CHEMICAL ENGINEERING TRANSACTIONS
VOL. 62, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216
DOI: 10.3303/CET1762072

Study on Evolution Process of Chemical Characteristics of Groundwater in Pearl River Basin

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This paper studies the degree of chemical pollution of groundwater in the Pearl River Basin and the chemical evolution mechanism of water body. Then it analyzes the change trend of discharge, balance, total dissolved solids (TDS), water ion concentration and other parameters of groundwater in the basin in the past 20 years, as well as discusses the impact of chemical evolution process of groundwater on water cycle. According to the study, the groundwater storage volume in the Pearl River Basin has begun to decrease year by year because of the excessive exploitation of groundwater caused by increased human activities, industrial and agricultural water consumption. When the cover depth of groundwater is great, the external replenishment of groundwater gradually reduces with salt, minerals and chemical pollutants continuously accumulating, which will lead to the gradual increase of TDS of groundwater. Seasonal changes have a little impact on the chemical evolution of groundwater. Groundwater recharge area mainly contains Ca^{2+}-Na^{+}-HCO_3^{-} that will be converted to Na^{+}-K^{+}-HCO_3^{-}-Cl^{-} in discharge area. The chemicals contained in groundwater are mainly related to geotechnical types, environmental conditions and various chemical reactions. The study on the chemical characteristics and evolution rule of groundwater can provide theoretical reference for the rational and effective use of water resources.

1. Introduction

The Pearl River Delta is one of the most economically developed regions in China. However, the rapid economic development has also caused serious environmental pollution. According to relevant surveys, the chemical element contents in rivers and groundwater in many areas of the Pearl River Delta have seriously exceeded, and pollutants and eutrophic bacteria have aggregated in a large area. In addition, human activities have increased frequently and industrial and agricultural water consumption has increased rapidly. The combination of many factors has led to the serious water quality shortage in the Pearl River Delta (Ma et al., 2005; Shi et al., 2001; Wang and Jiao, 2012; Yuan et al., 2013; Wang et al., 2013).

At present, the circulation mechanism of groundwater in the Pearl River Delta basin and the management of water resources have been carried out and relevant research results have been obtained (Cheung et al., 2003; Yang 2013; Chen et al., 2005; Wong et al., 2002; Huang et al., 2005). However, few studies are about the degree of chemical pollution of groundwater in the basin and the chemical evolution mechanism of water body (Cui et al., 2012; Kjøller et al., 2004).

This paper studies the degree of chemical pollution of groundwater in the Pearl River Basin and the chemical evolution mechanism of water body. Then it analyzes the change trend of discharge, balance, TDS, water ion concentration of groundwater in the basin in the past 20 years, as well as discusses the impact of chemical evolution process of groundwater on water cycle. The study on the chemical characteristics and evolution rule of groundwater can provide theoretical reference for the rational and effective use of water resources.

Please cite this article as: Linbo Qian, 2017, Study on evolution process of chemical characteristics of groundwater in pearl river basin, Chemical Engineering Transactions, 62, 427-432 DOI:10.3303/CET1762072

2. Overview of study area and test methods

2.1 Overview of hydrogeology

The selected study area is located in the university town of Guangzhou City, Guangdong Province. The study area belongs to island surrounded by water. An area of 3 km^2 on the island is selected for sampling. Guangzhou City boasts a subtropical climate with the annual average temperature of 15°C-25°C. Each April-August is the rainy season and the rest is the dry season. Its annual precipitation is about 2000mm and rainfall gradually reduces from south to north. It is moisty with the annual surface evaporation is about 1400mm (Wang et al., 2012; Liang et al., 2009).

Located in the estuary of the Pearl River, Guangzhou boasts thick soft soil, abundant rainfall and good discharge conditions, all of which have created excellent conditions for the supply of groundwater. The underground rock mass is numerous and fragmented and the rock stratum develops in fracture. The groundwater in the selected study area mainly includes superstratum water, which is found in the medium sand and clay layer. The confined water exists in the fine sand layer and the bedrock fissure water exists in strongly weathered and moderately weathered layers.

2.2 Sampling and test methods

In the selected study area, longitudinal profile information of rock and soil above the groundwater is collected and 15 monitoring wells in the study area are used to monitor the groundwater. The main monitoring contents include groundwater level, pH value, water quality and water temperature change. Groundwater samples are taken for test of chemical characterization in the dry and rainy seasons of the same year respectively. The concentration of Ca^{2+}, K^+, Cl^-, and NO_3^- in the water is analyzed by spectrometer and 0.4μm filtering membrane is used to filter before the test. TDS in the groundwater are tested by a dedicated environmental quality testing center.

3. Test results and analysis

3.1 Equilibrium characteristics of groundwater

According to the statistics issued by the local water resources bureau, the irrigation water consumption along the Pearl River Basin can be obtained as shown in Figure 1. Irrigation water is the main way of discharge of groundwater.

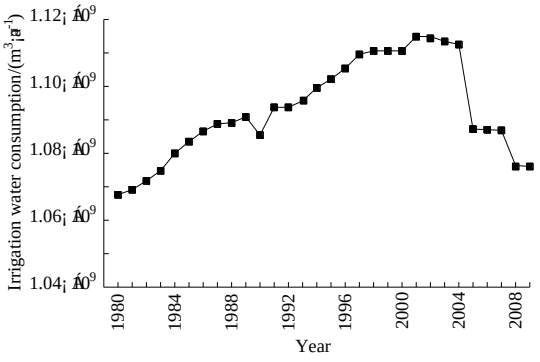


Figure 1: Discharge Volume of Groundwater in the Study Area from 1980 to 2010

The equilibrium characteristic of groundwater W refers to the difference between groundwater inflow and discharge, and its calculation formula is:

$$W = X + Y + I + G - (Q + Z + S) \quad (1)$$

Where, X, Y, I and G respectively represents precipitation, river water, field irrigation and groundwater lateral infiltration; Q, Z and S respectively represents exploitation, evaporation and outflow of groundwater. The above statistics units are all m^3/a.

Combined with formula 1, the changing curve of the groundwater storage in the Pearl River Basin from 1980 to 2010 is obtained as shown in Figure 2. It can be seen from the figure that since 1980, the groundwater storage in the Pearl River Basin has decreased year by year with an annual reduction of nearly 3.03 × $10^8 m^3/a$ mainly

because of excessive exploitation of groundwater caused by increased human activities, industrial and agricultural water consumption.

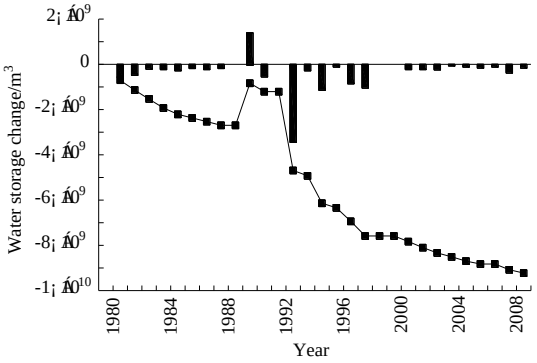


Figure 2: Groundwater Balance Changing Curve in the Study Area from 1980 to 2010

3.2 Change in TDS of groundwater

Figure 3 shows the TDS changing curve of a vertical section of groundwater selected in the study area with the abscissa being the lower reaches of the basin. It can be seen from the figure that starting from the selected vertical section of groundwater, the mineral concentration of groundwater in the lower reaches of the basin is much higher than that in the upper reaches, and the water quality is worse. The TDS concentration of a vertical section of groundwater is 135mg/L, and the TDS concentration of the lower reaches that is 30-60km away from the section is 350-500mg/L. When the distance is greater than 60km, the TDS concentration increases to over 900mg/L, and groundwater has been seriously polluted. At the same time, when the cover depth of groundwater is great, the external replenishment of groundwater gradually reduces with salt, minerals and chemical pollutants continuously accumulating, which will lead to the gradual increase of TDS of groundwater.

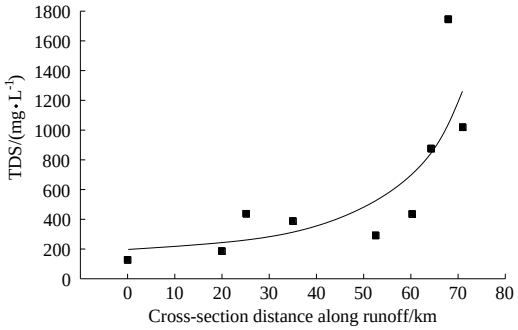


Figure 3: TDS Changing Curve of a Vertical Section of Groundwater

3.3 Chemical evolution characteristics of groundwater in the study area

Figure 4 shows Piper map of chemical type distribution of groundwater selected in the rainy season in 2010. The chemical characteristics of groundwater are determined by the geotechnical characteristics, runoff speed, inflow water and discharge conditions, industrial and agricultural water consumption. As shown in the figure, chemical composition of the water quality of groundwater in the Pearl River Basin from the recharge area to the discharge area is complex. The recharge area mainly contains Ca2+-Na+-HCO3- that will be converted to Na+-K+-HCO3--Cl- in discharge area. In the recharge area in the upper reaches of the groundwater, chemical soluble components in groundwater, such as Na+, K+, and Cl- will quickly flow into the drainage area because of good runoff condition and fast water speed. The residual chemical ions in water are mainly Ca2+ and HCO3-. Due to the continuous chemical interaction with the outside world and frequent chemical ion exchange in the middle groundwater and discharge area, the residual chemical ions in the water are Na+, K+, and Cl-. From the survey results, it can be seen that the chemical substances contained in groundwater are mainly related to geotechnical types, environmental conditions and various chemical reactions.

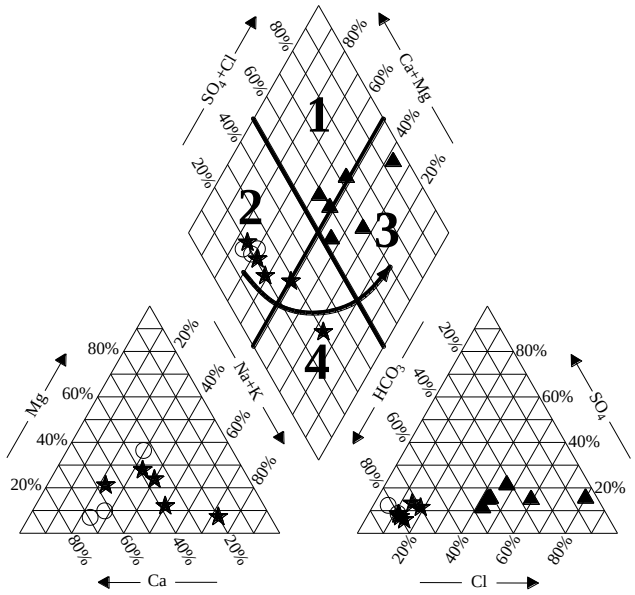


Figure 4: Chemical Type Distribution of Groundwater in the Rainy Season in the Study Area

Figure 5 shows the relationship between the cover depth of groundwater and TDS in 1990 and 2010. As shown in the figure, when the cover depth of groundwater gradually increases, the TDS value in the water body shows a decreasing trend. In 1990, the rate of decrease was about 10.96mg/(*La*), and in 2010, the rate of decrease reached to 48.29mg/(*La*).

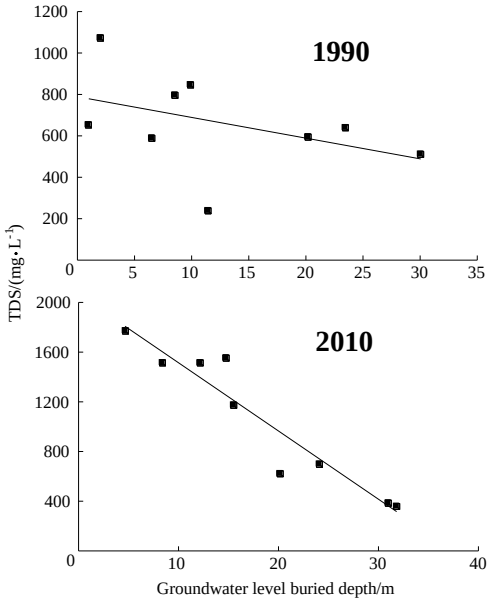
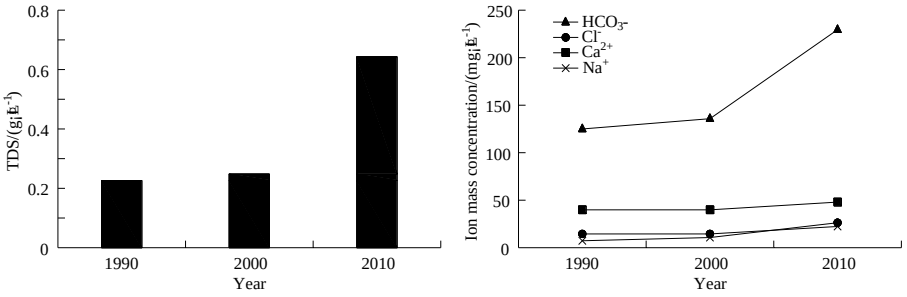


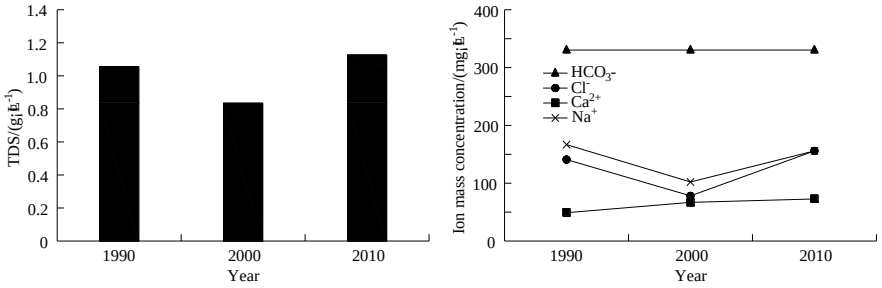
Figure 5: Relationship between the Cover Depth of Groundwater and TDS in 1990 and 2010

Figure 6 shows the TDS value and the changes in concentration of major ions monitored at two typical points selected in the study area. (a) sampling point is the main groundwater exploitation point. Groundwater is affected by many external factors and the water quality alternates frequently. It can be seen from the figure that the TDS value in 2010 was much larger than that in 1990. As a whole, the TDS shows an increasing trend and the growth rate is about 20mg/(La); In terms of ion concentration, concentration of HCO3- increases the most with the increase rate of 5.78mg/(La). The increase rate of Cl- and Na+ is 1.08mg/(La) and 0.49mg/(*La*) respectively.

The TDS value of (b) sampling point first decreases and then increases. In terms of ion concentration, there is almost no change in HCO3- while Cl- and Na+ first decrease and then increase. Combined with the change of TDS, we can see that changes in Cl- and Na+ affect TDS.



(a)



(b)

Figure 6: TDS Value and the Changes in Concentration of Major Ions at Two Typical Points

4. Conclusions

This paper carries out a study on the degree of chemical pollution of groundwater in the Pearl River Basin and the chemical evolution mechanism of water body. Then it analyzes the change trend of discharge, balance, TDS, water ion concentration and other parameters of groundwater in the basin in the past 20 years, as well as discusses the impact of chemical evolution process of groundwater on water cycle. The following conclusions have been drawn:

(1) The groundwater storage volume in the Pearl River Basin has begun to decrease year by year for the excessive exploitation of groundwater resulted from increased human activities, industrial and agricultural water consumption. When the cover depth of groundwater is great, the external replenishment of groundwater gradually reduces with salt, minerals and chemical pollutants continuously accumulating, leading to the gradual increase of TDS of groundwater.

(2) Seasonal changes have a little effect on the chemical evolution of groundwater. Groundwater recharge area mainly contains Ca^{2+}-Na^{+}-HCO_3^- which will be converted to Na^{+}-K^{+}-HCO_3^--Cl^- in discharge area. The chemicals contained in groundwater are mainly related to geotechnical types, environmental conditions and various chemical reactions. Through the study on the chemical characteristics and evolution rule of groundwater, this paper can provide theoretical reference for the rational and effective use of water resources.

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