Treatment of recharge water during the subway construction in Nantong

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Abstract. Water recharge is a key point to the construction of metro foundation pit, hence recharging water should be treated in order to make sure that the quality of water satisfies the need of protection of environment and recharging well. The aquifers in Nantong contain lots of ferrous ions and manganese ions, and are very heterogeneous in regions and layers. Shanghai Changkai Geotechnical Engineering Co., Ltd studies about the water treatment and finds the appropriate filter materials, suitable thickness of these materials and size of sieve by the experiment in small water treatment installation. The result of experiment is applied in great water treatment installation and good results have been achieved.

1. Introduction

The geological engineering conditions along the subway in Nantong area are quite complex. The aquifers involved in the construction of subway in Nantong are mainly sand and silt layers which have a large thickness and abundant water content. Usually the subway crosses the downtown district with many surrounding buildings which leads to high environmental protection requirements. The dewatering of foundation pit during the construction is likely to cause settlement of surrounding strata and deformation of structures, seriously affecting the safety of subway construction. For settlement sensitive areas, two approaches are mainly used to reduce the formation deformation caused by dewatering: deepening waterproof curtain and groundwater recharge. Because the method of deepening waterproof curtain is pricy, and the effect of deep water proof curtain is difficult to guarantee (especially under the condition of thick sand layer), studies about groundwater recharge is of great significance to the construction of subway foundation pit.

Based on cost considerations, groundwater pumped in the foundation pit is often used for recharge outside the pit. Recharge wells are often blocked due to suspended solids, bubbles, chemical ions, microbial growth, and fine-grained media of the aquifer, affecting the recharge effect. In addition, in order to protect the surrounding environment of the recharge area, the water quality of the recharged water must be superior to the water quality of the original groundwater to ensure that the water quality of the regional groundwater will not be adversely affected after recharging. Therefore, it is necessary to treat the underground water before the groundwater is recharged so as to ensure that the water quality of the recharged groundwater satisfies the needs of protecting the environment and extending the life of the recharge well.

According to the Nantong City Environmental Status Bulletin [1], the iron and manganese content of the groundwater in Nantong area is relatively high, for example, the iron ion averagely exceeds 18 times above national standard, and the maximum exceeds 73 times in some area. The excessive iron and manganese in the water is detrimental to domestic drinking and industrial water. Excessive levels of iron
and manganese affects the central nervous system of human beings, has an serious impact on intelligence and reproductive function, and can cause loss of appetite, vomiting, diarrhea, and gastrointestinal disorders. When the concentration of iron and manganese exceeds a certain limit, a reddish-brown precipitate will be produced, which will turn the white fabric into yellow, block the water supply pipe, and leave a yellow spot on the vessel and sanitary utensils. In industry, when used in textile, printing and dyeing, knitting, paper and other industries, it will affect the quality of products. In production, the boiler can be scaled, the ion exchange resin can be poisoned, the rust stain can be generated on the textile, and the brewed beverage can be discolored and tasted. If groundwater is not treated, direct recharge will inevitably affect the water quality of other aquifers, which will adversely affect residents’ lives and industrial water use [2] [3].

In addition, the application of groundwater source heat pump in the main urban area of Nantong City is mainly in the first confined aquifer in the upper layer, and most of them are also the target layer of subway dewatering and recharging. The future use of the dewatering well and the recharge well as the groundwater source heat pump for subway stations is also a direction for future research. High-iron manganese water easily breeds iron-manganese bacteria, blocks pipes, corrodes metals, affects the normal use and life of pumping equipment, and affects the efficiency of groundwater source heat pump. Therefore, it is necessary to analyze and treat water quality in groundwater in Nantong area to remove iron and manganese ions from groundwater.

Regarding the related research on groundwater to remove iron and manganese, many researchers [4] [5] have conducted a lot of research on their local engineering practice, which are mainly divided into three categories: natural oxidation method, aeration contact oxidation method and microbial oxidation method. Besides microbial methods, other related processes are mature enough to be applied in practice. However, there are few targeted studies on groundwater in the Nantong area. At the same time, most of the research is directed to the process of the operating environment of the waterworks, and there are few relevant studies on the conditions of groundwater pumping and recharge. For example, aeration contact oxidation method for long-term exposure to groundwater, natural oxidation of oxygen in the air, can be carried out under the conditions of the tap water plant, and in the process of pumping and recharging, due to the large flow velocity of the inlet and outlet water, the oxidation is not sufficient and difficult to achieve.

Therefore, it is necessary to study how to effectively and economically remove iron and manganese ions from groundwater during the construction process, and summarize the operation rules for groundwater pumping and recharge of iron and manganese.

2. Analysis of groundwater quality in Nantong

Shanghai Changkai Geotechnical Engineering Co., Ltd. is entrusted by Nantong Urban Rail Transit Company to conduct hydrogeological investigation on Nantong Urban Subway Line 2, and analyzed water quality in three proposed subway stations: Railway Station Station, South Street Station and Taiping Road Station. Table 1 Iron and manganese test results of each aquifer in Nantong at these three sites

As can be seen from the above table, the iron ion content of each aquifer in different area of Nantong almost exceeds the national standard “Groundwater Quality Standard GB14848-2017” (0.3mg/L), and the manganese ion content is also on the national standard line (0.1mg/L). Especially in the railway station area, in the ③4-layer and ⑤1-layer, iron ion content exceeds the standard by several times. The content of iron and manganese ions in different aquifers in the same area is quite different, and the same aquifer in different areas also has large differences, indicating that the iron and manganese content of groundwater in Nantong is affected by both region and aquifer.
The groundwater extracted from each aquifer began to be clear and transparent, and then gradually became cloudy. The color of the suspension gradually changed from white to red (see in Figure 1). After standing for 1 day, the upper liquid became clear and a large amount of red precipitate appeared at the bottom (see in Figure 2).

It is indicated that the iron in the underground aquifer exists in the form of Fe$^{2+}$, and when the groundwater is drawn to the surface, it forms the Fe(OH)$_2$ precipitate, which is then oxidized to Fe(OH)$_3$ precipitate. Water quality treatment is conducted on the ⑤₁-layer of the railway station with the highest iron content.

3. Groundwater filter comparison and optimal filter layer thickness, filter diameter selection
At present, the contact oxidation method has many applications for removing iron and manganese from the waterworks, and the process is relatively mature, so it can be applied to the recharge water treatment. At present, the commonly used filter materials for contacting iron and manganese are: natural
manganese sand filter material, SS filter material, activated carbon filter material, river sand filter material, modified zeolite filter material [6] [7]. The river sand filter material has a long maturity period, and the modified zeolite filter material is difficult to obtain. In addition, their related technology is not mature. In this study, only the natural manganese sand filter material, SS filter material and activated carbon filter material are considered. And before others is used to the removal of iron and manganese, the quartz sand filter material is used to initially filter the impurities with larger particle size in the groundwater.

In order to determine the appropriate filter material and the optimal filter layer thickness, firstly we use a small treatment installation to carry out multiple parallel tests to determine the permeability coefficient of each filter material and the groundwater treatment under various filter materials. In order to eliminate the influence of the test results caused by the difference in groundwater aeration, the groundwater entering the small treatment installation is groundwater that has been evacuated from the underground for 1 hour.

Figure 3 Schematic diagram of small treatment installation

The small treatment installation is of 1.2 meters high and of 0.67m in diameter. The bottom is covered with a filter sieve. The groundwater to be treated enters from the upper inlet, and is discharged from the lower outlet through the filter material. A schematic diagram of the construction of a small processing tank is shown in Fig.3.

By adjusting the type of filter material in the installation and the thickness of the filter layer, a group of parallel comparison test is carried in three small treatment installations. A total of 12 groups of parallel test were tested. The conclusions of the test are as follows:

1. The new manganese sand needs maturity, hence the water treated by new manganese sand does not meet the requirements, while the water treated by the previously used manganese sand treatment meets the requirements.

2. The quartz sand filter used in the test has a high mud content and can also meet the needs of iron removal. The treatment speed is also fast, but as time goes by, the mud in the filter material blocks the filter sieve and greatly reduces the groundwater treatment efficiency.

3. Through the upper 30cm thick SS filter material, the groundwater iron ion content of the lower 20cm thick activated carbon filter material is less than 0.1mg/L, far lower than the national standard, and the processing speed is the fastest.

4. SS filter material contains much dust. At the beginning, the water is black and needs to be rinsed with 15 times the volume of water to clear.

5. According to the obtained permeability coefficient, the upper layer of 30cm thick SS filter material is used, and the processing capacity of the lower layer 20cm thick activated carbon filter material is about 1.2m³/h. It can be estimated that the processing capacity of large processing box is about 48m³/h.
The diameter of the filter in the bottom of the treatment installation has a significant influence on the filtration effect and the water treatment speed. If the diameter of the filter is too large, the filtration effect will not be achieved, and the filter will flow out of the treatment installation with the water flow. If the diameter of the filter is too small, it is easy to block the filter and slow down the speed of water treatment.

The 40 mesh, 60 mesh, and 80 mesh sieves were selected for testing. The test showed that the 60 mesh filter sieve has the best filtration effect and water treatment speed.

4. Large water treatment installation test

The filter material is filled in the large-scale water treatment installation by using the optimal filter material filling method obtained by the small-scale treatment installation test, and the recharge test is performed after the completion of the filling.

After the groundwater is pumped and treated by the water treatment installation, the groundwater concentration is about 0.5mg/L, which exceeds the national standard and is much higher than the level of the small treatment installation. The oxygen content in water standing for 1 hour is about 3–4, while the groundwater oxygen content just extracted is only 2, so it is necessary to increase the oxygen content of the water body and accelerate the oxidation of iron ions.

Japan's Hideo Nakasone [8] proposed that the use of drop-aeration will help increase the oxygen content of the water. Jiang Xiangshan [9] and others used water aeration to improve the drainage system to treat wastewater, and also achieved good effect. Therefore, a three-stage drop-aeration is added before the water treatment tank, and an inverter fan is added to blow oxygen into the water body.

After drop-aeration and ventilation aeration, the treated groundwater iron ion concentration is 0.2mg/L–0.3mg/L, which can meet the requirements of recharge water quality. The treatment capacity of the water treatment tank is about 50 m$^3$/h, which can basically meet the requirements of most recharge projects.

After continuous operation, it was found that the groundwater iron ion concentration after treatment for 3 days increased to 0.5mg/L, indicating that a large amount of iron ions adhered to the treated filter material, which affected the treatment efficiency. Therefore, the backwashing was operated, and after half an hour of backwashing, the recharge continued, and the groundwater iron ion concentration was 0.2 mg/L, indicating that the backwashing had a good effect.

5. Conclusions and prospects

The iron and manganese content of groundwater in Nantong is affected by both regional and aquifer levels, and the iron and manganese ion content is generally high. Water quality treatment is needed to protect the environment and to extend the life of the recharge well.

The contact oxidation process is selected to remove iron and manganese from groundwater. According to the test results of the small treatment tank, the upper layer of 30cm thick SS filter material, the lower layer of 20cm thick activated carbon is the most suitable filter material ratio. The three-stage water drop device and ventilation aeration are used, and the treated groundwater iron ion concentration is 0.2mg/L–0.3mg/L, which can meet the requirements of recharge water quality. The backwashing should be operated every three days, and the backwashing time is half an hour.

In the future, the test results and the groundwater treatment device will be applied to the groundwater recharge practice of rail transit in Nantong area. This study also has considerable reference for other areas with excessive iron and manganese ions such as in the Yangtze River Delta and Pearl River Delta.

References

[1] Nantong City Environmental Status Bulletin, 2017, Nantong Environmental Protection Bureau
[2] JI Qingwen. Progress in Treatment of Groundwater Iron and Manganese[J]. China Science and Technology Fortune, 2012(16).
[3] TANG Chaocun, CHEN Huimin, YE Xin, et al. Research progress of iron and manganese removal methods in groundwater[J]. Water Treatment Technology, 2016(3): 7-12.
[4] Wang Xiaodan, Wang Zhijun, Shang Qinghai, et al. Treatment of high hardness iron-bearing manganese-containing groundwater[J]. Water Supply and Drainage, 2015(4): 17-19.
[5] Liu Wei. Process and design of iron removal and manganese removal by groundwater aeration contact oxidation method[J]. China Mine Engineering, 1999(3): 29-32.
[6] XUE Wei, ZOU Lian-pei, LIU Jian-yong, et al. Comparative study on properties of different filter materials in addition to groundwater ferromanganese by contact oxidation method[J]. Journal of Donghua University (Natural Science), 2002, 28(6): 58-61.
[7] Chen Tao, Zhu Baoyu, Sun Chengxun, et al. Study on treatment of high-iron and manganese groundwater by contact oxidation with river sand as filler[J]. Environmental Pollution Control, 2011, 33(11): 67-71.
[8] Hideo Nakasone Masuo Ozaki, Oxidation- Ditch process Using falling Water as aerator[J]. Journal of Environmental Engineering, 1995, 121(2): 39-42.
[9] Jiang Xiangshan, Wang Chunlei. Design of treatment of slaughter wastewater by improved filling (filter material) drainage system [J]. Environmental Engineering, 2002(6): 25-26.