Study on water quality of tunnel type underground reservoir in island areas

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Abstract. The water quality of tunnel type underground reservoirs was good generally, problems such as turbid water, weak pH, and excessive total colony problems are common. Some underground reservoirs were affected by water supplement sources, the water quality was uncertain and always with high concentrations of total nitrogen, nitrate nitrogen, manganese, zinc, etc. Therefore the water quality monitoring of water supplement sources and storage needs to be strengthened and appropriate follow-up water purification measures should be taken.

1. Introduction
In order to make full use of water resources without occupying land resources and ensure the safety of water use in island areas, the construction scheme of underground storage reservoir is proposed, which provides new solutions for increasingly prominent constraints and new ideas for comprehensive development of water resources. The underground reservoir is an exploration of the comprehensive development and utilization of water resources in the island area, which is characterized by insufficient water resources storage capacity, weak flood control and drainage capacity, and low water resources guarantee. In recent years, through the transformation and utilization of abandoned tunnels on the island, Zhoushan City has realized the water storage and internal networking of 35 tunnels on 6 remote islands, with an annual effective water supply of more than 70000 m³, effectively ensuring the water safety of residents on remote islands.

The application and research of underground reservoir in China has a history of more than 40 years [1-4]. However, the research on underground reservoirs was mainly focused on natural underground reservoirs, while the research on artificial tunnel-type underground reservoirs is basically in a blank situation [5], especially the water quality evolution of tunnel water storage, which is a direction worthy of attention.

2. Water demand characteristics in island areas
Zhoushan City has a typical tunnel-style underground reservoir for 2.5 years in the biggest island. The water quality of the reservoir was monitored and analysed from the date of impoundment [6], the result showed the water quality remains stable and in a good level, and the turbidity and organic pollution are low. The main problems are that the pH, TN, TP, manganese, turbidity and the total number of bacteria exceed the drinking water quality standards, so they cannot be directly used as drinking water and
require subsequent purification treatment. There are also others tunnel-style underground reservoir in other islands of Zhoushan City, the basic characteristics of four typical projects are listed in Table 1.

Table 1. Basic characteristics of typical reservoirs

| Characteristics                  | reservoir 1       | reservoir 2   | reservoir 3       | reservoir 4       |
|----------------------------------|-------------------|--------------|-------------------|-------------------|
| Closed situation                 | Fully Enclosed    | Semi-closed  | Semi-closed       | Semi-closed       |
| Groundwater infiltration         | Not obvious       | Obvious      | Not obvious       | Not obvious       |
| Exchange with other water sources| No                | No           | Surface reservoirs, pit wellwater | Surface reservoirs |

3. Characteristics of storage water quality changes

3.1 Change trends in Key Indicators

PH is rising and weakly alkaline. The sea water is generally alkaline due to its large amount of soluble carbonate, and the offshore groundwater is also alkaline. When the water source was injected in 2017, it was neutral. With the exchange with groundwater, the pH of the stored water gradually rose and became weakly alkaline. Permanganate index and COD showed a downward trend. This may be because in the absence of external input, organic pollution is gradually reduced due to the self-purification ability of the water body.

The TN shows an upward trend after first decline. Initially, in the absence of external input, the TN gradually decreased due to the self-purification capacity of the water body; however, due to the impact of rainfall and groundwater infiltration, the nitrogen in the water quality was gradually increased due to the sedimentation of nitrogen sources in soil and groundwater caused by activities such as pesticide and fertilizer. Among them, the TN of the underground reservoir with more obvious groundwater infiltration is significantly higher than that without obvious groundwater infiltration. While total nitrogen increased, nitrate nitrogen increased, while ammonia nitrogen and nitrite nitrogen were lower. Nitrate nitrogen is the final product of the oxidative decomposition of nitrogen-containing organic matter, indicating that nitrogen and other pollution may exist in the soil and groundwater in the early years, but water pollution has tended to be self-purification. Nitrate nitrogen itself is non-toxic or low-toxic, but if the content is too high, it is easy to form nitrite in the human body, which is harmful to human health.

3.2 Impact of water source

Figure 1-3 show the comparison of the main water quality indicators of different reservoirs. Compared with fully-closed reservoir 1, semi-closed, especially reservoir 3 and reservoir 4 which connected to the surface water source, have higher water temperature, dissolved oxygen and other indicators, with obvious variation range, which are greatly affected by the supplemental water source.

Compared with a tunnel connected to surface water sources, an independent tunnel, especially a groundwater infiltration tunnel, has a higher total nitrogen. Through the monitoring of surface reservoir water source in the same period, the TN concentration was below 0.9mg/L. Through the supplementation of surface water, the TN of reservoir 3 was maintained below 3 mg/L. In comparison, the TN of reservoir 1 without water supplement and no obvious groundwater infiltration was maintained at about 4mg/L, and the TN of reservoir 2 without water supplement and with obvious groundwater infiltration was maintained at about 6mg/L, even above 7 mg/L in May 2019. It showed that with fissure water as the main water source, the TN of the storage water quality is on the high side, while with surface reservoirs as the main water source, the quality of the stored water is affected by the water quality of the surface reservoir.
Figure 1. Temperature change of reservoir water

Figure 2. Oxygen change of reservoir water

Figure 3. Total nitrogen change of reservoir water

4. Follow-up water treatment measures
According to the different water quality characteristics, different follow-up measures were recommended. Because the underground reservoir is less disturbed, the turbidity is usually below 3 NTU, other indicators are better, the main problem is that the total number of colonies exceeds the standard. Therefore, the basic conventional treatment process, including mixing, flocculation, sedimentation (clarification), filtration, disinfection and other treatment units, can be generally used.

When the external water source is poor, leading to the increase of pollutants in raw water, the purified water through the conventional treatment process cannot reach the water quality standard. The pretreatment should be added before the conventional treatment process to solve the problem of polluted drinking water source treatment. The main pretreatment processes include biological pretreatment, chemical pre oxidation, powder activated carbon adsorption, etc.

When the iron content in the water is high, the iron removal process should be adopted. The iron removal methods mainly include aeration oxidation, chlorine oxidation, contact filtration oxidation and
potassium permanganate oxidation. When the manganese content in the water is high, a manganese removal process should be used. Manganese in groundwater generally exists in a divalent form and is the main object for manganese removal. Manganese cannot be oxidized by dissolved oxygen, and it is also difficult to be directly oxidized by chlorine. The main methods for removing manganese include potassium permanganate oxidation, chlorine contact filtration, and biological manganese removal. When the fluoride content in the water exceeds the standard, the defluorination process should be adopted, which mainly includes coagulation sedimentation method, ion exchange method, activated alumina adsorption filtration method, membrane method, etc.

When the raw water is polluted or the drinking water quality standard is high, membrane treatment technology is adopted, mainly including reverse osmosis, nanofiltration, ultrafiltration, microfiltration, etc. The process energy consumption and drug consumption are low, and no adverse by-products are produced, but the cost of membrane investment needs to be reduced. Because the pore size of the ultrafiltration membrane is smaller, the retention rate of particulate matter, especially pathogenic microorganisms and viruses is higher, and it is safer to use ultrafiltration in the drinking water field.

5. Conclusion
The common problem of water quality in underground reservoir was that pH is weakly alkaline, turbidity and the total number of colonies exceed the standard, and cannot be directly drunk. Some underground reservoirs were affected by the early pollution of the surrounding environment, soil and groundwater, and the TN and nitrate nitrogen were relatively high. Some underground reservoirs were affected by the surrounding geology and groundwater, and the trace elements such as manganese and zinc exceed the standard. Some underground reservoirs were connected with the surface water source, and the water quality is uncertain due to the influence of the water source. Therefore, it is necessary to strengthen the water quality monitoring of supplementary water sources and storage water, and take appropriate follow-up water purification treatment measures.

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