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A regional scale investigation on factors controlling the groundwater chemistry of various aquifers in a rapidly urbanized area: A case study of the Pearl River Delta

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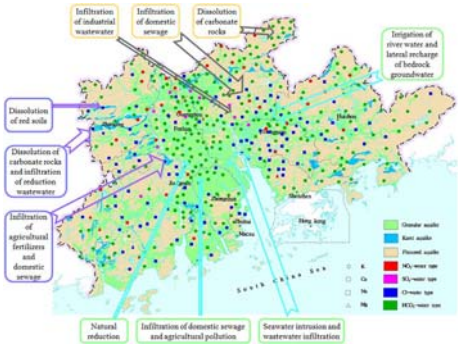
HIGHLIGHTS

- Groundwater chemistry in the PRD after 3 decades of urbanization was investigated.
- Emerge of NO_3 and SO_4 water types is driven by the urbanization and industrialization.
- Quantity of water types was up to 89 after decades of urbanization.
- Factors which control groundwater chemistry in various aquifers were extracted.

GRAPHICAL ABSTRACT



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ABSTRACT

A growing population accompanied by urbanization has increased groundwater resource demands in the Pearl River Delta (PRD) area, southern China, and a comprehensive understanding of the groundwater chemistry in the PRD is necessary. The aims of this study were to investigate the groundwater chemistry in various aquifers in the PRD on a regional scale and to discuss the factors that control the groundwater chemistries of different types of aquifers. In addition, the effect of the expansion of construction land on the groundwater chemistry was also taken into consideration in this study. Nearly 400 groundwater samples were collected and fourteen chemical parameters were investigated. The results show that natural factors, such as seawater intrusions, are mainly responsible for the higher concentrations of total dissolved solids, Na^+, Mg^{2+}, K^+, and Cl^-, in granular aquifers than those in fissured and karst aquifers. Similarly, higher concentrations of NH_4^+, Fe and Mn in granular aquifers than those in the other two types of aquifers are mainly ascribed to natural reduction. In contrast, human activities, such as the continuous irrigation of river water, upon granular aquifer are mainly responsible for the higher concentrations of Ca^{2+} and HCO_3^- in granular aquifers than those in other two types of aquifers. Urbanization and industrialization are the main driving forces for the frequently occurrences of NO_3 and SO_4 water types, respectively. Moreover, the number of water types in the PRD increased to 89 after the decades of urbanization. Factors that control groundwater chemistries in various aquifers were extracted. A four-factor model controlled the groundwater chemistry of granular aquifers, while two three-factor models controlled the

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groundwater chemistries of fissured and karst aquifers, respectively. The results of this study show that the expansion of construction land is a powerful driving force for the change of groundwater chemistry in the PRD.

1. Introduction

The Pearl River Delta (PRD) is an important economic area and is located in the coastal area of southern China. It has rich surface water resources. However, urbanization and industrialization have accelerated the deterioration of surface water quality in this area for the last three decades (Huang et al., 2013). Moreover, a growing population accompanied by urbanization has increased water resource demands in this area. As a result, attention to groundwater resource abstraction has increased, and a comprehensive understanding of the groundwater chemistry in the PRD is vital for managing the regional groundwater resources.

The PRD is characterized by three types of aquifers: granular aquifers, fissured aquifers and karst aquifers (Fig. 1). Several previous studies have been recently performed regarding groundwater chemistry issues in this area. Wang and Jiao (2012) discussed the groundwater salinity and hydrogeochemical processes in a granular aquifer of the PRD and focused on the natural factors controlling the groundwater chemistry. Our previous study investigated the groundwater chemistry of granular and fissured aquifers in Dongguan city, which is located within the PRD (Huang et al., 2013). The groundwater chemistries in karst aquifers and other areas within the PRD are not well known. In addition, the PRD is a rapidly developed economic zone and has shown a rapid expansion of construction land during the past three decades (Ye et al., 2013). However, the expansion of construction land in the PRD was not taken into consideration when discussing the factors controlling the groundwater chemistry in the previous studies.

The present study, therefore, aims to 1) investigate the spatial distribution of groundwater chemistry in different types of aquifers in the whole PRD on a regional scale, 2) discuss the factors controlling the groundwater chemistry in different types of aquifers, and 3) put forward suggestions for groundwater protection based on the impacts of human activities to groundwater chemistry in this rapidly urbanized area. In addition, the effect of the expansion of construction land on the groundwater chemistry was also taken into consideration in this study. Groundwater chemistry in the economic zone may be affected by both some natural factors and some human activities, and a principal components analysis (PCA) was a useful tool to identify these factors controlling the groundwater chemistry (Güler et al., 2012; Huang et al., 2013; Huang et al., 2014). Therefore, multivariate statistical techniques such as PCA have also been used in this study. The results will be beneficial to improving groundwater protection for sustainable development in rapidly urbanized areas in China.

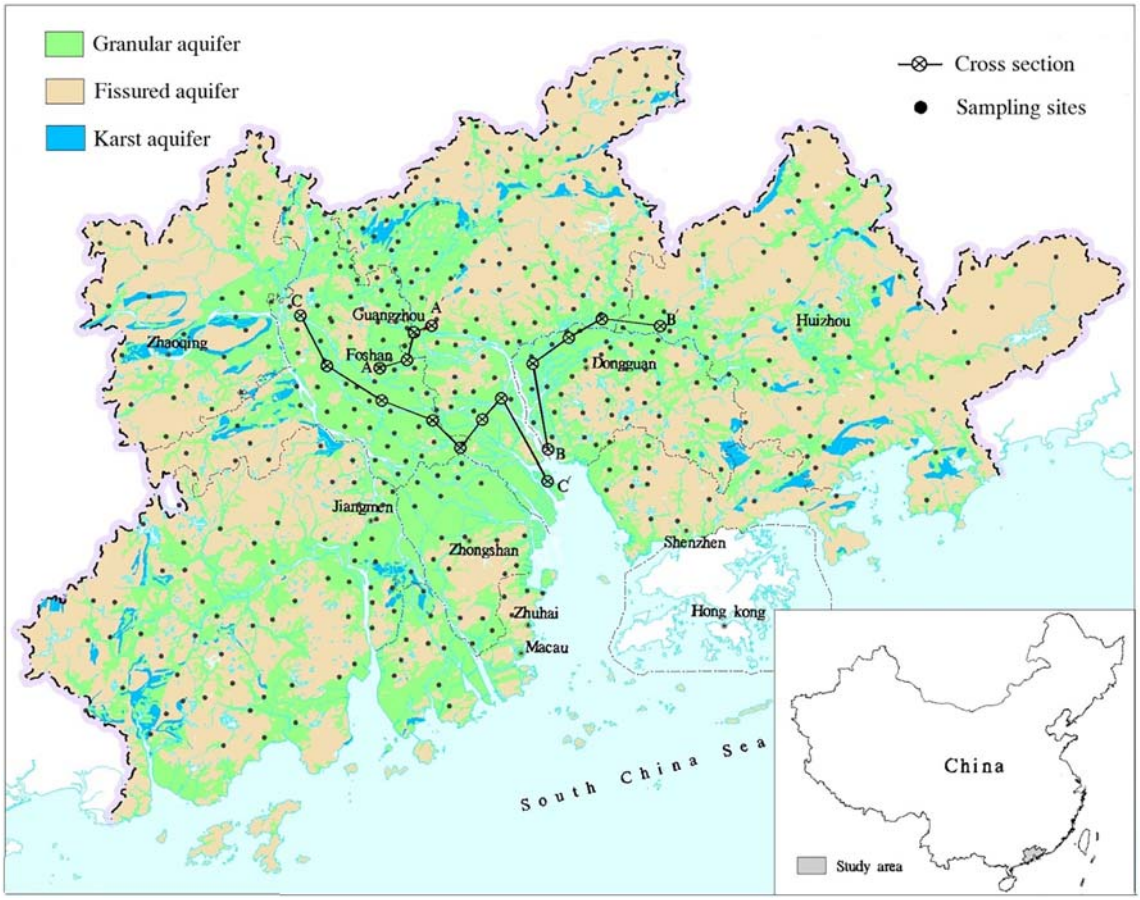

Fig. 1. Hydrogeological setting and sampling sites in the PRD.