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# Impact of anthropogenic and natural processes on the evolution of groundwater chemistry in a rapidly urbanized coastal area, South China

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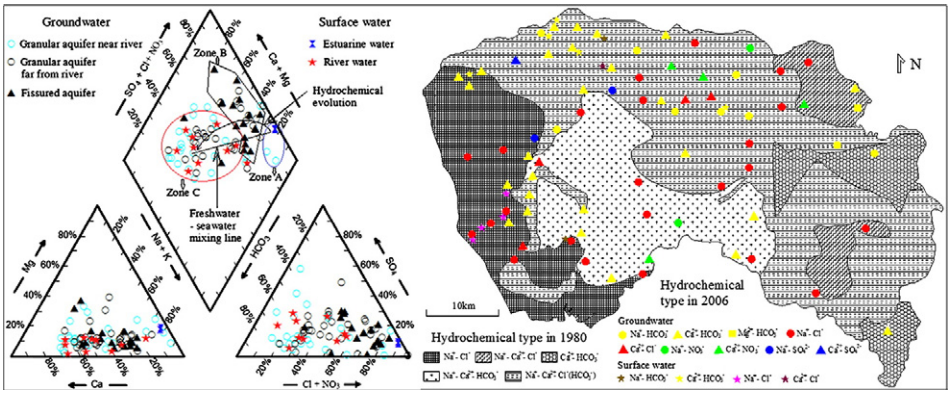
## HIGHLIGHTS

- Human activities are responsible for the occurrences of NO3−, SO42− and Mg2+ types.
- The anthropogenic and natural processes occurring are identified as four PCs.
- Natural processes mainly control the evolution of groundwater chemistry.
- Human activities are also the factors for the evolution of groundwater chemistry.

## GRAPHICAL ABSTRACT

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## ABSTRACT

The moving of manufacturing industry from developed countries to Dongguan, China, promoted the semi-urbanization and rural industrialization in this area. It is urgent to acquire the impact of the enhanced anthropogenic pressure on the evolution of groundwater chemistry in this area. The objectives, in this study, were to understand the evolution of groundwater chemistry in Dongguan area based on the comparison of hydrochemical data variations and land use changes during the urbanization, to distinguish the impact of natural processes and anthropogenic activities on the groundwater chemistry by using principal components analysis (PCA) and hierarchical cluster analysis (HCA), and to discuss the origins of trace elements in groundwater. Eighteen physico-chemical parameters were investigated at 73 groundwater sites during July 2006. By analyzing the hydrochemical data, it shows that lateral flow from rivers and agricultural irrigation are the mechanisms controlling the groundwater chemistry in the river network area where the cation exchange of $Na^+$ in sediments taken up by the exchanger $Ca^{2+}$ occurs. Seawater intrusion is the mechanism controlling the groundwater chemistry in the coast area where the cation exchange of $Ca^{2+}$ in sediments taken up by the exchanger $Na^+$ occurs. The ion exchange reaction for fissured aquifer is weak in the study area. In addition, the comparison of hydrochemical data between in 2006 and in 1980 shows that anthropogenic activities such as excessive application of agricultural fertilizers, inappropriate emissions of domestic sewage and excessive emissions of $SO_2$ are responsible for the occurrences of groundwater with $NO_3^-$, $SO_4^{2-}$ and $Mg^{2+}$ types. Four principal components (PCs) were extracted from PCA, which explain 80.86% of the total parameters in water chemistry: PC1, the seawater intrusion and As contamination; PC2, the water–rock interaction, surface water recharge and acidic precipitation; PC3, heavy metal pollution from industry; and PC4, agricultural pollution and sewage intrusion. Four clusters were generated

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from HCA: cluster 1 is mainly influenced by the industrialization; cluster 2 is mainly affected by the water–rock interaction and the irrigation and lateral flow of river water; cluster 3 is mainly influenced by the seawater intrusion; and cluster 4 is mainly influenced by the sewage intrusion and agricultural pollution. The results show that both natural processes such as seawater intrusion, water–rock interaction and lateral flow of river water and anthropogenic activities such as industrialization, sewage intrusion and agricultural pollution are the two major factors for the evolution of groundwater chemistry in Dongguan area.



## 1. Introduction

Groundwater is often the most important water resource for drinking, irrigation and industry in coastal areas (Kim et al., 2003; Leung et al., 2005; Güler et al., 2012; Wang and Jiao, 2012; Carol et al., 2013), especially in the areas where available surface water resource is scarce. Groundwater not only supports all kinds of human activities such as drinking and irrigation, but also plays an important role in (bio)geochemical reactions in subsurface (Hancock et al., 2005). It is known that changes in groundwater chemistry can disrupt many important ecological processes (Moore, 1999). Therefore, sustainable management of groundwater resource requires a good understanding of groundwater chemistry/quality, in order to ensure a reliable supply for all life forms.

The evolution of groundwater chemistry is largely determined by the natural processes (such as hydrogeological conditions, lithology, interaction of water with soil and rock, tidal fluctuation, seawater intrusion) and anthropogenic activities (such as agriculture, industry, urban development) (Adams et al., 2001; Rademacher et al., 2001; Guo and Wang, 2004; Aris et al., 2007; Lin et al., 2012). Many researchers have devoted to study the effect of natural processes and anthropogenic activities on the current situation of groundwater chemistry/quality in some areas such as coastal areas (Jeen et al., 2001; Zilberbrand et al., 2001; Kim et al., 2003; Xing et al., 2013), arid or semi-arid areas (He et al., 2012; Wang et al., 2013), karst areas (Jiang et al., 2009), and volcano areas (Aiuppa et al., 2003). Recently, some researchers have also focused on the evolution of groundwater chemistry in the rapidly urbanized areas (Leung et al., 2005; Barron et al., 2013).

Dongguan is located in the Pearl River Delta area of South China (Fig. 1). The moving of manufacturing industry from developed countries to Dongguan has promoted the semi-urbanization and rural industrialization in this area since the 1980s (Du et al., 2012; Gu et al., 2012). The water supply of this area almost entirely relied on surface water before the urbanization due to the abundant rainfall and the well-developed river network. However, rapid urbanization and industrialization have led to the deterioration of surface water quality through pollution and declining river discharge (Cheung et al., 2003; Lu et al., 2006, 2009). Furthermore, the enhanced anthropogenic pressure has substantially increased the demand for water due to the urbanization. As a consequence, surface water alone can no longer meet the needs of the area, and groundwater plays an increasingly vital role in supply of water resource in this area due to the shortcoming of available surface water.

The purposes of this study were to: 1) investigate the evolution of groundwater chemistry in Dongguan area based on the comparison of hydrochemical data variations and land use changes during the urbanization; 2) distinguish the impact of natural processes and anthropogenic activities on the groundwater chemistry by using principal components analysis (PCA) and hierarchical cluster analysis (HCA); and 3) discuss the origins of trace elements in groundwater. Unlike many other studies that discuss the evolution of groundwater chemistry mainly based on the major ions and stable isotopes (Jeen et al., 2001; Jiang et al., 2009; Lin et al., 2012; Barron et al., 2013; Wang et al., 2013; Xing et al., 2013), this study discusses the groundwater chemistry on the aspect of major ions and trace elements based on the comparison of land use changes and hydrochemical data (major ions) variations, moreover, the multivariate statistical analysis has

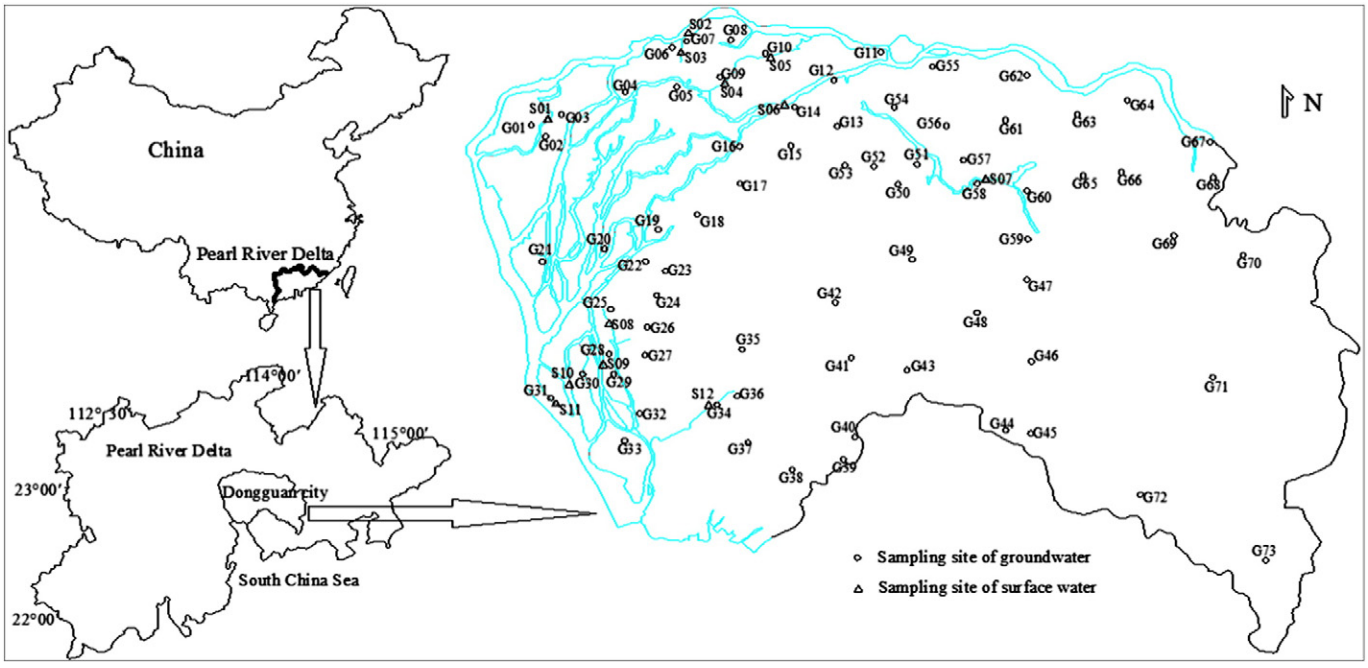


**Fig. 1.** Schematic showing the geographical locality of the sampling sites within Dongguan city, South China (S — surface water, G — groundwater).