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Ground water hydrochemical characteristics: seawater intruded area in eastern and southern coast of Laizhou Bay

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Abstract: Eastern and southern coastal zones of Laizhou Bay are the most representative seawater intruded areas in the world, with two intrusion sources of contemporary seawater and paleobrine. In order to reveal the complicated hydrochemical changing process and the mechanism of fresh groundwater being polluted by saltwater, we conducted long-term observation and hydrochemical analysis at four observing sections of typical salt-fresh water transitional zone. The study indicates that seawater and brine intrusion processes have different hydrochemical features, and that ion exchange and adsorption actions between water and aquifer produce great influence on the intrusion.

Ground water hydrochemical characteristics: seawater intruded area in eastern and southern coast of Laizhou Bay ZHANG Zu-lu, JIANG Lu-guang, YANG Li-yuan, QI Yong-hua (Department of Geography, Shandong Normal University, Jinan 250014, China) Seawater intrusion is a special process of groundwater pollution. The contemporary seawater intrusion and buried paleobrine intrusion especially the latter in eastern and southern coasts of Laizhou Bay are the most representative ones in the world [1]. According to the research on seawater intrusion at home and abroad, In-depth studies on change process and mechanism of hydrochemical composition, while ion adsorption and exchange between the permeable stratum and groundwater are studied shallowly though they are of great importance on high-mineralized brine intrusion in cohesionless sands. This paper presents the recent research progress on the groundwater hydrochemical characteristics in this area and strives to push forward the studies on seawater intrusion. 1 Hydrochemical types of shallow groundwater in eastern and southern coastal plains of Laizhou Bay 1.1 Hydrochemical types and their characteristics 1.1.1 Hydrochemical types Based on more than 400 data of underground hydrochemical monitoring and analysis and applying Shukaleve classification, we can classify the hydrochemical types of surficial groundwater in the area (Table 1). 1.1.2 Combination characteristics of hydrochemical types Three characteristics of hydrochemical types can be induced from statistics: (1) Chloride water holds a dominant position, which covers a vast area north to the total salinity isotimic of 2 g/l. Na+ holds a dominant position among the cations. SO42- is a minor part among the anions. All these evidences show that the change of surficial groundwater quality in the littoral plain is mainly caused by seawater hybridization. (2) Restricted by natural environment, the hydrochemical background type of underground fresh water in littoral plain is different between the eastern and southern coastal zones. It is a narrow piedmont littoral plain in the eastern coast. Type HCO3--Ca2++Mg2+ and type HCO3-+Cl--Ca2+ are the main types of its underground freshwater. Differently, it is wide river-alluvial plain in the southern coast. Type HCO3--Ca2+ and type HCO3- -Ca2+ +Mg2+ are its main types. The discrepancy is obviously caused by the Cl- which was brought by the sea-to-land wind and removed into the groundwater[2]. (3) Type Cl--Ca2+ which seldom appears in the world is discovered in these areas. But this type is only found in the paleo-transgressive sediment. So it is a result of the remnant paleo-seawater. Table 1 Hydrochemical types of shallow groundwater in the eastern and southern coastal zones of Laizhou Bay 1.2 Regional distribution laws of hydrochemical types of groundwater From inland to coast, the anion groups´ distribution are type HCO3-, type HCO3-+Cl-, type Cl-+HCO3- and type Cl-, which are consistent with the distribution of landforms as piedmont plain, river-alluvial plain, river-marine deposition plain and marine deposition plain. They are all zonally transited from inland to coast. Along Mihe, Weihe and other main rivers, the belt of type HCO3--Cl- is ligulately projecting toward lower reaches. This indicates the freshwater supply from river to underground has played a notable role to resist the seawater intrusion. 2 Analysis on hydrochemical characteristics of seawater (brine) Discriminated by the line from Hutouai t

o Shahe town (Figure 1), seawater intrusion in the eastern coast is caused mainly by the offshore seawater. West to t he line, seawater intrusion in the coast is caused mainly by the buried paleobrine, which has been formed by paleo-tr ansgression since Epipleistocene[3]. Having gone through a long geologic period and exchanged chemical composition wi th sediment around, the chemical composition of paleobrine is different with that of the contemporary seawater. Hydro chemical characteristics of different kinds of saltwater can be seen from Table 2. The concentrations of main ions o f different saltwaters are basically consistent with each other, and their arranged order is the same one: Cl->SO42-> K+>Ca2+>Br-. Figure 1 Location of study area and isotimic of groundwater mineralization Table 2 Contrast of chemical characteristics of seawater and underground brine in the eastern and southern coast of Laizhou Bay (mg/l) By field in vestigation and water quality monitoring, three items of difference between seawater and brine intrusion can be foun d as follows: (1) There is a great difference in mineralization degree between seawater and brine. So in the transiti onal belt where seawater (or brine) and freshwater are blended, mineralization degree of the southern coast is highe r than that of the eastern coast. Furthermore, the variation of mineralization degree in southern coast is more compl icated than that of the eastern coast. (2) Variation of Cl- consistency of brine is more massive than that of seawate r. Though the mineralization (M) degree and Cl- consistency are notably interrelated, the interrelation coefficients are different in different parts of this area. This can be proved by the four M-Cl- linear regression equations (see Table 3). (3) The consistency of K+ and SO42- of contemporary concentrated seawater are higher than that of paleobrin e. The reason may be that K+ of paleobrine bas been adsorbed by stratum and SO42- of paleobrine has been combined by Ca2+ in stratum and deposited as plaster stone[4]. Table 3 M-Cl- linear regression equation of four monitoring sectio ns 3 Characteristics and mechanisms of hydrochemical variation of groundwater During the cause of seawater intrusio n, mineralization, Cl- and other ions´ consistency change obviously. 3.1 Hydrochemical variation process in salt-fres h water transitional zone It has been proved that it is not a sudden change boundary surface but a wedge-like transit ional zone with its tip on the top between salt and fresh water[5-7]. Hydraulic gradient and consistency gradient is different in different sides of the transitional zone. 3.1.1 The main ions of the original fresh water in this area a re HCO3-, Ca2+ and Mg2+. During the cause of seawater intrusion, their concentrations decrease relatively while the c oncentrations of Cl-, Na+ and K+ increase. In the salt-fresh water transitional zone, there are usually no paired ion s with concentrations surpassing 50%. They are called type Cl-+HCO3--Ca2++Na+ or type Cl-+HCO3--Ca2++Mg2+. 3.1.2 In t he salt-fresh water transitional zone, the concentration of Cl- increases rapidly with the development of seawater in trusion while the concentration of alkali metal ions does not vary obviously. Only when the milligram equivalent prop ortion of Cl- exceeds 85% and the concentration of Cl- is stable does the concentration of Na+ begin to increase fas t. Ultimately, groundwater of type Cl--Na+ forms in the transitional zone. 3.1.3 It has been proved by monitoring dat a that the variation of positive ion is complicated. Generally speaking, the concentrations of Na+ and K+ decrease wh ile the concentration of Ca2+ increases in the salt-fresh water transitional zone. On the boundary surface between fr eshwater and water in the transitional zone, the concentration of Ca2+ increases very rapidly and reaches peak valu e. While towards the freshwater side, the concentration of Ca2+ decreases rapidly (Figure 2). 3.1.4 The content of SO 42- is rather little in the coast of Laizhou Bay, and its variation is not notable during the cause of seawater intru sion. 3.2 Analysis on hydrochemical mechanism of seawater intrusion With the relative variation of ion concentration in the process of seawater intrusion, ion adsorption and exchange between groundwater and permeable stratum produce a great impact on the variation of hydrochemical characteristics[4,8]. 3.2.1 During the initial stage of seawater int rusion, the concentrations of Cl-, Na+ or K+ do not increase because of the distinct adsorption between stratum and C l-, Na+ and K+. Only when the adsorption attains its saturation point does the concentration of ions increase fast an d reach its balance state. 3.2.2 In the salt-fresh water transitional zone, the concentration variations of Ca2+ and Na+ are contrary. That is to say, the concentration of Ca2+ increases with the decreasing of concentration of Na+. Ca 2+ attains its peak concentration around the fresh-transitional water boundary surface. The plentiful of Ca2+ comes f rom two channels: one is the Ca2+ of water-bearing stratum, the other is the ion exchange between water and rock[9]. The ion exchange can be proved by the test data in Table 4. The two reasons mentioned above are accountable for the p eak concentration of Ca2+ in the salt-fresh water transitional zone. Figure 2 Hydrochemical composition variable curv e of groundwater in Baima river downstream of Longkou city Table 4 Statistics of cation content in both sides of eart h layer of saltwater intruded transitional zone at downstreams of Weihe River (mg/100g) 3.2.3 Groundwater of type SO4 2- can hardly be found in the seawater intruded area. This can be explained by two reasons: for one thing, the concen tration of Cl- is too high and the concentration of SO42- is relatively low. For another, SO42- is easy to combine wi th Ca2+, produces CaSO4 and settles down. So the concentration of SO42- is rather low in this area. As an evidence, g ypsum and other secondary calcium sediments can be easily found in the saltwater area in the southern coast of Laizho

u Bay. 4 Conclusions 4.1 Because of different intrusion sources, contemporary seawater or paleobrine, the changes of hydrochemical characteristics are different between the eastern and southern coasts of Laizhou Bay. 4.2 During the ca use of seawater intrusion, ion adsorption and exchange between water and stratum exerts a great impact on the change s of hydrochemical characteristics in permeable stratum. 4.3 As is mentioned, the relations between the mineralizatio n degree and Cl- consistency are different in the eastern and southern coast of Laizhou Bay. At present, mineralizati on degree (M, 2-3 g/l) and Cl- consistency (200-300 mg/l) are used as judgment index for seawater intrusion. It has b een proved that utilizing a single index is rather limited to solve the problem. If the two indices are used simultan eously, their judgment can hardly be unified. So the research on multi-index comprehensive judgment should be strengt hened in the future. References

关键词： seawater intrusion; eastern and southern coastal areas of Laizhou Bay; hydrochemical characteristics of groundwater

