Advances in Environment and Energies
Volume 1, Issue 1, No. 1
Received 13 July, 2022; Accepted 11 August 2022
Published online August 29 2022

Sanderman Publishing House

Waterlogging prevention risk analysis of underground urban sewage treatment plant: taking Zhuhai Qianshan water purification plant as an example

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Abstract. Underground urban sewage treatment plants emerge as the times require due to the advantages of saving land & having little impact on the environment. The *Zhengzhou Flood on July 20* caused great human & economic losses, especially the loss of underground space & underground facilities. Through the analysis & interpretation of the waterlogging prevention & drainage facilities of Qianshan Water Purification Plant, an underground urban sewage treatment plant in Zhuhai, it expounds the key elements & main measures of waterlogging prevention of the underground urban sewage treatment plant for reference.

Keywords. Underground urban sewage treatment plant, waterlogging prevention standard, site elevation, drainage pump pool, receiving water body, emergency plan.

The *Zhengzhou Flood on July 20* caused great economic losses and casualties to local people. As of 18:00 on August 1, 292 people died and 47 were missing citywide, including 39 drowned in underground spaces such as basements, underground parging lots and underground pipe galleries; direct economic losses verified recently amounted to 53.2 billion yuan (the press conference held by Henan Provincial People's Government on August 2). Six and fourteen people were killed respectively in the Beijing-Guangzhou North Road Tunnel and the rail transit L5 underground spaces, major disaster sites, which was painful and startling. The issue of waterlogging control in underground spaces has once again attracted great attention from the industry.

In recent years, with the acceleration of urbanization, the urban sewage discharge volume has increased rapidly, and urban sewage treatment plants are generally under overload operation. A demand for increased construction land is put forward by scale expansion and improvement of quality and efficiency. As cities grow, most of sewage treatment plants originally planned to be located on the edge of town or in the suburbs are gradually surrounded by new land for construction and development, which restricts the expansion. Reputed for such advantages as land conservation, environmental protection, less polluted air and low noise, and little impact on aboveground landscape, underground urban sewage treatment plants provide an effective way to relieve the shortage of construction land for municipal sewage treatment plant. However, underground urban sewage treatment plants also have inherent disadvantages in flood control and drainage. For example, they have many exposed spaces, such as access and equipment hoisting channels, which are easily encroached by rainfall flood during heavy rain and become the focus and difficulty of urban flood control and drainage; the overflow of sewage pools connected with the urban sewage pipe network (or the combined sewage pipe network) via the pipes into the plant is more likely to directly cause waterlogging in underground urban sewage treatment plants, leading to major accidents and serious environmental pollution.

Th underground urban sewage treatment plant refers to the urban sewage treatment plant whose water treatment structure is located below ground, equipment operation floor is closed, and ground level is comprehensively utilized. Provisions of TCAEPI 23–2019 *Technical guideline for underground municipal wastewater treatment plant* on flood control and drainage of the plant are as follows: "4.2.6 The plant shall have good drainage conditions, and the flood control standard shall not be lower than the urban flood control standard. Current limiting and overrunning measures shall be considered for waterlogging, and drainage pump pits shall be set up at the low areas of the underground plant. 5.1.2 For underground sewage treatment plants waterlogged by gravity flow, the water inlet shall be equipped with the water quick close gate and the electric gate for double safety" [1]. Provisions of T/CECS729–2020 *Technical specification for urban underground wastewater treatment plant* [2] on flood control and drainage of the plant are as follows: "12.5.18 When a heavy rain occurs, the underground sewage treatment plant shall monitor the flow of water into it, and, if the water volume exceeds the hydraulic load limit it can bear, shall immediately launch the emergency plan".

Taking Zhuhai Qianshan Water Purification Plant (see Figure 1) as an example, the flood control and drainage risks of it and the measures taken are analyzed and discussed.

1. Natural environmental profile

Qianshan Water Purification Plant, a main urban sewage treatment plant in the downtown of Zhuhai, takes on urban sewage treatment and discharge after reaching the standards in Shangchong and Qianshan areas of the downtown, with an actual scale of 100,000 m^3/d, an actual floor area of about 4.5 hm^2, and a controlled land use of about 9.9 hm^2. Qianshan Water Purification Plant adopts the A^2O+MBR advanced treatment technology, where the sewage into the plant passes through coarse and fine screens, lifted by pump stations, and treated by aerated grit chambers, primary settling tanks, membrane screens, biological filters and membrane filters, and finally discharged into the Qianshan River and the flood discharge channel on Zaobei Road after UV disinfection. The actual tail water from the plant is subject to the 1A standard

of GB 18918–2019 *Discharge standard of pollutants for municipal wastewater treatment plant* and the standard of DB 44/26–2001 *Discharge limits of water pollutants* in Guangdong Province.

Qianshan Water Purification Plant, located in the Qianshan area of the downtown of Zhuhai, is near Baiyun Road in the north, Jinji Road in the south, Xinzhu Road in the west, and Wangyun E-commerce Industrial Park in the east. Two pipes from the plant, which are reserved for Phase II expansion, are D1800 and D1000, by which the tail water is discharged southward into the Qianshan River and eastward into the flood discharge channel on Zaobei Road, respectively. Qianshan River, the mother river of the downtown of Zhuhai and once the main source of drinking water in Zhuhai, was abandoned as the source of water due to severe pollution caused by the development of industries in Zhongshan upstream. In recent years, Zhuhai and Zhongshan have paid high costs for renovation, thus restoring the clear water and green banks of the Qianshan River and making it an important water system landscape belt (see Figure 2).

Figure 1. Zhuhai Qianshan Water Purification Plant

Figure 2. Qianshan River

Qianshan Water Purification Plant is built underground, where the first floor is mainly for sewage treatment structures and the second floor for some mechanical and electrical equipment, such as water pumps; distribution equipment of the plant is located on the ground outside.

2. Waterlogging risks of the plant and measures

The terrain around Qianshan Water Purification Plant is generally high in the north and west and low in the south and east. The Qianshan River on the south side of the slope is conductive to road and construction land drainage, Baiyun Road on the north side has an elevation of 3.80–4.10 m in the center (Huanghai Elevation System in 1956, the same below), Jinji Road on the south side has an elevation of 3.50–3.70 m in the center, and Xinzhu Road on the west side has an elevation of 3.50–3.80 m. The design elevation of the road in the plant is 5.10 m, the elevation of the entrances of the up and down ramps of the first floor underground is controlled at 5.24 m, the rainwater discharge standard for the plant is based on a return period of three years, and collected rainwater is discharged westward into the municipal rainwater box culvert ($B \times H = 4.5$ m $\times$ 1.0 m) of Xinzhu Road and southward into that ($B \times H = 2.4$ m $\times$ 1.0 m) of Jinji Road via D1000 and D600 rainwater pipes, and finally is discharged southward into the Qianshan River.

In accordance with the *Comprehensive Planning of Drainage (Rainwater) and Waterlogging Prevention in Zhuhai (2020–2035)*, waterlogging prevention standards for the downtown of Zhuhai are rainfall in 24 h in a return period of fifty years and no waterlogging caused by the external tidal bore level in a return period of five years. Waterlogging in the Qianshan Water Purification Plant is mainly discharged into the Qianshan River via the Geli flood discharge channel ($B = 12.0$ m) along the west side of Xinzhu Road in the west.

During construction, the elevation of the outdoor site of the Qianshan Water Purification Plant is set at 5.1 m, which is 1.0–1.3 m higher than that of Baiyun Road in the north and 1.3–1.6 m higher than that of Jinji Road in the south; the elevation of Qianhe West Road on the north bank of Qianshan River is 3.0–3.2 m, the terrain of the whole region is high in the north and low in the south, with Qianshan River in the south of the slope. Qianshan River, the receiving water body in the south, is an inland waterway system within the levee of Zhongshan and Zhuhai, which is connected to the Modaomen watercourse or Maliuzhou watercourse of the outer river via Lianshiwan, Majiao, Denglongshan, Dayongkou, Guangchang, Hongwan and Shijiaoju sluices. These sluices are managed by Zhuhai and Zhongshan, who jointly dispatch the system according to the tidal changes of the Modaomen watercourse to control the water level of the Qianshan River system within the levee at 0.6–1.3 m, thereby ensuring the safety of water intake of Zhongshan Tanzhou Water Plant, as well as the safety of flood control in the low-lying sections of Tanzhou, that is, the maximum flood level in the Qianshan River section is no more than 1.3 m.

Although the rainwater discharge standard for the plant is based on a return period of three years, excessive rainfall, if causing waterlogging in the plant, can be discharged into Qianshan River via the Geli flood discharge channel and drain pipes on surrounding municipal roads by combining rainwater pipes with surface diffusion, and thus there is no waterlogging risk in the plant. To prevent the rainwater in the plant from flowing into the first floor underground along the up and down ramps, the exposed sections are covered with canopies, the area for rainfall collection is reduced, and two intercepting dikes are set up in the ramp section to discharge the intercepted rainwater into the drainage pump pool on the first floor underground; a waterproof baffle with a height of 0.6 m and sandbags for flood prevention are set up at the entrance to reduce the amount of rainfall entering the underground facilities. For rainwater that overflows into the intercepting dikes during heavy downpour, the bottom elevation of the underground drainage pump pool ($L \times B \times H$ = 11.0 m × 7.0 m × 7.1 m) is consistent with the elevation of the second floor underground, and the top elevation is consistent with the elevation of the first floor underground, so that the rainwater entering the underground area is pumped by rainwater pump and discharged into the outdoor rainwater pipe channel.

Measures, such as raising the elevation of outdoor sites to avoid the formation of low-lying areas that causes site waterlogging, covering the exposed areas, such as vehicle entrances and exits, with canopies to reduce the heavy rain that directly enters, and setting up intercepting dikes at the ramp section to intercept a small amount of rainwater into the drainage pump pools on the second floor underground (see Figure 3) and pumping it to the outdoor rainwater pipe channel, are taken to ensure the safety of waterlogging prevention in the underground sections in case of rainfall.

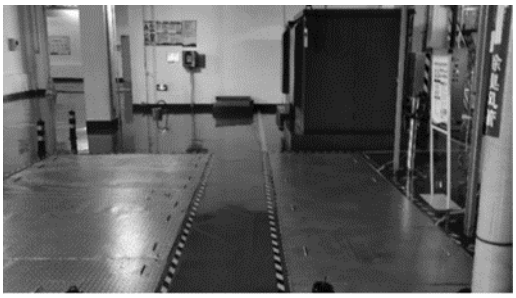

Figure 3. Drainage pump pool on the second-floor underground

In addition to locating the main structures for sewage treatment process in the first and second floors underground, to ensure the safety of power supply in the plant, electric power facilities required for production, such as power supply and distribution, are on the ground, and the elevation in the distribution room (± 0.00 m) is about 0.8 m higher than the outdoor site elevation (equivalent to the absolute elevation of 5.9 m); there is also difference in the elevation of the site and surrounding municipal roads and the maximum water level of Qianshan River, which can ensure the flood and waterlogging control of power supply and distribution facilities. Aboveground transformer and distribution rooms are shown in Figure 4.

Figure 4. Aboveground transformer and distribution room

3. Waterlogging prevention measures for sewage into the plant

To prevent the shutdown of underground sewage treatment structures due to power failure or emergency, which thus results in the overflow of sewage into the plant and underground sewage waterlogging, Qianshan Water Purification Plant sets up an electric gate valve at the end of the sewage pipes into the plant in strict accordance with *Technical guideline for underground municipal wastewater treatment plant* (see Figure 5), and the gate valve falls by the weight of its own in the event of a sudden power failure and forms a gravity-type quick closing valve that closes the sewage pipe into the plant, thus effectively avoiding underground waterlogging caused by the loss of control of sewage into the plant of various reasons [3–4]. Meanwhile, two emergency pumps are set up to further improve the safety of the forebay in the underground sewage pump house, and, if necessary, the sewage in the forebay is forcibly discharged into the receiving accidental water body via accidental sewage overrunning pipe (see Figure 6) after confirmation by the environmental protection department.

Figure 5. Electric gate valve

Figure 6. Accidental sewage overrunning pipe

4. Conclusion

According to the analysis on waterlogging prevention risks and measures in Zhuhai Qianshan Water Purification Plant, when the urban construction land is decreasing and the urban sewage pipe network has formed a system, to deal with the urban sewage that continuously breaks the original planned scale in a more economical and reasonable way, the underground urban sewage treatment plant demonstrated by total factor has such advantages as saving construction land, having little impact on the environment such as air and landscape, and having little impact on the exiting sewage collection and delivery systems. Nevertheless, the risk of the flood disaster cannot be avoided since sewage treatment facilities are located underground. The flood disaster is from two aspects: the "flood" that occurs outside the treatment facilities, and the "waterlogging" caused by the overflow of the sewage to be treated in the treatment facilities due to an accident. For the former, designers need to reasonably determine the site elevation of the plant according to the flood standard in their region after fully understanding the site elevation of the plant and its surrounding areas and the maximum level of the water system, to ensure that the rainfall that does not exceed the design standard can be safely discharged into the receiving water body; for the latter, namely the rainfall that exceeds the design standard, corresponding emergency measures should be taken to ensure the normal operation of the sewage plant.

Full, concrete and effective measures should be developed for the exposed parts, such as access, hoisting channels and ventilation opening, of the underground sewage plant. On the one hand, this can reduce the rainfall into the underground area; on the other hand, the rainfall into the underground area must be collected into the underground drainage system in an organized way, pumped by drainage pump and discharged into the urban drainage system outside. The rainfall that exceeds the flood and waterlogging design standard should not damage aboveground transformer and distribution facilities and others; for sewage into the sewage treatment plant, an electric gate valve and a quick closing valve in response of sudden power failure should be set up at the end of the sewage pipe into the plant in strict accordance with *Technical guideline for underground municipal wastewater treatment plant* and relevant regulations, so as to ensure that the sewage into the plant is controllable; accidental sewage overrunning pipes should also be set up for accident discharge of sewage that has entered the forebay of the sewage pump station and yet cannot not be dealt with in the normal process flow.

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