Characteristics of seawater intrusion in the coastal area of Weihai

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Abstract. Based on the comprehensive investigation, sampling and analysis of hydrogeology and environmental geology, this paper analyzes the characteristics of seawater intrusion in the coastal area of Weihai and points out the influence of human engineering activities on seawater intrusion in the area.

1. Introduction

Seawater intrusion refers to the phenomenon that seawater moves inland and disperses, resulting in saltiness of fresh water under the influence of natural and human factors. Seawater intrusion will cause great losses to industry, agriculture and people's life, and will cause industrial wells to be abandoned, machinery to be damaged, water supply to be polluted, agricultural irrigation water is scarce, crops are withered, and the environmental quality of farmland soil becomes worse, residents have difficulty in drinking water and a series of other problems. The seawater intrusion front in this work is based on the water quality analysis and the Cl-content is more than 250 mg / L as the main criterion.

2. General situation of the seawater intrusion

Under the influence of chloride and salt in seawater, the Cl-content in regional groundwater is dominant, forming chloride groundwater. The quaternary pore water near the coast is mostly brackish and salt water with TDS greater than 1 g / L, and the rest is fresh water with TDS less than 1 g / L.

The seawater intrusion mainly occurs in the areas where the groundwater is abundant, the exploitation is concentrated and the amount of exploitation is large, which leads to the decrease of groundwater level, and in the areas near the seawater, it is also caused by the change of farming methods or the improper exploitation of coastal beaches.

The seawater intrusion in Weihai was divided into two stages: the first stage in 1992-1993 and the second stage in 2003-2016.

During 1992-2003, the area of seawater intrusion in Weihai increased greatly, and the area of each district and city increased in different degree, especially in Wendeng district (Table 1.). The first survey of seawater intrusion in 1992 found that seawater intrusion made drinking water difficult, but due to the small area of seawater intrusion, the problems caused by seawater intrusion did not attract enough attention. From 1999 to 2001 [1-4], the Weihai suffered from three years severe drought, the surface water supply was insufficient, which led to the exploitation of groundwater, the seawater intrusion in the coastal area developed rapidly, and the groundwater environment in the coastal area continued to deteriorate, the problem of drinking water security has aroused the high attention of the
relevant departments, and the understanding of controlling seawater intrusion and protecting groundwater resources has raised the strategic height [5-6]. The government has issued and formulated a series of laws, regulations and policies for the rational development and utilization of groundwater, such as reducing the exploitation of groundwater through price leverage, stopping the exploitation wells of groundwater in seawater intrusion areas, and expanding the centralized surface water supply pipeline network, expanding the area of centralized water supply. The implementation of these measures has effectively protected groundwater resources, effectively contained the trend of seawater intrusion and restored the groundwater environment in some areas.

| Table 1. Statistical table of seawater intrusion area in Weihai (1992-2003). |
|---------------------------------------------------------------|
| **Years** | **Huancui** | **Wendeng** | **Rongcheng** | **Rushan** |
|------------|-------------|-------------|---------------|-----------|
| 2003       | 24.5        | 189.0       | 37.4          | 34.0      |
| 1992       | 3.4         | 86.9        | 25.4          | 17.7      |
| Area change| +21.1       | +102.1      | +12.0         | +16.3     |
| Unit of area: km² |                 |             |               |           |

During 2003-2016, the overall development trend of seawater intrusion has been effectively stopped, and the total area of seawater intrusion has been decreasing. The key areas (over-exploited areas in Wendeng) have been recovered to a greater extent, but the specific situation varies from district to district and city, and the invasion area of sea water in Wendeng, Huancui District and Rushan, Shandong has been reduced to a greater extent. The invasion area of Rongcheng sea water was basically unchanged (Table 2.).

| Table 2. Statistical table of seawater intrusion area in Weihai (2003-2016). |
|---------------------------------------------------------------|
| **Years** | **Huancui** | **Wendeng** | **Rongcheng** | **Rushan** |
|------------|-------------|-------------|---------------|-----------|
| 2016       | 10.8        | 51.0        | 38.6          | 9.0       |
| 2003       | 24.5        | 189.0       | 37.4          | 34.0      |
| Area change| -13.7       | -138.0      | +1.2          | -25.0     |
| Unit of area: km² |                 |             |               |           |

3. Seawater intrusion mode
There are several main ways of seawater intrusion in this area.

3.1 Bedding invasion
This type of seawater intrusion mainly occurs in the alluvial and flood plain areas where rivers flow into the sea. The aquifers in these alluvial plains are layered, with seawater penetrating inland along the aquifers to form bedding invasion. For example, at the mouth of the sow river in the Wendeng area and at the mouth of the Rushan River in the Rushan, Shandong area, the sand layers of the quaternary system permeate inland. In the area with large thickness of quaternary system, the strata are generally of multi-element structure, and there are several aquifers at the same time.

3.2 Along the ancient river, fault zone invasion
Palaeochannel and fault zone usually have strong permeability. If the groundwater level drops, the seawater often invades along these structural zones, and the invasion speed is very fast.

3.3 Along the modern riverbed invasion
This intrusion mainly refers to the upward intrusion of sea water along the low-lying modern riverbed at high tide. Especially in recent years, the illegal sand excavation in the riverbed under the condition of generally small runoff has reduced the riverbed and intensified the speed of seawater intrusion.
3.4 Intrusion along bedrock weathered layer and semi-weathered layer
The quaternary thickness of Weihai is generally small. The underlying bedrock is composed of metamorphic rocks, clastic rocks, weathered rocks of gneiss, etc. Seawater also invades along the weathered and semi-weathered layers of bedrock. It's a rare condition.

4. Main influencing factors of seawater intrusion

4.1 Groundwater overdraft
Due to the rapid economic development of coastal areas, water resources shortage, the contradiction between supply and demand has become increasingly acute. Since the mid-1970s, more and more wells have been drilled in the coastal plain area. Under the condition of insufficient recharge of groundwater, the groundwater level is decreased greatly, and the area of negative value area is enlarged, which leads to seawater intrusion. In its natural state, freshwater in the aquifer is discharged towards the sea. When the mining amount exceeds the recharge amount, the groundwater level drops continuously and is lower than the sea level, the groundwater dynamic plane change state is changed, and the water level drop funnel appears. Or there is no funnel, but the water level is below sea level and falling. Groundwater flows to the center of the funnel or to low water levels below sea level, where seawater enters the channel.

4.2 Hydrologic and hydrogeological conditions
The underground brackish brine in Weihai is mainly distributed in the total brackish water hydrogeological zone and the brackish fresh water mixed hydrogeological zone. In the brackish water area, there is no shallow fresh water above the salt water body, and the salt water body invades the fresh water area in a wedge shape. In the multi-layer structure of brackish water, the salt water body is overlain with shallow fresh water body. If years of drought, less precipitation, river water cut-off lead to lower underground fresh water level, then the tide upstream inland, seawater back into the infiltration rate will be accelerated. On the contrary, when the river is full of water, the upstream of the tide will be supported, on the one hand, the distance will be greatly shortened, on the other hand, the concentration of salt in the mixed water of the sea and river will be low, the groundwater level on both sides of the river will be high, and the difference between the sea and fresh water level will be reduced, seawater infiltration will be limited. If there is a hydraulic connection between sea water and fresh water in the strong pervious layer, as long as the sea water potential is higher than fresh water potential, and the sea-fresh water balance is destroyed, the sea water will move to the land. Seawater intrusion is not likely to occur unless there is a natural barrier, such as a water-resisting fault or an impermeable rock mass, between seawater and a water-bearing sand-gravel layer or a silt-sandy layer, or if the sand-gravel layer is completely enclosed by an impermeable layer such as a clay layer. Weihai coastal plain generally thick sand, coarse particles, good water permeability, low elevation. This highly permeable formation provides a favorable channel for seawater intrusion.

4.3 The effects of storm surges
Storm Surges sometimes occur along parts of the coast of Weihai. The storm tide level is high, generally 3-5 m, and the tide invades the land area widely, may reach 5-10 km, may cause the sea water to pour into the infiltration. At the same time, the tide upstream support, but also aggravated the intrusion of sea water. Combined with the coastal meteorological, hydrogeological and topographic conditions, the impact of storm surge on the sea water intrusion in the estuary area is more obvious.

4.4 Unreasonable utilization of tidal flat
A large amount of sea water has been artificially transported into the inland hinterland by the blind development of artificial sea-water farming in the coastal areas, by pumping sea water into open channels or drilling deep wells over a long distance. Since the 1990s, some villagers in the coastal area blindly developed the artificial sea water to raise shrimp and fish, which caused a large amount of sea
water to enter the land artificially and aggravated the sea water invasion. Villagers dig pits and fill them with water to breed in the salinized fields at the head of their village. At the beginning, some villagers transported seawater for cultivation from a distance, but later they began to use the local underground brine, which made the underground brine invade the inland fresh water from the ground and the surface respectively, thus speeding up the seawater invasion. Land-based farming and sun-baked salt are continuously extracting the underground brine while also salinizing the cultivated land around them.

4.5 The effects of hydraulic engineering
We have built a series of reservoirs, dams, sluice gates and other water interception works in the upper reaches of the rivers that flow into the Weihai Sea to intercept surface runoff from the upper reaches, causing severe water shortages in the middle and lower reaches. Groundwater recharge is greatly reduced, especially in dry years when rainfall is low, and there is little surface runoff in the lower reaches of the river, which cuts off the recharge of the groundwater in the lower reaches and aggravates the water level decline and seawater intrusion. At the Muzhu river and the Rushan river in Weihai, due to the lack of groundwater recharge, high tide water upstream accelerates the occurrence of seawater intrusion.

5. Hydrochemical characteristics of seawater intrusion zone
The seawater intrusion seriously affected the quality of groundwater in the region. The groundwater in the coastal plain area without seawater intrusion is HCO₃-Ca or HCO₃-Ca Mg type water. The chemical composition of the water is mainly Ca²⁺, Mg²⁺ and HCO₃⁻, and the TDS is about 0.5 g / L. Under the influence of seawater intrusion, the contents of Cl⁻ and Na⁺ in groundwater increased, the contents of Ca²⁺, Mg²⁺ and HCO₃⁻ decreased, and mixed water was formed. The Cl⁻ content and the Na⁺ content in seawater increased sharply, and the TDS exceeded 1.0 g / L, which was called as Cl-Na type water.

According to the collected and monitored data, the groundwater quality in the seawater intrusion area is mainly affected by the location of the intrusion salt water body, but the overall trend is deteriorating. The horizontal spatial variation of F ion in groundwater shows that the correlation between Cl and F is more than 80% in the south China sea water intrusion area of Laizhou Bay, and 250 mg / L of Cl ion corresponds to 2 mg / L of F ion.

6. Conclusion
The seawater intrusion in Weihai was divided into two stages: the first stage in 1992-1993 and the second stage in 2003-2016. In the first stage, the area of seawater intrusion increased greatly, while in the second stage, the trend of seawater intrusion slowed down and the area of seawater intrusion decreased. Human engineering activities such as groundwater exploitation, tidal flat utilization and hydraulic engineering construction have a significant impact on seawater intrusion in the area.

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