Xi'an South-Suburb Water Treatment Plant
Shaanxi, China

1. Background Information

Xi'an south-suburb water treatment plant (XSWTP) is the first Sino-foreign cooperative water supply project in Northwest China. It is one of the important down-stream WTPs treating which treats surface water from Heihe and other reservoirs. XSWTP was constructed under the joint venture of Xi'an Water Supply Company, Hong Kong Rongdi Co., Ltd, and Berlin Water Supply and Drainage Co., Ltd. It covers an area of 170,170 m^2 and was constructed with an investment of 0.28 billion RMB. It has the capacity of 500,000 m^3/d and 30,000 m^3/d for drinking water treatment and wastewater treatment, respectively. The service area of XSWTP is extended to almost all of the urban district in Xi'an city.

The construction work of the XSWTP was commenced on December 1999, and was completed on 15th August, 2002. From then on, XSWTP has reliably provided 40% of total water supply to Xi'an city. With the operation of XSWTP and other existing WTPs, it is expected that the water demand of Xi'an city will be guaranteed until 2020.

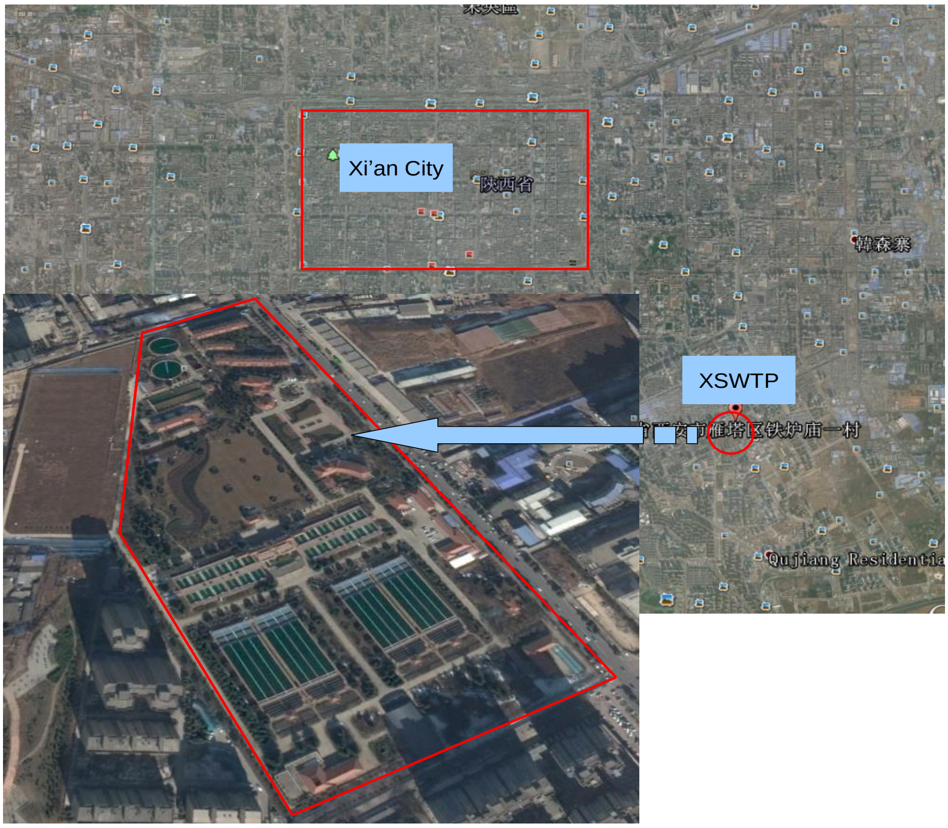

Figure 1 Location of XSWTP

Table 1. Overall information of XSWTP

Constructed Year	2002
Water Source	Heihe and Shitouhe reservoirs
Operating Capacity (m^3/d)	480,000
Peak Capacity (m^3/d)	500,000
Backwashing Water Treatment Capacity (m^3/d)	10,000
Sludge Treatment Capacity (m^3/d)	20,000
Date of access of the source information	April, 2016
Reference	Xi'an south-suburb water treatment plant

2. Water treatment process flow

The major processes are as follows:

- ✓ Raw water extraction (intake) ⟶ Screen and grit chamber ⟶ Pipeline static mixing (PAC and polymers) ⟶ Vertical flow folded-plate flocculating tank ⟶ Horizontal flow and lateral flow flex-plate sedimentation tank ⟶ Modified V-type filter ⟶ Clean-water tank (chlorine disinfection) ⟶ Gravitational transportation (to distribution network)

- ✓ Sludge (from grit chamber & sedimentation tank) ⟶ Equalization tank ⟶ sludge thickener ⟶ Thickened sludge storage tank ⟶ Sludge dewatering ⟶ Sludge disposal

- ✓ The backwashing water from V-type filter and the supernatant from sludge thickener are regulated by an equalization tank, and then are pumped back to the grit chamber for cyclic treatment.

Figure 2 and **Figure 3** show the treatment process at XSWTP.

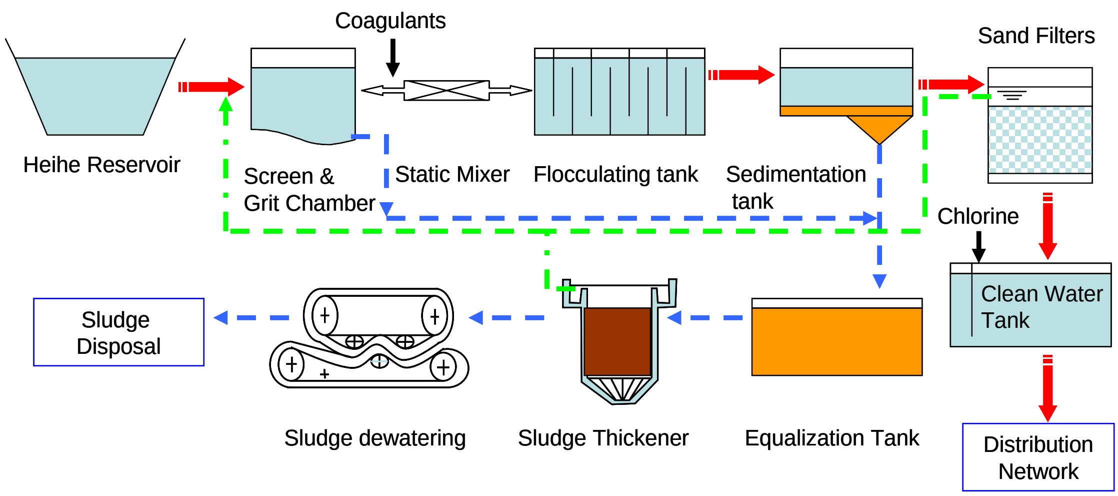

Figure 2 Water treatment process at XSWTP

Figure 3 Water treatment unit at XSWTP

2.1 Water intake

The sources for water intake are Heihe (**Figure 4)**, Shitouhe and other minor reservoirs, all of which originates from the northern part of QinLing Mountain. The water from these reservoirs is delivered to Qujiang distribution station through 83 km of pipes/channels utilizing the gravity flow. A portion of the source water is then distributed to XSWTP for further treatment using 5.9 km of pipeline.

Figure 4 Heihe reservoir

2.2 Pre-chlorination unit

XSWTP uses Cl_2 gas as the pre-chlorination agent. Firstly, the liquid chlorine (**Figure 5**) is evaporated into gas chlorine, and then is injected by chlorine dosing machine (**Figure 6**). Pre-chlorination which is carried out in the chlorine-dosing well is mainly used for inhibiting algae growth, reducing chroma, and pre-oxidation of potential pollutants. Chroma or chromaticity is a common sensuous property of water which reflects the color of water samples caused by dissolved matter and colloids. It as an important parameter documented by national drinking water standards of China. Through regular measurements of algae and chroma in raw water samples the laboratory technician determines the appropriate chlorine dosage required and the average chorine dosing in XSWTP is 1.5 mg/L.

Figure 5 Liquid chlorine tank **Figure 6 Chlorine dosing system**

2.3 Mechanical screen and Grit chamber

XSWTP utilizes automatic mechanical screen (**Figure 6)** with the bar clearance of 5 mm. The grit chamber **(Figure 7)**, is divided into 4 compartments, which can remove substantial suspended solids and reduce the sludge production in the subsequent treatment units. Grit chamber also receives the wastewater from the wastewater reuse system (Refer to **Figure 2**).

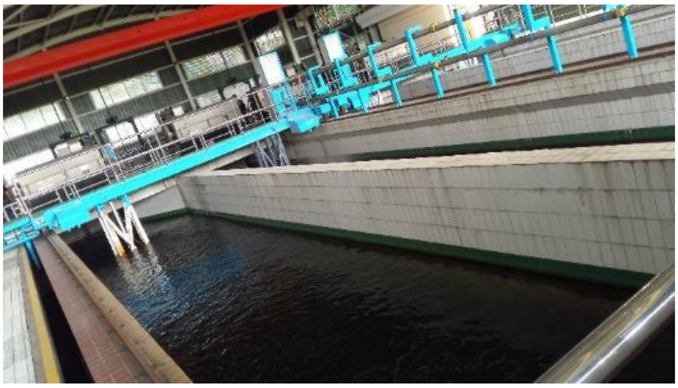

Figure 6 Mechanical screen **Figure 7 Grit chamber**

2.4 Chemical feeding and flocculation unit

According to the varying raw water quality, coagulants and coagulant aids are used (**Figure 8** and **Figure 9**) at the XSWTP. Under normal water quality condition, polyaluminium chloride (PAC) (**Figure 10**) is used as the coagulant. However, under unfavorable conditions source water is polluted with high turbidity or low temperature, low turbidity and low alkalinity and under these conditions several coagulation aids, such as polyacrylamide (PAM) and sodium silicate, are also applied to enhance flocculation. After mechanical mixing (**Figure 11**), water runs into vertical flow folded-plate flocculating tank (**Figure 12**), which has the folded-plates to facilitate the effective collision and growth of flocs.

Figure 8 Coagulant dosing system

Figure 9 Coagulant aids dosing system

Figure 10 Chemicals

Figure 11 Mechanical stirrer

Figure 12 Vertical flow folded-plate flocculating tank

2.5 Sedimentation tank

In XSWTP a set of flex-plates (first time applied in China) are added at the end of the horizontal flow sedimentation tank (**Figure 13**). The flex plates are made of stainless steel and are different from those used in the conventional inclined plate settler. The flex plates has wave pattern plates. This compact system facilitates the collection of SS and agglomerates when water flows through the inclined wave-pattern plates. There are 4 tanks in parallel and each tank is divided into 2 compartments. This configuration of combined sedimentation tank can achieve a high treatment capability regardless of varied raw water qualities. The total settling time is 81 min and the velocity of horizontal flow is 15 mm/s.

Figure 13 Horizontal flow and lateral flow flex-plate sedimentation tank

2.6 Filtration tank

Two parallel filters (**Figure 14**) are constructed in XSWTP, and each is divided into 12 compartments. The filter used at XSWTP is the rapid sand filter. Given the large area of one single filter, the backwashing process has been improved to obtain better filtration performance, superior backwash efficiency and lower energy consumption. Homogeneous quartz sand is used as the filter material. The thickness of filtering media is 120 cm with the effective sand size of 0.95 mm. The filtration rate is set at 7.6 mm/h. Combination of air scouring and water wash is applied with the air and water wash intensities of 50-60 m/h and 14-15 m/h, respectively. Filtered water is used for water backwashing purpose. Backwashing is performed once a day and it takes 15 min for the backwashing cycle to complete which includes 4 min of air scouring, 7 min of air scouring and water backwashing and 4 min of water backwashing.

Figure 14 Modified V-type filter

2.7 Clean water tank

Similar to pre-chlorination, gas chlorine is used for as disinfectant (post-chlorination) and has a contact time over 30 minute. The residual chlorine level of 0.3-0.6 mg/L is maintained in the treated water. After disinfection conventional microbiological indexes cannot be detected. The disinfected water is then stored in the clean water tank (**Figure 15**), followed by delivery to the municipal water supply distribution network through gravity flow.

Figure 15 Clean water tank

2.8 Backwashing water and waste sludge disposal

In order to save the limited water resource and ensure that wastewater will not cause secondary pollution to the surrounding environment, XSWTP has established the wastewater treatment system to treat the used water and the generated sludge. The unit process involved in the backwash water and sludge treatment are as follow:

2.8.1 Equalization tank

Two equalization tanks are built in XSWTP for different purposes. First equalization tank is the reuse water equalization tank (**Figure 16**) which receives backwash water (from filters) and sludge supernatant (from sludge thickening tank). After equalization in the first tank, the used water is pumped to the grit chamber for re-treatment. The second equalization tank is the wasted sludge equalization tank (**Figure 17**) used for the regulation of sludge from the grit chamber and sedimentation tank. Sludge from the second equalization tank then follows through the sludge treatment in sludge thickener and dewatering treatment units.

Figure 16 Reuse water equalization tank

Figure 17 Wasted sludge equalization tank

2.8.2 Sludge thickener

The coagulant PAM is firstly mixed with the wasted sludge before entering the sludge thickening tank (**Figure 18**). The thickened sludge flows into the storage tank (**Figure 19**) by gravity for further treatment. After gravitational liquid/solid separation in the sludge thickening tank, the supernatant flows into the reuse water equalization tank for cyclic treatment.

Figure 18 Sludge thickening tank

Figure 19 Thickened sludge storage tank

2.8.3 Sludge dewatering

The thickened sludge from the storage tank is further pumped to the sludge dewatering unit. The centrifugal dewatering machine (**Figure 20**) is used for sludge dewatering, and the dewatered sludge has the moisture content between 70% and 80%. Finally the sludge cake (**Figure 21**) is taken out for landfill disposal.

Figure 20 Centrifugal dewatering machine

Figure 21 Sludge cake

3. Aspects of treatment processes posing most difficulty for daily operation

- **The daily regulation and emergency control for raw water intake under multiple-source condition:** The raw water is taken from several surface water sources (majorly from Heihe and Shitouhe reservoirs). After mixing and regulating, it is delivered to two important WTPs of Xi'an city, namely Xi'an Qujiang WTP and XSWTP which accounts for about 90% of the total water treatment capacity for Xi'an. So the daily regulation and emergency control for raw water intake under multiple-source condition could be a critical issue.

- **The eutrophication of water reservoirs and its impacts:** Surface water quality can be affected by various exogenous and endogenetic pollutants, which causes the increase in nutrients (nitrogen and phosphorous) concentration, stimulates algae multiply greatly and results in seasonal eutrophication problem. During the period of algae bloom, the source water entering the XSWTP contains large amount of algae, which brings about a big challenge to the stable operation and water quality safeguard in XSWTP.

- **The significance seasonal fluctuation in raw water quality:** As the source water of XSWTP is entirely from surface water, mainly containing the water from reservoirs, the water quality could be easily affected by rain runoffs and other environmental factors (such as season and temperature). It is noted that source water quality greatly fluctuates especially in rainy season (the maximum turbidity of 6000 NTU), but in other time the turbidity is quite low (**Figure 22**). The turbidity can go as high as 6000 NTU during the rainy season as the runoff carries large amount of silt in the river. During the long winter season, low temperature, low turbidity and low alkalinity are the common features of source water. Under this condition, conventional water treatment process may not work, so during the design and operation of XSWTP some technical measures should be considered to enhance the treatment performance.

Figure 22 Fluctuation of source water quality in different seasons

- **The pipe blocking of coagulation dosing system:** Due to the fact that the commercialized coagulant (PAC) contains some impurity that can deposit in the chemical dosing pipelines, the blocking of pipes has occurred several times. This issue causes short interruption of coagulant dosing and influences the overall treatment performance of XSWTP.

4. Aspects of water services management in general posing most difficulty at the moment

Apart from the high water loss in the form of non-revenue water which accounts 15 % due to transmission and distribution pipe leakage, XSWTP is not facing any severe problem in its water service management.

5. Measures taken now to cope with 3) and 4)

- Along the pipes and channels, intersections and monitoring points for source water transportation; various valves; and online and manual monitoring systems has been installed. With these real-time control systems, the variations of water quality and quantity of multiple water sources can be measured. Facing the emergencies such as the sudden deterioration of water quality caused by rainstorm, timely alternation of water source and/or appropriate operational measures can be achieved to cope with the water quality variance.

- To resolve the seasonal eutrophication problem of water reservoir, Chinese patent water-lifting aerator technology (**Figure 23**) has been adopted (Ma et al., 2015). Intensive mixing between water in the reservoir and air produced by the air blower is achieved by the water-lifting aerator. It further stimulates the even distributions of water temperature and water quality.

Figure 23 Water-lifting aerators and its application in Heihe Reservoir

- For the treatment of high turbidity water, the mechanical screen and grit chamber can effectively remove suspended particles and algae. It is further followed by the usage of coagulant and coagulant aid which intensifies the performance of flocculation unit. For the treatment of low temperature and low turbidity water, excessive usage of PAC results the effluent aluminum concentration to exceed the limit of the drinking water standard. To overcome this problem the usage of a new coagulant (PACFe) is adopted to limit the concentration of effluent aluminum to desirable limit.

- The initial coagulant dosing pipeline is modified to a dual-pipeline system and the high-pressure water washing device is installed for cleaning purpose of the dosing pipeline. The regular exchange of working pipeline and cleaning of unused pipeline ensure the stable operation of coagulant dosing system.

6. Recent investment made for the plant's improvement

- Installation of online turbidity and algae meter
- Installation of online multifunctional water quality meter
- Conduction of awareness programs to protect source water reservoirs
- Some measures to control exogenous and endogenetic pollutants are also taken

7. Technologies, facilities or other types of assistance needed to better cope with operational and management difficulties in 3) and 4).

The remote water quality monitoring system in the distribution network is needed to be updated. Laboratory facility needs to be improved with the installation of instruments capable for measuring disinfection by products (DBP) and algae toxins(LC-MS/GC-MS).

8. **Customer's opinion on water quality and water services in general**

An internal survey conducted by XSWTP shows that within the coverage area of drinking water network of XSWTP, the water quality is superior to national drinking water standard (MH (China) and SA (China), 2006) accompanying with sufficient water quantity and hydraulic pressure. Moreover, except during the regular regional pipeline maintenance, the cut off of water supply never occurs. The customers are satisfied with the drinking water quality and water services.

9. **Advanced technology used in this water treatment plant or any points to improve the process, water quality and capacity**

According to the characteristics of source water, during the design period, advanced water treatment technologies, such as multistage mechanical mixing, vertical folded-plate flocculation tank, horizontal flow and lateral flow flex-plate combined sedimentation tank and modified V-type filter, has been considered and employed in XSWTP. Moreover, the control system in XSWTP is a combination of the centralized monitoring system (the SCADA system) and the decentralized control system (unit control system). This advanced control system provides advantages of reliable performance and easy management. Compared to the conventional WTP, the combination of these optimized technologies saved the construction cost at 5 Million RMB and cuts down the operation cost at 21.6 Million RMB per year.

10. **Other highlights**

- Since the completion of construction in 2002, XSWTP undertakes about 40% of the total drinking water supply in Xi'an city (**Figure 24**). The water division engineering from Heihe and Shitouhe reservoirs, and XSWTP are regarded as lifeline engineering of Xi'an City by local government and residents. Above mentioned lifeline engineering effectively relieved the water shortage problem in this water-deficient area, safeguarded the drinking water quality and promoted the economic development.

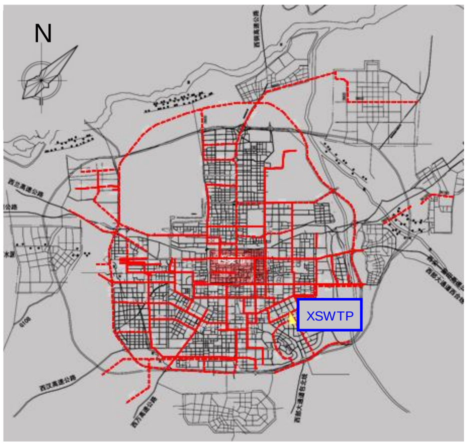

Figure 24 Service area of XSWTP

- As shown in **Figure 25**, there lies favorable terrain conditions from the drinking water intake to the distribution network. Thus gravitational transportation has been exploited and this measure has largely reduced the construction and operational cost.

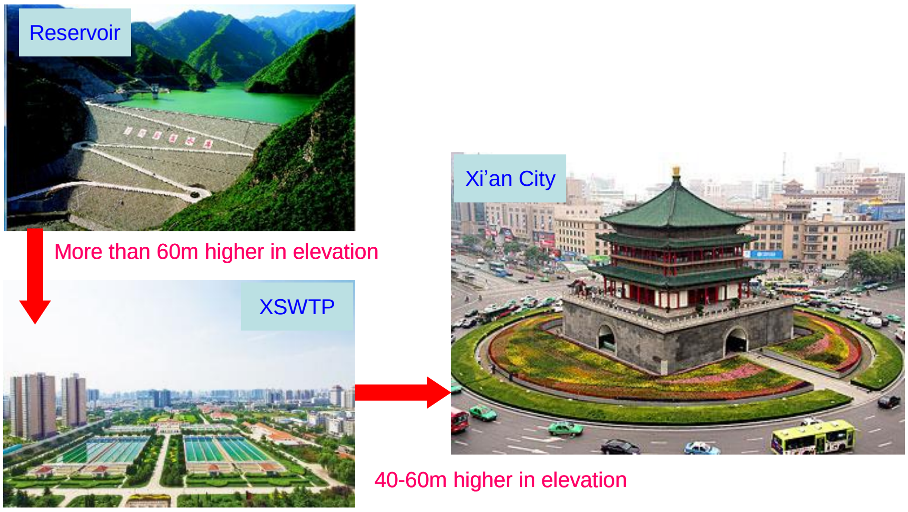

Figure 25 Schematic diagram showing the differences in altitude from different units.

- XSWTP has wastewater treatment system for zero discharge and process wastewater from WTP. This system saves water resources and enhance income. Moreover it does not cause secondary pollution to other water bodies. As estimated the amount of re-treated process wastewater is 10 Million m^3 per year and the increase in income from the wastewater reuse is about 31.7 Million RMB per year. It exhibits great social and economic benefits

- The main technical-economic indicators of XSWTP are shown in **Table 2**.

Table 2 Technical-economic indicators of XSWTP based on per m^3 water produced

Item	Value
Construction Cost (Yuan RMB/m^3)	572.75
Land Usage (m^2/m^3)	0.274
Total Running Cost (Yuan RMB/m^3)	1.37
Operating Cost (Yuan RMB/m^3)	0.96
Power consumption (kwh/m^3)	0.01743
Managing staff (person/10^4m^3)	1.8

11. Water quality data

The water quality data of XSWTP (2016) are presented in **Table 2**.

Table 2 Water quality data

Parameters	Unit	Raw water	Treated water	Standard (China)
pH		7.8-8.0	7.4-7.8	6.5-8.5
Turbidity	NTU	1.0-10.0	<0.7	1.0
Total hardness	mg/L	<300	50-90	450
COD_{Mn}	mg/L	2.0-5.0	1.5-1.8	-
NH_3-N	mg/L	0.1-0.3	<0.1	-

NO_3^--N	mg/L	-	<5.0	10
Iron	mg/L	-	<0.3	0.3
Manganese	mg/L	-	<0.1	0.1
Chlorine	mg/L	-	0.3-0.6	⩾0.3

(Source: XSWTP; Raw water quality data is acquired under normal condition)

12. References

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