The Analysis on Geochemistry of Groundwater in the Coastal Areas of Wanning, the Northeast Hainan Island

Yanyan LIANG[1], Feng LI[1,a], Kaixuan SHEN[1], Jiasheng WEN[1], Xiangyun ZENG[1], Xiaolin LONG[1], Haijun HE[2], Jinwei ZHANG[2]

[1] Department of Hydraulic Engineering, South China University of Technology, Guangzhou, 510641, China

[2] MLR Key Laboratory of Marine Mineral Resources, Guangzhou Marine Geological Survey, Guangzhou 510760, China

[a] Corresponding author e-mail: 13430254993@139.com

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Abstract. Groundwater is an important source of drinking water in the coastal areas of Hainan Island. In order to fully understand the condition of groundwater and impact of seawater intrusion, chemical data of logging groundwater in the northeast coast of Hainan Island, which was acquired by continuous sampling tests for 25 hours in the spring and neap tide, was employed to comprehensively analyze chemical characteristics of groundwater and evaluate the water quality. The results indicate that type of groundwater is Cl–Na without being affected by tide period significantly and groundwater quality is relatively poor under the influence of seawater intrusion.

1 Introduction

Groundwater in the coastal areas is an important source of water, but water quality is susceptible to following aspects: the seawater and land sewage. Currently, groundwater problem in the coastal areas has received worldwide attention. Water quality problems on different levels were found in coastal areas of many countries, resulting in a great impact on living water of local residents and economic development. Hence, to rationally utilize and preserve groundwater source in the coastal areas, groundwater monitor and sampling were carried out in different regions, the chemical composition and water quality were analyzed and the water quality was evaluated scientifically[1,2].

Wanning city in the coastal areas of northeast Hainan Island is one of the most economically developed religions of Hainan Island. Rapidly development of economy and improvement of living standards increase water demand and groundwater exploitation in the coastal areas. Large-scale exploitation and utilization of water has brought about a series of problems such as the groundwater drawdown, saltwater intrusion and deterioration of water quality, affecting the local economic and social development and productive live. By analyzing data acquired from continuous sampling tests for 25 hours in the spring and neap tide, chemical characteristics of groundwater and water quality in the region can be further understood, thus providing references for local protection and utilization of groundwater.

2 Materials and methods

Groundwater monitoring well (coordinate is 110°31′03.57″E，18°50′15.02″N）was drilled in coastal wetland of Wanning city in northeast Hainan Island. Continuous sampling tests were carried out hourly for 25 hours in the spring and neap tide with 26 water samples acquired respectively (recording spring tide as Ⅰ, neap tide as Ⅱ). After filtered with 0.45μm filterable membrane, samples were analyzed by the hydrochemical analysis of ion in Supervision and Inspection Center in Haikou of Land and Mineral Resources Ministry. All sample analyses were completed within one day.

All parameters were analyzed using national standard (GB/T5750-2006). Each groundwater sample was analyzed for major ions (K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-), total hardness

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(TH), total dissolved solid (TDS), pH, electrical conductivity(EC), total alkalinity. K^+, Na^+, Ca^{2+}, Mg^{2+} were analyzed using flame photometer. TDS was measured in situ with a Portable electrical conductivity instrument (DDBJ-350). pH was measured with a pH meter.

Based on measured data, Statistical Software SPSS 12.0 and water chemistry software were employed to systematically analyze chemical characteristics of groundwater and reveal temporal and spatial variability of water chemistry with Durov diagram and analysis of ionic proportional coefficient.

3 Results and discussion

3.1 General parameters

All physiochemical parameters were statistically analyzed to reveal the general characteristics of groundwater quality. Levels of them were compared with the acceptable limits recommended by the standard for drinking water quality [3] and quality standard for ground water [4] to see if they were suitable for drinking.

The concentrations of K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, CO_3^{2-} and HCO_3^- are in the range of 31.4~68.4, 602.0~1950.0, 83.2~178.0, 83.4~243.0, 1110.0~3770.0, 167.0~517.0, 4.8~4.8, 101.0~145.0 mg/L, respectively. The level of Ca^{2+} and HCO_3^- are within the acceptable limits of WHO and Chinese standards (Ca^{2+}: 200 mg/L, HCO_3^-: 600 mg/L), The level of Na^+ and Cl^- in all the samples exceed permissible limit (Na^+: 200 mg/L, Cl^-: 250 mg/L), which is associated with location of logging well. The level of Mg^{2+} in 40% samples and SO_4^{2-} in 84.6% samples exceed limit(Mg^{2+}: 150 mg/L, SO_4^{2-}: 250 mg/L).

The TH (as $CaCO_3$) values range between 559 to 1450 mg/L, and all of samples have TH level higher than the permissible limit (450 mg/L) of the national standard, suggesting that the groundwater is extremely hard water, which is not suitable for domestic use. The levels of TDS are in the range of 2210.0~6840.0mg/L with an average value of 4031.92 mg/L. According to the salinity classification by Rabinove [5], groundwater were classified into non-saline/fresh water (TDS < 1,000 mg/L), slightly saline (TDS = 1,000~3,000 mg/L), moderately saline (TDS= 3,000~10,000 mg/L), and very saline (TDS > 10,000 mg/L). All samples have TDS >1,000 mg/L, indicating saline water. 13.46% of samples are slightly saline, other are moderately saline. pH is the term used universally to express the acidity or alkalinity of a solution [6]. The pH values of groundwater samples varied from 8.30 to 8.38 with a mean value of 8.33 and a standard deviation of 0.02, suggesting that the waters are slightly alkaline. The pH values for all samples are well within the permissible limits (6.5~8.5) prescribed by the national standards. The EC of groundwater varies widely between 1200 to 9500 μS/cm with an average of 6784μS/cm and 98.1% of the samples cross the permissible limit of 3000 μS/cm. The total alkalinity (as $CaCO_3$) values are in the range of 91.0~127.0, well within the permissible limit of 600 mg/L.

Sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) are always were used to evaluate groundwater for irrigation purposes in this coastal area [7]. These parameters can be calculated as follows:

$$\mathrm{SAR} = \frac{\mathrm{Na^+}}{\sqrt{(\mathrm{Ca^+} + \mathrm{Mg^+})/2}} \tag{1}$$

$$\mathrm{RSC} = (\mathrm{CO_3^{2-}} + \mathrm{HCO_3^-}) - (\mathrm{Ca^+} + \mathrm{Mg^+}) \tag{2}$$

Where, all ions are expressed in meq/L.

Groundwater with SAR < 18 and RSC<1.25 is considered suitable for irrigation. SAR is in the range of 11.08~22.32, and 25% of samples exceeded the accepted limit. RSC varied from -27.07 to -8.63, which indicates that groundwater meets the general requirements for agricultural use.

3.2 Groundwater types

Controlled by lithology, hydrogeological conditions, flow patterns of the groundwater, and groundwater in different locations is of different types. A Durov diagram (Fig. 1) was used to illustrate the relative concentrations of the different ions in the individual water samples extracted from the well. The Durov diagram shows the geochemical evolution of groundwater [8].

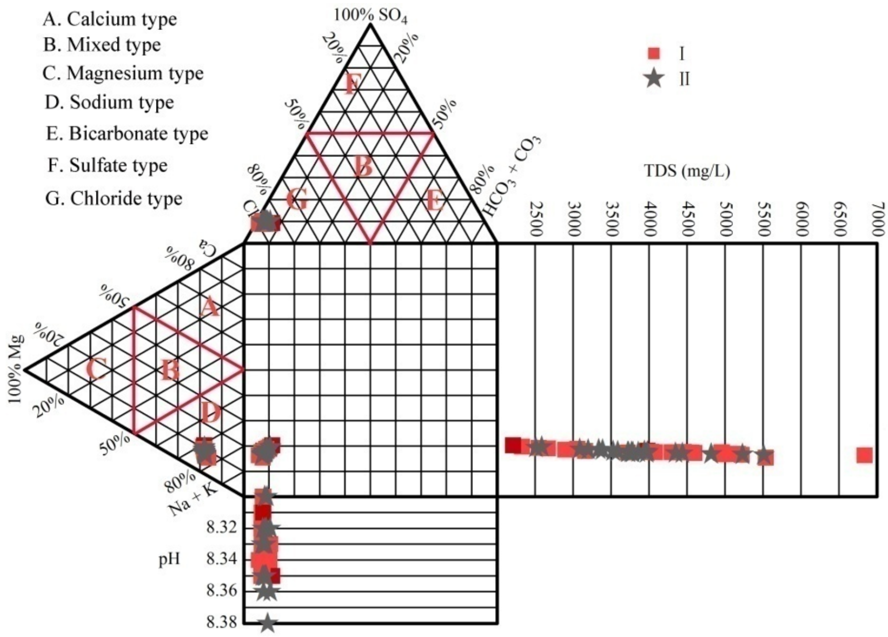

Fig.1. Durov diagram of samples

During spring tide and neap tide, samples were plotted in zone G of the upper triangle for anions and zone D of the left triangle for cations, representing Cl–Na type. Cl^- is the major anion for the groundwater, whereas Na^+ is the main cation . The relative abundance of ions is in the following orders: $Cl^- > SO_4^{2-} > HCO_3^-$ for anions and $Na^+ > Mg^{2+} > Ca^{2+}$ for cations. Cl^- and SO_4^{2-} are stable ions of seawater. Hence, large content of two ions indicate that coastal groundwater was affected significantly by seawater.

On account of rock leaching effect, evaporation and concentration effect, alternating adsorption effect of cation, mixing effect of seawater, groundwater formed its own content, proportional distribution and chemical type. The composition of fresh groundwater in coastal area was often dominated by Ca^{2+} and HCO_3^- ions which resulted from the carbonate aquifer dissolution. In seawater, the most dominant ions are Na^+ and Cl^-. Na–Cl plots can be used to identify mechanisms of groundwater evolution [9]. Fig.2 revealed relationship between Na^+ and Cl^-. All plots are above the 1:1 line, indicating that Cl^- exceeds Na^+ in groundwater and these ions are also influenced by other factors. The range of Na^+/Cl^- is 0.78~0.80 and exceed 0.5, which show that leaching effect is not the main cause while mixed seawater and cation exchange of water-bearing medium are obvious cause of formation.

In general, freshwater was dominated by calcium and seawater by magnesium, The Mg^{2+}/Ca^{2+} ratio provided an indicator for delineating the seawater–freshwater interface [2]. In general, Mg^{2+}/Ca^{2+} ratio of sea water is 5.4. According to Ravikumar [10], waters can be classified as safe (<1.5), moderate (1.5~3.0), or unsafe (>3.0) for irrigation base on the Mg^{2+}/Ca^{2+} ratio. Fig.2 showed that $Mg^{2+}/Ca^{2+} < 5.4$. The range of Mg^{2+}/Ca^{2+} is 1.59~2.33, indicating that groundwater is moderate suitable for irrigation.

4 Conclusion

Though Durov diagram and analysis of ionic proportional coefficient, coastal groundwater of logging region was dominated by Cl^- and Na^+, which show that water quality degrade seriously under the influence of saltwater tide and tide period has no obvious effect on chemical type of groundwater. Hence, it is imperative to strengthen groundwater preservation for prevention of seawater intrusion resulted from excessive exploitation of groundwater.

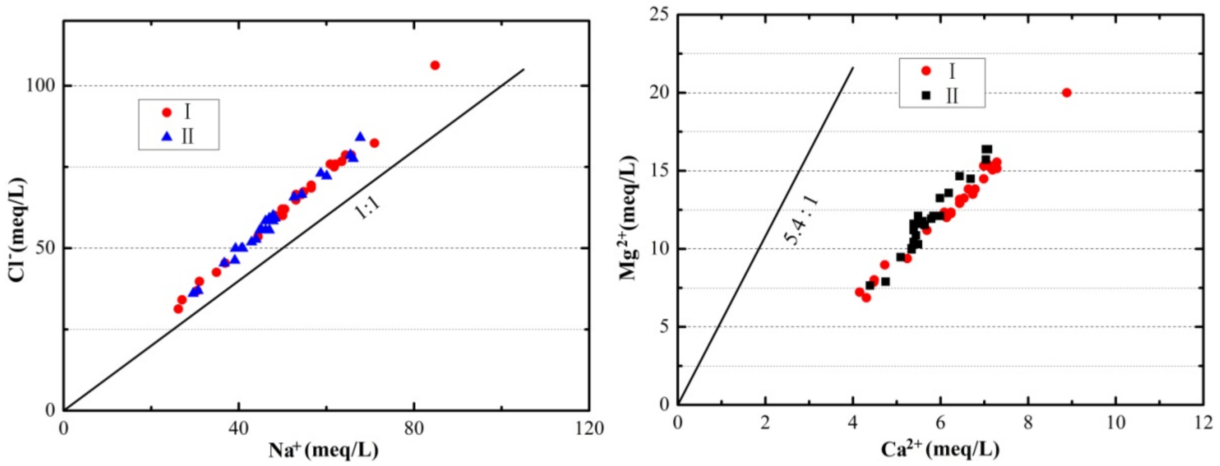

Fig.2. Plots representing relation between different ions

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