Study on division of groundwater function zones in Pingtan Island

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Abstract. Based on the topography, geomorphology, groundwater exploitation and other hydrogeological data of Pintan Island, the study area was divided into three levels and basic evaluation units were divided. According to the zoning principle of Technical Outline of Groundwater Function Zoning in China, and through the spatial analysis function of ArcGIS, the zoning index data was spatialized and the overlay analysis was carried out. The study area was divided into three types of first-level function zones and eight types of second-level function zones. Moreover, the groundwater function zones map of the study area was drawn. Relevant results can provide reference and basis for relevant departments to develop, utilize and protect groundwater.

1. Introduction

Groundwater resources refer to the water resources that exist in the surface of the earth crust and can be used by human beings, which is an important part of water resources[1]. Groundwater not only provides water for human production and living, but also plays an important role in maintaining the ecological environment and stabilizing the geological environment. In recent years, unreasonable exploitation of groundwater in some areas has led to the decline of groundwater level and the drainage of aquifer, which led to the degradation of surface ecosystems, environmental and geological problems[2-5]. The above problems have greatly affected the function of groundwater, and have seriously threatened the long-term development of social economy[6]. In order to improve this phenomenon and realize sustainable utilization of groundwater, it is urgent to divide groundwater function zones.

In order to better divide the groundwater function zones, the Ministry of Water Resources of China compiled the Technical Outline of Groundwater Function Zoning (hereinafter referred to as the Outline) in 2005. Meanwhile, it proposed the two-level groundwater zoning system and clarified the basis for the division of each function zone. In 2006, Ministry of Land and Resources compiled Technical Requirements for Groundwater Function Evaluation and Zoning, which stipulated the main contents, evaluation system and evaluation methods of groundwater function zones. Subsequently, more scholars conducted further research on groundwater function zones on this basis[7-8]. Based on the Outline and the hydrogeological data of the Pintan Island, the basic evaluation units of Pingtan Island were divided. Moreover, through the spatial analysis function of ArcGIS, the groundwater function zones of Pingtan Island were divided and the map of the groundwater function zones of Pingtan Island was drawn and visualized in this paper. The zoning results can provide reference for the relevant departments to formulate the development, utilization and protection policies for groundwater in Pingtan Island.

2. Study area

Pingtan Island is located in the eastern sea area of Fujian Province, China, with a land area of 267.13
km². It is the largest island in Fujian Province. The terrain of Pingtan Island is high in the north and south and low in the middle. Most of the southern and northern parts are undulating hills and low mountains, while the central part is a marine and aeolian plain. Pingtan belongs to the south subtropical maritime monsoon climate, with annual precipitation of 1100 mm and abundant rain flood resources. However, the river system in the Island is extremely undeveloped, the stream is short and the runoff is fast, all of which flow into the sea alone, and the surface runoff is difficult to use effectively. The shortage of water resources has seriously restricted Pingtan's social and economic development. Therefore, under the premise of rational development and utilization of surface water, the rational planning, development and utilization of groundwater resources is particularly urgent.

3. Division of groundwater function zones

3.1. Division of groundwater evaluation unit

In order to objectively characterize the spatial distribution of groundwater function in the study area, the study area was divided into three levels and the basic evaluation units were divided according to the topography, geomorphology, hydrogeological conditions and other hydrogeological data of Pingtan Island. During the process of division, the whole Pingtan Island was regarded as a first-level evaluation area. Pingtan Island was divided into plain areas and hill areas according to the topography and geomorphology of Pingtan Island. And the hill areas were divided into hill-population residential area and hill-population non-residential area according to the population distribution. Thus, the first-level evaluation area was divided into three parts. Then, the watershed of Pingtan was divided by the “Hydrological Analysis” module of ArcGIS based on the DEM data of the study area, and the first-level evaluation area was divided along the boundary of divided watershed, which was used as the second-level evaluation area. Subsequently, the second-level evaluation area was divided by the boundary of the main surface reservoir, reclamation area, salt field and seawater intrusion area of Pingtan Island, which was used as third-level evaluation area. And the third-level evaluation area was used as the basic evaluation unit of groundwater function in the study area.

3.2. Zoning indexes of groundwater function

According to the dividing principle of the Outline and the actual situation of Pingtan, groundwater exploitable quantity modulus, single well water yield, groundwater mineralization, and groundwater quality were selected as zoning indexes in this paper.

3.2.1. Groundwater exploitable quantity modulus. The groundwater exploitable quantity modulus refers to the exploitable quantity of aquifer per unit area, which is an important factor to measure the exploitable potential of aquifer. According to the 1:50000 Hydrogeological Survey Results Report of Pingtan, the aquiferous rock formations and their exploitable quantity modulus in the study area were shown in Table 1. The exploitable quantity modulus was assigned to different zones by ArcGIS, and the distribution map of groundwater exploitable quantity in the study area was obtained, as shown in figure 1.

| Aquiferous rock formation | Exploitable quantity Modulus $M_o\times10^4\text{m}^3/\text{a} \cdot \text{km}^2$ |
|--------------------------|---------------------------------------------------------------------------------|
| Bedrock                  | 4.25                                                                             |
| $Q_{p1}$                 | 3.16                                                                             |
| $Q_s$                    | 17.50                                                                            |
| $Q_h$                    | 35.88                                                                            |
3.2.2. Single well water yield. Single well water yield is an important index to measure the water abundance of the aquiferous rock formations. According to the data of the Pingtan Hydrogeological Report, the single well water yield data of 38 pumping boreholes in the study area was selected in this paper, and the inverse distance weighted method was used for spatial interpolation in the study area. The distribution map of single well water yield in study area was obtained and shown in figure 2.

3.2.3. Groundwater mineralization. Groundwater mineralization is an important factor for groundwater function zones. The distribution map of groundwater mineralization in the study area was shown in figure 3.

3.2.4. Groundwater quality. Referring to the Groundwater Quantity Standard (GB/T14848-93), thirty-four groups of water quality data were obtained, then eighteen components including pH, total hardness, SO$_4^{2-}$, Cl$^-$, Fe, Mn$^{2+}$, volatile phenols, NO$_3^-$, NO$_2^-$, NH$_4^+$, F$^-$, cyanide, Hg, As, Cd, Cr$^{6+}$, Pb and groundwater mineralization were selected as comprehensive items to evaluate groundwater quality by the comprehensive evaluation method. Moreover, the distribution map of groundwater quality in the study area was drawn, as shown in figure 4.
3.3. The system and basis of groundwater function zone

According to groundwater recharge and exploitation conditions, groundwater quality, the demand for groundwater development in the planning period and the requirements of ecological civilization in the study area, the groundwater function zone is divided into two levels.

3.3.1. Zoning basis.
(1) First-level function zone.
Groundwater first-level function zones were divided into three types: development zones, protection zones and preserved zones. They mainly coordinate the relationship between water use for social development and ecological protection, reflecting the overall deployment of the state for rational development, utilization and protection of groundwater resources. The bases for first-level function zones in the study area are consistent with the Outline.

(2) Second-level function zone.
On the basis of dividing the first-level function zones, the second-level function zones of groundwater are divided according to the dominant function of groundwater resources. The second-level function zones of groundwater mainly coordinates the relationship among regions, water departments and different groundwater functions. Except that the division basis of geological hazard prone zone is different from that of the Outline, the division basis of other second level function zones is the same as that of the Outline. The division basis of geological hazard prone zone is as follows.

In the coastal areas of the sandy coast, the area within 300-500 m of the coastline is prone to sea water intrusion; In the area of saltwater intrusion area caused by groundwater exploitation, the area of saltwater intrusion area is determined by extending the saltwater aquifer area 300-500 m inward; Due to the hydrological structural characteristics of groundwater, areas where groundwater quality is extremely vulnerable to pollution.

4. Results and analysis of groundwater function zones

According to the division principle of the Outline, Pingtan Island was first divided into three types of
first-level function zones: development zone, protection zone and preserved zone. On this basis, taking the first-level function zone as the vector base map, then using the spatial analysis function of ArcGIS, the spatial data of the corresponding two-level function zoning index was analyzed and the overlay analysis was carried out. Then, the government's groundwater plan and the hydrogeological status were combined, the first-level function zones were divided into eight types of second-level function zones: centralized water supply water source zone, decentralized development and utilization zone, ecologically fragile zone, geological hazard prone zone, groundwater source conservation zone, unsuitable exploitation zone, reserve zone and emergency water source zone. The groundwater function zones in the study area was shown in figure 5.

4.1. Development zone
The development zone was divided into two second-level function zones: centralized water supply water source zone and decentralized development and utilization zone. Moreover, the area of decentralized development and utilization zone was larger than that of centralized water supply water source zone. The centralized water supply water area was mainly distributed in the plain area with better water abundance in Pingtan Island, including Jianglou-Jiudian-Shangpan, Luyangpu, Lianjiupu, Longwangtoupu, Qilipu and Yangzhongyangpu. Because of the existence of decentralized exploitation model of one household-one well in the residential area, there were densely populated hill areas and poor water abundance plain areas such as Baiqing Town, Su’ao Town, Beicuo Town, Ao’dong Town and Ao’qian Town, which were divided into decentralized development and utilization zone.

4.2. Protection zone
The protection zone was divided into three types of second-level function zones: ecologically fragile zone, geological hazard prone zone, and groundwater source conservation zone. The ecologically fragile zone was distributed in the Thirty-Six-Foot Lake provincial nature reserve and the Island National Forest Park with ecologically significant in the study area. The groundwater source conservation zone was mainly distributed in the bedrock mountainous area with important ecological significance, capable of ensuring a certain ecological base flow, and the confluence area of important reservoirs in the study area, which mainly distributed in the bedrock mountainous areas of Su’ao Town and Beicuo Town and Jun Mountain area. Combined with the hydrogeological data of the study area, the geological hazard prone zone was mainly distributed in Zhonglou-Lancheng, Changjiangao, Liushui-Xilou, Haitan Bay, Tanan Bay and the west side of reclamation area.

4.3. Preserved zone
Preserved zone was divided into three types of second-level function zones: unsuitable exploitation zone, reserve zone and emergency water source zone. The unsuitable exploitation zone was mainly located in reclamation area, seawater intrusion area of Yangchaoyu-Guayu and salt field area of Huoshao Port. The reserve zone was mainly distributed in the Xiakunhu-Daping, Shanglou-Gongdong-Liushui Town, Beilou and Zhongjingbian areas, which had good groundwater storage and exploitation conditions in this area, and human activities were rare in the current planning period. Emergency water source zone was mainly located in Zhonglou, Xinlou and Hutou areas. The emergency water source zone of Zhonglou and Xinlou belong to Junshan piedmont plain area. The groundwater in the emergency water source zone of Hutou had a higher water abundance. Moreover, the conditions of groundwater storage, exploitation and water quality were good in these areas.
5. Conclusions
The study area was divided into three levels and basic evaluation units were divided in this paper. According to the zoning principle of the Outline, the study area was divided into three types of first-level function zones in development zone, protection zone and preserved zone, and eight types of second-level function zones: centralized water supply water source zone, decentralized development and utilization zone, ecologically fragile zone, geological hazard prone zone, groundwater source conservation zone, unsuitable exploitation zone, reserve zone, and emergency water source zone. The spatial patterns of groundwater development, protection and retention in the study area are clearly defined, which provide the basis and reference for the government to further formulate policies.

From the groundwater function zones results, we can see that the plain areas with better water abundance are mostly divided into groundwater development and utilization areas. During the development and utilization process, relevant departments should carry out planned recharging and exploitation to achieve scientific regulation and storage. The bedrock mountain area with sparse population in the study area has rich groundwater and good water quality, which plays an important role in groundwater conservation. The government can establish a protected area to reduce the impact of human activities, strictly prohibit to discharge pollutants into water bodies and protect important reservoir water sources and nature reserves. In the unsuitable exploitation area of the study area, there are seawater intrusion, high degree of mineralization and other pollution problems. The government can regulate groundwater in these areas, limit artificial exploitation, adopt water-saving projects and water transfer projects to meet people's water demand and avoid further expansion of unsuitable exploitation zones.

Figure 5. Groundwater function zones map.
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