, on-site sewage disposal, and contaminated land and rivers (Wakida and Lerner, 2005). Among these sources, evaporation ponds have been widely used in arid regions for the storage and disposal of wastewater (Geophysics Study Committee, 1984; Al-Kharabsheh, 1999). Although these ponds are often lined, many are unlined and therefore have the potential to impact groundwater quality via leakage. To effectively manage water resources within a basin, it is important to investigate the impacts of polluted

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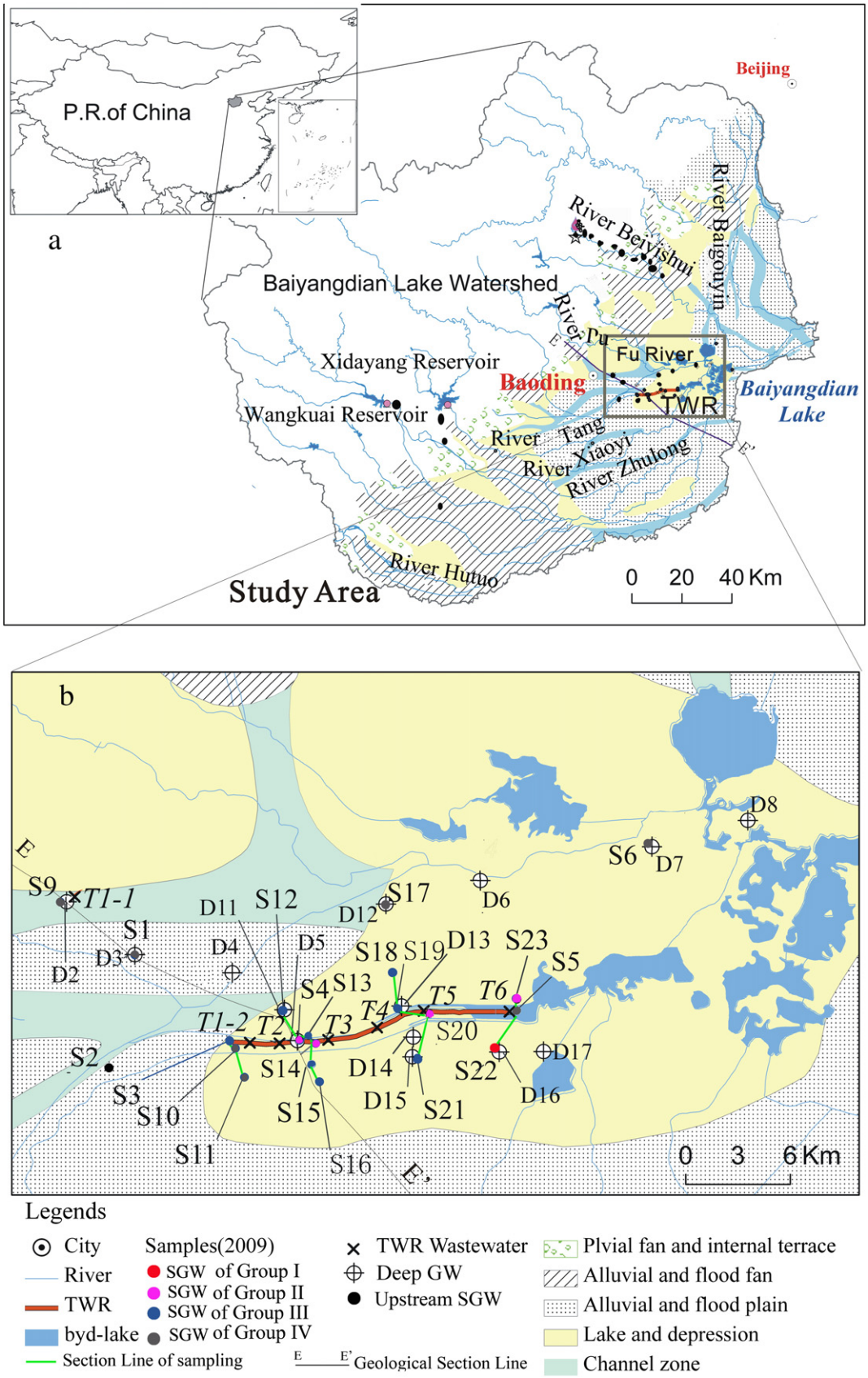

Fig. 1. Location of the study area in Lake Baiyangdian watershed (a) and sampling points in the study area (b).