Desalination and Water Treatment
www.deswater.com

doi: 10.1080/19443994.2013.781566

51 (2013) 3710–3714
May

Taylor & Francis
Taylor & Francis Group

Design and operation of Jibei water plant in Ji Yang county

Wu Daoji, Yu Xiaobin, Tan Fengxun, Tie Zhongyong*, Luo Congwei

School of Municipal and Environmental Engineering, Shandong Jianzhu University, Jinan 250101, China
Email: tiezhongyong@163.com

Received 25 June 2012; Accepted 25 February 2013

ABSTRACT

The water plant in Jibei is larger for advanced treatment of shallow groundwater along the Yellow River water in china, which scale of water is 20,000 m^3/d. Its core technology is the use of ultrafiltration and reverse osmosis composite membrane process for the treatment of excessive groundwater hardness, sulfate, total dissolved solids, fluorides, and others. This paper described the construction of the waterworks structures, processes, equipment, design parameters, commissioning and operation. Operation proved that factory water quality achieved the requirements of criterion (GB 5749-2006), and made a stable operating results, improved the security of water quality effectively.

Keywords: UF; RO; Combined membrane process; Design; Debug; Operation

1. Introduction

Jiyang county in Jinan is located in the north bank of Yellow River, county residents had always been drinking shallow groundwater of the Yellow River, which was good water quality. In recent years, because the water consumption increases near the coast of Yellow River, ground water levels fall, and the water supply is not enough, leading to the flow of shallow groundwater changed. Water quality change greatly, total hardness, sulfate, total dissolved solids (TDS), fluorides and other indicators, beyond the requirements of drinking water health standard (GB 5749-2006), and therefore the county invested 26 million Yuan in 2011, required to improve water quality in limited time, improving resident's life quality.

The water of Jibei water plant mainly comes from the 23 wells of GouYang along the coast of the Yellow River, through the water pipes to the water plant. Design scale of water supply is 20,000 m^3/d, continuous running water 24 h a day. Using ultrafiltration (UF) and reverse osmosis (RO) composite membrane process [1–4] to deal with shallow groundwater, effective removal of water TDS content, reduced hardness, sulfate, and fluoride content, the produced desalted water and another part of the original water is blended by design mix and then treated with chlorine dioxide disinfection, to meet national health standards for drinking water quality requirements.

The specific processes of water plant in Jibei is shown in Fig. 1. After the storage pond, original water pump, the clean strainer, UF host, UF water tank, mudline booster pump, the security filter, high-pressure pump, RO host, water tank, pumping stations, municipal pipe network, which contains acid, alkali,

*Corresponding author.

Presented at the 2012 Qingdao International Desalination Conference June 26–29, 2012, Qingdao, China

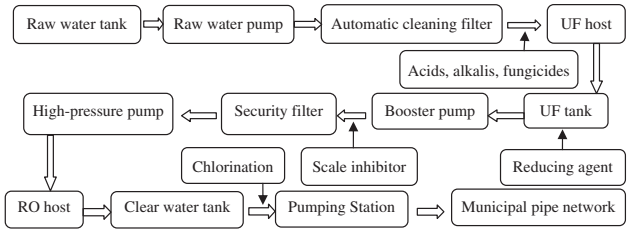

Fig. 1. Process flow diagram.

disinfection, sterilization, scale, device, and related equipment, instrument, etc.

2. Project overview

New structures arrangement is shown in Fig. 2, and the dashed part represents new structures.

2.1. Pressure pump station layout

The size of new pressure pump station in Jibei water plant is 6,840 mm × 16,680 mm, with a storey height of 4.8 m. Pumping station that consists of collecting well, set up 300 mm × 200 mm drains along the wall, control room and the distribution room is the steel reinforced concrete frame structure. Distribution room is brick-concrete structure.

2.2. Clean water tank layout

Clean water tank using *in situ* reinforced concrete structure, with a single flat size 29200 mm × 45600 mm, 4,000 mm ceiling in the pool, effective water depth 3.5 m. Structure without beams at the top cover. Internal is supported for column grid, column grid spacing for 4,000 mm. Pool is provided with four brick guide walls and an inspection hole, sump, ventilation holes and accessory frame. One meter of soil is covered on the top of the pool, reinforced concrete pool by grade C25, cushion C10. Pool antiseepage label is S6, the upper pool body turns the soil afforestation.

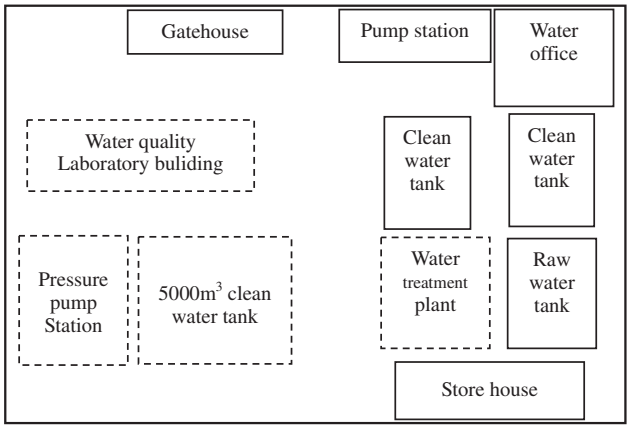

Fig. 2. Floor plan of water plant.

2.3. Water quality laboratory building layout

Water quality laboratory building is two-storey brick and concrete structure, design of high 3.6 m, hall 3.6 m, inside and outside elevation 0.78 m, the building body is east-west, length 36.24 m, width 13.24 m, direct lighting and natural ventilation is used to north and south, the proportion of lighting window and ground of each room and natural ventilation opening fan area all meet the design requirements.

2.4. Water treatment plant layout

Water treatment comprehensive workshop is a layer of block structure, design layer is 5.6 m, inside and outside elevation is 0.3 m. Building is north-south, length 30,400 mm, width 20,400 mm, design service life is 50 years. Inlet water pipe of RO system is connected with raw water pool, and outlet water pipe is connected with the new clean water pool and the original water pool, sewage discharges to plant area sewage pipe network. The maximum power of equipment operation system is 401.4 kw, current is about 800 amperes.

3. Introduction of main equipment process

The system uses UF + RO membrane process to remove hardness. The pretreatment of process is automatic cleaning filter and UF system, which purpose is to remove suspended particles, colloidal ion and organic pollutants, in order to achieve the RO membrane influent water quality requirement. Specifically, its turbidity drops to below 0.5 NTU, and Silting Density Index (SDI) is reduced to below 3. UF produced water goes through security filter to RO membrane device for hardness removal process. To remove the TDS in the water, reduce the hardness, fluoride, and sulfate content.

3.1. Pretreatment system

3.1.1. Raw water promotion pump

In order to provide power, system equipped with UF water booster pump, this system used three sets of

ES150-125-250 type frequency horizontal centrifugal pump, single run power was 18.5 KW, dual-use and one backup, used a variable frequency pump to supply water when running one or two sets of RO, and a variable frequency as well as a power frequency to supply water when you open three or four sets of RO.

3.1.2. Automatic cleaning filter

Automatic cleaning filter has the function of filtering original water and automatically cleaning sewage and system uninterrupted water supply when cleaning sewage. Filtering precision is 100 μ, larger filter area,and higher dirt-holding capacity. Using CNAF-FT12-1.6 type of automatic cleaning filter.

3.1.3. UF system

The UF membrane component used in this system is a kind of external pressure type hollow fiber [5] which made in Singapore Memstar, the diameter of UF membrane hollow is fiber 0.6 mm, and average cut-off molecular weight is 50,000 Dalton, the membrane surface area is 38 m^2, the membrane materials is PVDF. The system can automatically compressed air purge backwashing, chemical enhanced backwashing and chemical cleaning.

As shown in Fig. 3, this system has designed a total of 5 sets of UF device with water flux of 112 m^3/h. There are 40 UF membranes of each set, with method of cross-flow filtration, automatic backwashing every 30–60 min.

In the process of actual operation, the backwash frequency of UF and water consumption will be adjusted according to water quality; the backwashing frequency of chemical enhanced backwash device [6] is usually 10 days/time, acid dosage concentration is 30%, reducing agent dispensing concentration is 5%. At the same time the system was also equipped with a differential pressure switch, forced backwash and automatic dosing would conduct on the UF when the water quality is very poor or differential pressure exceeds the set value 0.08 MPa, in order to eliminate the pollution of UF, guarantee the safe operation of system.

Fig. 3. UF membrane frame actually install figure.

3.1.4. UF water tank

A stainless-steel UF water tank was set in the system, which size is 14 m × 6 m × 3 m, the water tank equipped with liquid level sensor, monitoring water level-and controlling operation of system, and interlock with the UF device, RO would automatic shutdown when the water level is less than 1.6 m, monitoring and maintenance a sufficient amount of water.

3.2. RO desalination system

3.2.1. RO booster pump

RO booster pump provides stable water flow and water pressure for the RO system normal operation. The system used 4 sets of SES100-80-125 type single stage single suction centrifugal pump, respectively, corresponding to 4 sets of RO system, single pump power is 11 KW, all work with power frequency.

3.2.2. Security filter

The function of 5 μm security filter is interception of the pellets greater than 5 μm into the RO system. According to water yield of the system, filter specification is Φ1,000 × 500, it contained 110 melt-blown filter element with the size of 40 inch, filter accuracy is 5 μm. Single run flow is $Q = 140\ m^3$/h. Filter is disposable used, according to the water quality, its replacement cycle is 3–5 months. It is generally depends on the loss of pressure filter on import and export in the specific operation, the filter should be replaced when pressure drop is greater than the set value (usually 0.1–0.15Mpa).

3.2.3. High-pressure pump

Hig-hpressure pump provides adequate water pressure for RO membrane group, to maintain the normal operation of RO membrane. Each system set 1 SES100-65-315 type high-pressure pump, a total of four sets, which single power is 75 KW, each pump flow was set to 140 m^3/h, head of 1.20 MPa. Pressure switches was set on the high pressure pump inlet,

Fig. 4. RO membrane frame actually install figure.

alarming and stopping the pump when pressure is lower than 0.6 MPa. At the same time pressure switches was set on the high-pressure pump outlet, alarming, and stopping the pump when pressure is higher than 1.8 MPa.

3.2.4. RO membrane group

The RO membrane group is the main part of the whole desalination system [7,8], it is responsible for the removal of water soluble salt, colloid, organic matter, and microorganism. As shown in Fig. 4, the RO system has designed 4 sets of output for 118 m^3/h RO device. Membrane module arranged according to three segments of one level, 120 low-pressure resistance pollution composite membranes produced by HYDRANAUTICS are used in the system with the model of PROC20, 1 m length, diameter 8, 10 pressure containers were set in the first segment, 6 pressure containers were set in second segment, 4 pressure containers were set in third segment. Each pressure container was installed of 6 membrane components, under the bear pressure of 600 PSI. The inflow pipe of RO system adopted lateral inlet, the interface valve was arranged on inlet and outlet water pipe of the water and concentrated water, which made it connect inlet and outlet pipe of cleaning liquid conveniently on cleaning membrane, produce water pipes was installed explosion-proof membrane. To control the water recovery rate, cutoff valve was set on the concentrated water discharge pipe. System recovery was set to 80%.

3.2.5. Scale inhibitor dosing device

In the RO membrane module, with the continuous precipitation of fresh water, hardness material in concentrated water will gradually concentrate such as calcium and magnesium, it will separate out at the membrane surface and pipeline when reaches its saturation, and has an effect on water yield and water quality of membrane. Thus, set scale inhibitor dosing device in the system, which mainly composed of imported metering pump and PE kit. The system selected RO membrane scale inhibitor King Lee PTP-0100 of the United States of America, its main ingredient is organic acids and polymers, according to the raw water profiles, the dosage is 4 ppm per ton of raw water.

3.2.6. RO-cleaning system

Effect of RO cleaning-system: While the long-term operation of RO membrane group, system would have some pollution that is difficult to wash away, such as long-term micro-salinity scale and the accumulation of organic matter, causing performance degradation of the membrane components. So it must be cleaned with chemicals, in order to restore the normal desalting ability.

4. Operation

According to a time of observation on water treatment device operation situation of Jibei water plant in Ji Yang county, the SDI of UF water tank produced water was stability under 1 during RO unit normal operation, conductivity of RO water was stability under 20, blending RO produced water and raw water at the proportion of 6:4, then detecting the water sample of clean water tank, the result is shown in Table 1.

Table 1
Water quality monitoring results (average)

Item	Limits	Raw water	UF water	RO water	User water
Fluoride, mg/l	1.0	1.63	1.67	0.05	0.54
TDS, mg/l	1,000	1,343	1,267	155	921
pH	6.5–8.5	7.02	7.11	7.61	6.93
Total hardness, mg/l	450	628	624	10	390
Sulfate, mg/l	250	442	435	11	142

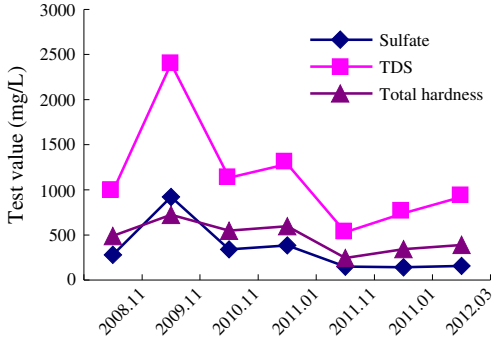

Fig. 5. Test value of fluoride, turbidity, pH.

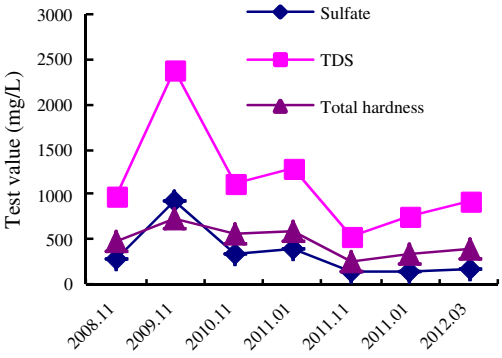

Fig. 6. Test value of sulfate, TDS, total hardness.

As we can see in the table, the indicators exceed the standard before processing all meet the national drinking water health standards (GB 5749-2006) after processing during normal operation of the system. Specific water quality conditions can be seen in Figs. 5 and 6.

5. The problem and counter measure

UF and RO combination of advanced treatment of shallow groundwater process is the emerging technology of the twenty-first century, it has the advantage of good water quality and easy management. In the process of continuous exploration, accompanied by manufacturing cost of UF and RO membrane dropping considerably, this technology has been used widely. At the same time, the system occupied with small area and save space, it has good application value for the medium-sized city in domestic with the serious situation of increasing land.

As the use of membrane technology for the depth processing of the water plant, due to the membrane component itself by the influent of water quality or temperature [9], which will affect water production. Therefore, we should find the law during operation to ensure the stable operation of the waterworks.

The recovery rate is only 80–85% after the normal operation of the entire system of water plant. The concentrated water of current system is discharged into the municipal sewer pipe network, so we can consider the transform of town municipal pipe network, of supply water according to the quality, and the concentrated drainage can be used for flushing and greening.

Scale inhibitor plays a big role in the normal running process of RO system, but for now, we have no idea whether the scale inhibitor used do harm for the body. Future research should be strengthened in this area.

References

[1] J. Witte, New development in nanofiltration and reverse osmosis membrane manufacturing, Desalination 113 (1997) 153–156.
[2] F.L. Jia, Z.H. Li, T.C. Wang, Application of ultrafiltration-reverse osmosis technology in Cidong water plant, Water Ind. Market. 12 (2009) 71–73.
[3] L.Z. Dong, Ultrafiltration + reverse osmosis process for advanced treatment of iron and steel plant waste water, Environ. Eng. 29 (2) (2011) 58–61.
[4] M.Z. Huang, G.D. Cao, D.M. Lee, X.Z. Lee. Design and operation analysis of Foshan new urban high-quality water plant. Water Supply and Drainage 34 (3) (2008) 12–16.
[5] X.Y. Guo, Z.J. Zhang, L. Fang, L.G. Su, Study on ultrafiltration for surface water by a polyvinylchloride hollow fiber membrane, Desalination 238 (2009) 183–191.
[6] G. Singh, L.F. Song, Impact of feed water acidification with weak and strong acids on colloidal silica fouling in ultrafiltration membrane processes, Water Res. 42 (2008) 707–713.
[7] W.L. Zhong, Y. Luo, Application of reverse osmosis technology in Philippines ILIJAN power plant water treatment system, Ind. Water Treat. 30 (10) (2010) 89–91.
[8] Y.H. Zhang, Existing problems and measures in application of reverse osmosis technology, Large Nitrogen Fertilizers 33 (2) (2010) 102–104.
[9] J. Xing, X.W. Di, W. Wang, Discussion on design of reverse osmosis system, Science view 32 (2007) 34–36.