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Discussion on the General Design of Inland Waterway Tank Washing Station

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Abstract

Inland waterway tank washing station is a special place for oil or dangerous chemical liquid cargo ship to washing tank, which is an important infrastructure for the implementation of ship pollution control. This paper takes a tank washing station in the middle reaches of the Yangtze River as an example, focuses on the key elements of general design such as site selection, ship type, process design and plan layout, etc., and summarizes the general design experience of inland waterway tank washing station by combining with the actual operation effect of the station, so as to provide reference for the construction and design of the same kind of projects.

Keywords

Inland Waterway Tank Washing Station; General Design; Discussion.

1. Introduction

In inland navigation, since most of the inland dangerous chemicals ships do not have tank washing equipment, in order to ensure the quality of goods and prevent the chemical reaction between different goods from jeopardizing the safety of navigation, the cargo owner usually requires the shipping company to wash the tanks when replacing the incompatible goods. Inland waterway tank washing station is a special place for oil or dangerous chemical liquid cargo ship to washing tank, and to receive, treat or transfer the sewage of tank washing, including jetty, tank washing equipment, tank washing sewage receiving and treatment facilities, etc. [1]. Inland waterway tank washing station can effectively improve the phenomenon environmental destruction, for example, washing tank with substandard equipment or processes and illegally discharging sewage of tank washing, which directly lead to water pollution. This paper takes a tank washing station in the middle reaches of the Yangtze River as an example to discuss the key elements of the general designing of inland waterway tank washing station, providing a reference for the construction and design of similar projects.

2. Engineering Background

The case engineering is located in the middle reaches of Yangtze River, which is the only tank washing station in that province planned by the “Layout Program of Waterborne Tank Washing Station on the Mainline of the Yangtze River”, and it is of great significance for the implementation of General Secretary Xi Jinping's entrustment of “guarding the blue water of the river”, the enhancement of Yangtze River's ecological environmental protection, and the advancement of Yangtze River's green development of shipping.

In the water area, two 5000-ton berths were built in range of 295m long Yangtze River shoreline, which has the capacity to wash 612 ships per year. In the land area, a tank washing sewage treatment plant was built on 25,711 square meters of land, which has a sewage treatment capacity of 1000 cubic meters per day. The investment of the whole project is about 300 million yuan. The jetty was built by floating pier structure, with two 90.0m×15.0m×4.0m×2.2m (length×width×depth×draft) floating

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dock for tank washing, connected to the land area by steel approach bridge, piled platform and pipe gallery.

Figure 1. Aerial view of the tank washing station

3. Engineering Design Characteristics

The tank washing station is the first batch of construction projects after the release of "Layout Plan for Waterborne Tank Washing Station on the Mainline of Yangtze River", which is different from traditional liquefied cargo wharf with the features of unclear nature of the jetty, diversified types of sewage for operation, complicated process of washing tank and sewage treatment, and numerous structures and buildings.

3.1 Site Selection

The preliminary work of the tank washing station was carried out in early 2019. In the case that relevant technical standards and supporting policies such as "Design Guidance for Tank-Washing Jetty of RiverPorts (JTS/T 173-2019)" have not yet been issued, considering the supporting environmental protection facilities of the tank washing station as a chemical terminal, as well as economizing the use of shoreline resources to facilitate supervision and management by the competent authorities, the project is located in Yunxi Industrial Park operation area. The operation area is planned to focus on the transportation of liquid chemicals, crude oil and products, with the function of LNG refueling, and mainly serves for the transportation of raw materials and products for the rear port chemical enterprises and enterprises in Yunxi Industrial Park.

The spacing between the berth and upstream and downstream projects is designed in accordance with the "Standard for General Design of River Ports (JTS 166-2020)" and "Code for Fire Protection Design of Oil&Gas and Chemical Terminals (JTS 158-2019)", and the spacing with the upstream petrochemical berth is taken as 50m, and the spacing with the downstream petrochemical berth is 348m.

The spacing between the land washing sewage treatment station and the neighboring facilities is designed in accordance with the "Fire prevention code of petrochemical enterprise design (GB 50160-2008)", and the distance between it and the rear petrochemical plant's liquid tank group (outer wall of the tanks) is about 110m.

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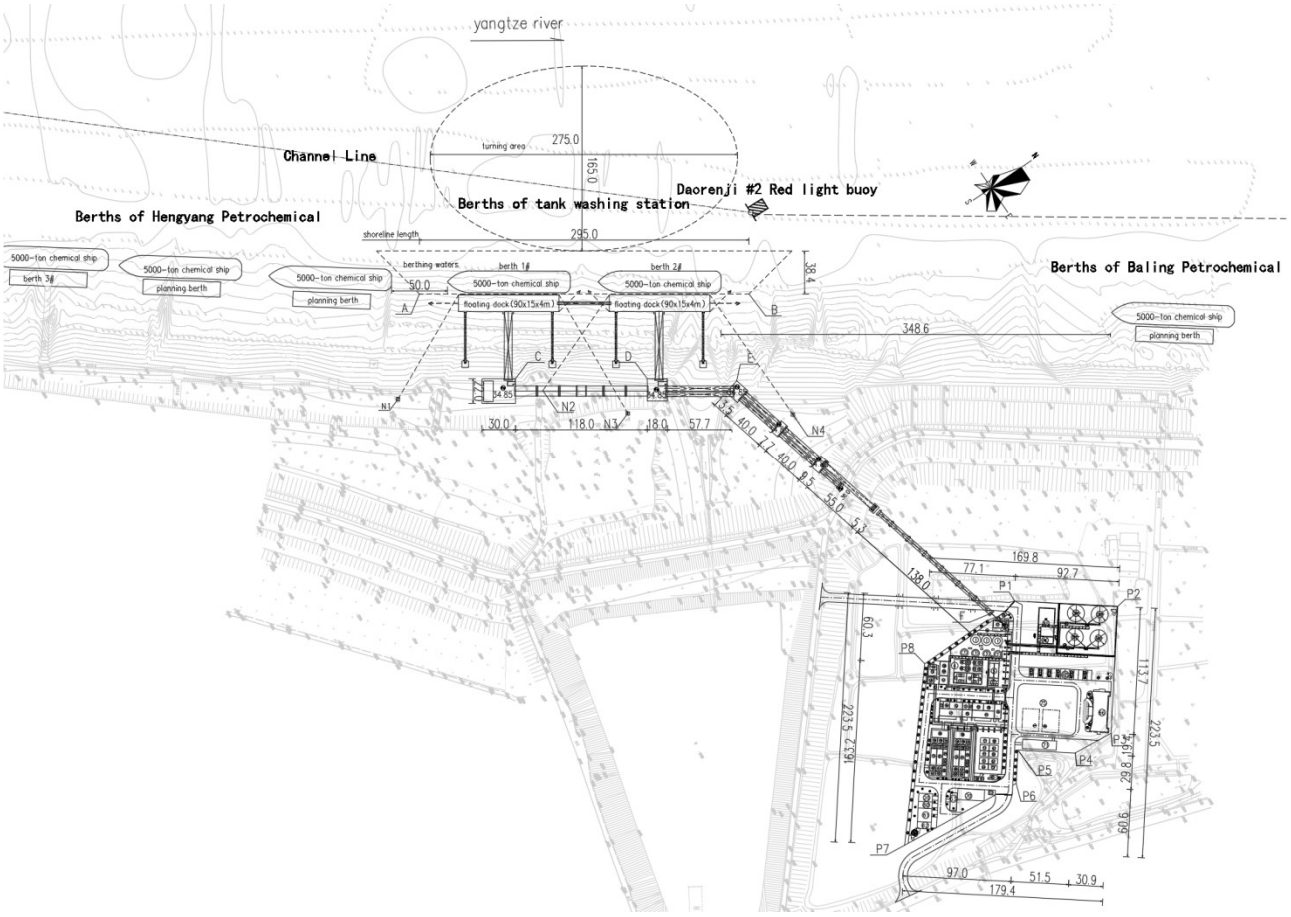

Figure 2. General arrangement plan of the tank washing station

It has been 3 years since the wash station was built and put into operation, and its operation experience shows that it was reasonable and far-sighted to consider the site selection of this project according to the nature of the hazardous chemical berth. When the tank washing station was put into operation for one year, there was an emergency oil leakage accident in the tank of a downstream petrochemical terminal, which was coordinated by the competent authority, and the accidental vessel was urgently towed to the terminal of the tank washing station for treatment, which saved a lot of time and provided effective support for the competent authority to deal with the dangerous situation. In addition, when the downstream petrochemical terminal starts the reconstruction project in 2021, the Project has sufficient safety distance from its water area, which effectively saves the shoreline, and this project is not constrained by the safety distance of the external petrochemical inter-plant pipelines during the land-based reconstruction and expansion of this project.

However, the disadvantage is that during the construction period, it was found that it was very difficult to apply for a direct discharge port for the tail water generated from the tank washing wastewater treatment, and it could only be connected to the sewage treatment plant 5 kilometers away through local coordination, which led to a large cost for the reporting and construction of the tail water pipeline.

3.2 Washing and Sewage Treatment Process Design

As the only tank washing station of the province, the engineering set the urban ship of the municipality as its target user, which petrochemical industry is the largest petrochemical industry cluster in the province. With the extension and development of the petrochemical industry chain, municipality demand for the transportation of petroleum and products, chemical raw materials and products will further rise, the number of dangerous chemicals ships to port will also increase. Through researching the situation of hazardous chemicals ships arriving at the port in 2017 and 2018, 24 categories of

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hazardous chemicals are statistically summarized, and according to their nature, they are divided into 5 categories, including oil, benzene, acid, alkali, alcohol, and so on.

Table 1. Ship types of tank washing

categories		hazardous chemicals	hazardous classification
oil oil		crude oil, gasoline, diesel oil, wax oil, fuel oil, solvent oil, aviation kerosene, catalytic diesel oil, reformed naphtha	A class of flammable liquid
chemicals	Benzene (containing alkanes, alkenes, esters)	ethylbenzene, styrene, xylene, o-xylene, mixed xylene, trimethylbenzene, cyclohexane, methyl acetate, n-butyl acetate, sec-butyl acetate	High hazard
	Acid	acetate	moderate hazard
	Alkali	caustic soda	mild hazard
	Others	methanol, ethanol	mild hazard

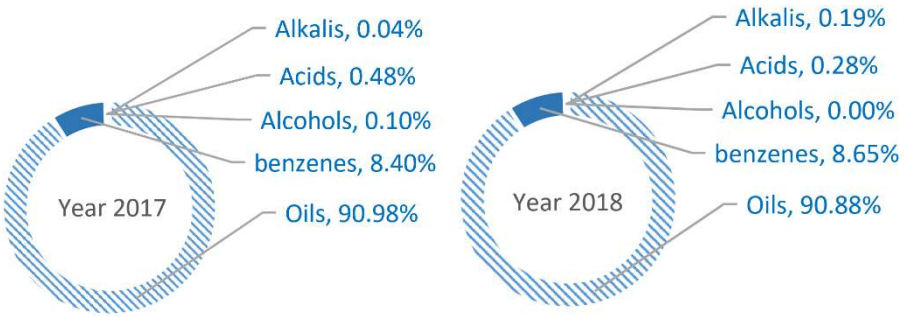

Figure 3. Ship type statistics chart

Tank washing process in jetty: residual liquid cleaning → dangerous gas replacement → washing by mobile tank washing machine → extraction of washing sewage → steaming tank → ventilation degassing → manual washing → extraction of washing water → drying treatment of the cargo pipe→ drying treatment of the cargo tank.

Tank washing wastewater transportation process. The tank washing wastewater is temporarily stored in the cabin of floating dock. After passing through the approach bridge corridor of about 600 m, it is transported by pipeline to the collection tank and collection pool of the land area tank washing sewage treatment plant. 20 # seamless steel pipe is selected for the pipeline except for the acid wastewater pipe, and the acid wastewater pipe is lined with polypropylene (PP) seamless steel pipe.

Solid cargo loading and unloading process. After the living materials are transported to the valve chamber platform by the vehicle through the approach bridge, they are transported to the floating dock through the suspended lifting trolley on the steel approach bridge, and then the materials are transported to the ship through the hydraulic crane on the deck. After the solid waste on the ship is sealed, it is lifted to the suspended lifting trolley by hydraulic crane, and then transported to the valve chamber platform at the end of the steel approach bridge, which is taken over by the garbage truck to the garbage treatment plant.

Sewage treatment Process. There are many kinds of sewage in the tank washing station. For the five types of sewage, from the aspects of economy and efficiency, ' oil separation precipitation + demulsification + two-stage air flotation + Fenton oxidation ' was used to pretreat oil and benzene

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tank washing sewage, ' Fenton oxidation ' was used to pretreat alcohol sewage, ' acid-base neutralization ' was used to pretreat acid-base sewage, ' oil separation precipitation + air flotation + Fenton oxidation ' was used to pretreat other chemical wastewater, and ' grille ' was used to pretreat domestic sewage and initial rainwater. The pretreated sewage was treated by the combined process of ' facultative oxidation (hydrolysis acidification) + A / A / O + A / A / O + ozone oxidation + MBR '. The main water quality indexes of the final effluent reached the main water quality indexes of table 1 in 4.2 of the ' Emission standard of pollutants for petroleum chemistry industry ' (GB31571-2015). Some of the effluent reached the standard were transported back to the wharf for washing, and the rest of the nano-tubes were discharged.

According to the statistical results of the operation after the completion of the tank washing station, the actual ship type is mainly oil tankers (more than 90 %), with less benzene, acid, alkali and alcohol, which is consistent with the previous research statistics. The effect of landing and treatment of tank washing sewage is good. The various sewage treatment processes adopted have achieved the expected results in the debugging and operation stages.

The shortcoming is that due to economic, epidemic and other reasons, the actual ship washing capacity of the tank washing station is far lower than that planned by the " Layout Program of Waterborne Tank Washing Station on the Mainline of the Yangtze River, " and there is a problem of operational difficulties. Therefore, it is suggested that in the design of similar projects, it can be considered to combine with the existing hazardous chemicals wharf and use the existing wharf reconstruction to save investment.

In addition, there are many typess of ship in the tank washing station. In order to meet the requirements of various types of wastewater treatment, the sewage treatment process is complex and the construction cost is high. In the actual operation, the oil wastewater treatment is the main one, resulting in a waste of investment. Therefore, it is suggested that the idea of phased construction can be considered in the construction of similar projects. In the early stage, only the main types of sewage treatment facilities can be built, and a small amount of sewage in other categories can be considered for the treatment of tankers to save the early investment.

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In addition, the tank washing station have more than 5 categories of ship type, which lead to diversified types of sewage for operation. In order to meet the requirements of diversified types of sewage treatment, the sewage treatment process is complex and the construction cost is high. In the actual operation, the oil sewage treatment is the main one, resulting in a waste of investment. Therefore, it is suggested that the idea of phased construction can be considered in the construction of similar projects. In the early stage, only the main types of sewage treatment facilities can be built, and a small amount of sewage in other categories can be considered for the treatment of tankers to save the early investment.

3.3 Plan Layout

The layout of the tank washing station is an important factor related to the tank washing process, tank washing efficiency and tank washing capacity of the jetty. In order to meet the safety and

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environmental protection requirements in the tank washing operation and the tank washing sewage treatment process, and improve the social and economic benefits of the tank washing station, the reasonable layout of the tank washing station plays an important role in the optimization of the tank washing and sewage treatment process.

In the design process of the tank washing station, the theory of Systematic Layout Planning (SLP) is used for analysis. The theory starts from three basic levels : the relationship between different layout areas, the space occupied by the area and the comprehensive adjustment of the area. The product, output, production route, auxiliary department and time arrangement of the production unit are taken as the research points. Combined with the location correlation diagram of the operation area, a reasonable layout planning scheme is obtained.

According to the process flow of the tank washing station and considering the production auxiliary facilities, a total of 14 operation areas are divided.

Table 2. Operation area division table

No.	Name	Quantity	Remark
1	Floating dock	1	
2	Pipeline gallery	1	
3	Sewage collection tank area	1	7 sewage collection tanks for oil, benzene and alcohol
4	Sewage collection pool area	1	Acids, alkalis, domestic sewage
5	Standby sewage collection tank area	1	4 standby sewage collection tanks
6	Pretreatment area	1	Two-stage flotation device, Fenton oxidation device, pretreatment tank, physical and chemical intermediate water tank, physical and chemical sludge tank, oil separation sedimentation tank.
7	Dosing area	1	Sulphuric acid storage tank, liquid alkali storage tank, hydrogen peroxide storage tank
8	Biochemical and advanced treatment pool	2	Comprehensive regulating tank, hydrolysis acidification tank, A / A / O biochemical tank, secondary sedimentation tank, ozone oxidation tank, degassing tank, MBR membrane reaction tank, off-line cleaning tank, disinfection tank, clear water tank, sludge buffer tank, sludge concentration tank.
9	Fire pool and pump house	1	
10	Machine repair room	1	
11	Comprehensive office building	1	
12	Sludge dewatering house	1	Ozone generation room, sludge dewatering room, hazardous waste temporary storage room, general solid waste room
13	Production auxiliary room	1	Distribution room, laboratory, fan room, water lift room, water quality online monitoring room, disinfection equipment room, MBR dosing room.
14	Exhaust treatment device	1	

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Analysis of logistics relationship. Starting from the process flow of each operation area of the tank washing station, this paper analyzes the operation area sequence of the tank washing sewage, sludge and treatment agent and the logistics operation volume of each area. It is the key and premise of the plane layout of the tank washing station. The purpose is to make the whole operation process avoid detour and crossover as much as possible, and realize the three purposes of the shortest transportation distance, the lowest operation cost and the highest operation efficiency.

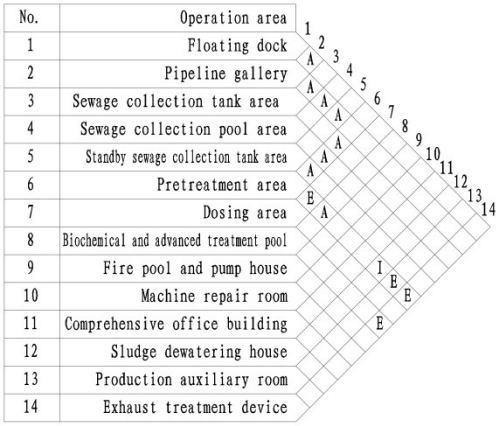

Figure 4. Analysis of logistics relationship

Analysis of non-logistics relationship. The following four factors are mainly considered : safety, environmental pollution, continuity of workflow, management and supervision. For example, the sewage collection area, the pretreatment area and the sludge dewatering house belong to the explosive gas environment area 1, which should be far away from the living area such as the comprehensive office building. The correlation is recorded as X, and the staff of the comprehensive office building needs to carry out the management work in the production auxiliary room and the fire pump house, and the relationship is recorded as I.

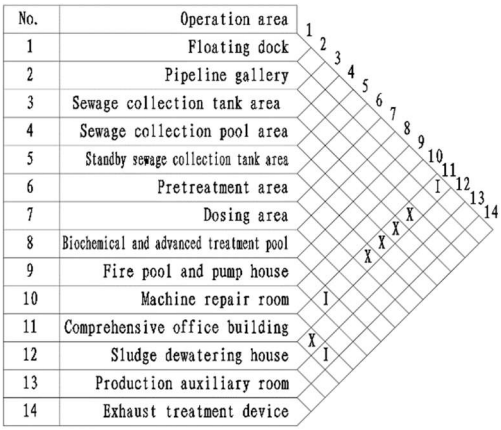

Figure 5. Analysis of non-logistics relationship

Analysis of comprehensive mutual relationship. It is necessary to weight the logistics relationship and the non-logistics relationship. The weighted value reflects the relative importance of the logistics relationship and the non-logistics relationship between the operation areas. In general, the ratio of the relative importance should be between 1 : 3 and 3 : 1. The ship types of the tank washing station is mainly liquid, which is transported by pipeline, involving oil, chemicals and other harmful sewage. Therefore, combined with the actual situation of the tank washing station, the weighted ratio of logistics relationship and non-logistics relationship is 2 : 1.

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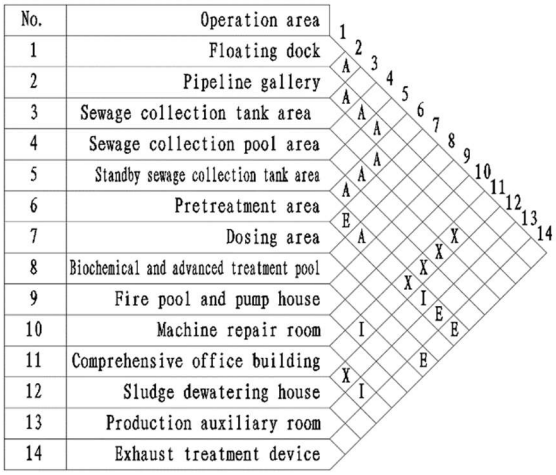

Figure 6. Analysis of comprehensive mutual relationship

According to the close degree of the relationship between each operation area, the mutual position relationship between each operation area is determined. Use //// to represent relationship strength A, /// to represent E, // to represent I, / to represent O, dotted line to represent X, ◯ to represent processing area, ▽ storage area, ∩ to represent auxiliary operation area, ⇧ and to represent office.

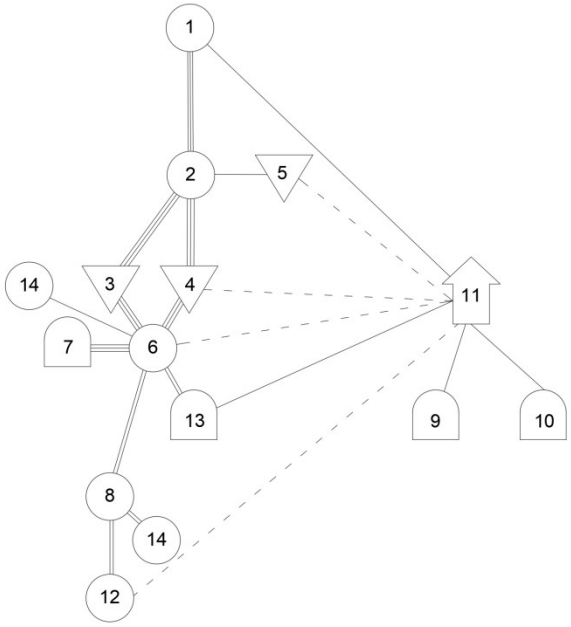

Figure 7. The mutual position relationship between each operation area

On the basis of the location relationship of each operation area, combined with the process flow of the tank washing station, multiple plane layout schemes can be obtained through arrangement and combination. However, when the SLP theory is applied to practice, it is necessary to consider the actual terrain conditions, the construction requirements of government departments, and the operation requirements of the enterprise itself. On the premise of comprehensive consideration, with the goal of safety, environmental protection and economy, the plane layout scheme is obtained. The main considerations are as follows : (1) The sewage treatment area and the office living area are separated ; (2) The office building is arranged on the upwind side of the perennial dominant wind direction, and the pipeline gallery is arranged on the west side of the land area by the river. (3) From the safety

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point of view, the operation area involving explosive gas environment, such as collection area and pretreatment area, is set in the corner of the site, away from the office building ; (4) From the perspective of environmental protection, the collection tank area, dosing area, pretreatment area and other areas that need anti-seepage treatment on the ground are arranged in a centralized manner ; (5) The centralized layout makes the sewage pipeline less, and the pipe rack does not need to cross the road many times, which is more economical; (6) Considering the later development, a large spare standby sewage collection tank area was arranged.

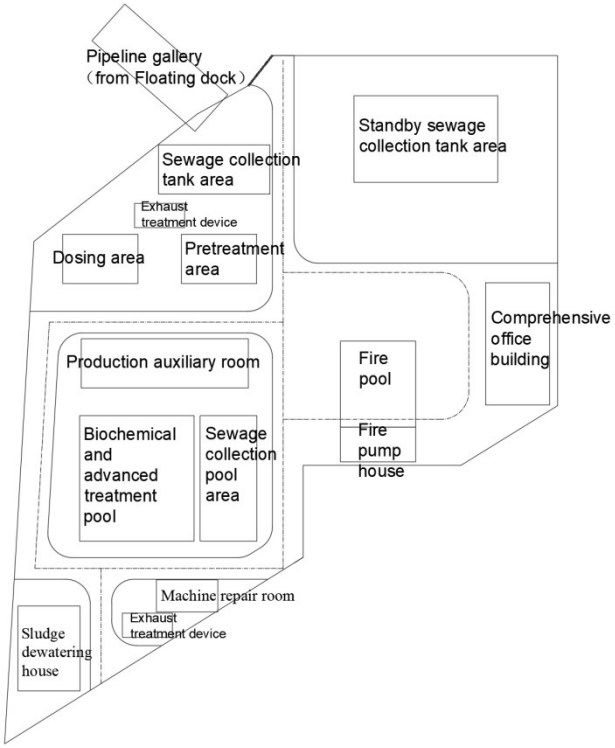

Figure 8. Layout drawing of the tank washing station

After the completion and operation of the tank washing station, the practice shows that the plane layout design realizes the coordination of safety, environmental protection and economy through multi-dimensional optimization. The closed-loop streamline of " tank washing operation-sewage collection-centralized treatment " formed in the production area has greatly improved the efficiency of personnel management, inspection and operation. The spare wastewater collection area has left a large space for the transformation and construction started in 2023.

4. Conclusion

The tank washing station started construction work in 2019 and put into operation in 2022. It washed 99 ships of various types of dangerous chemicals, received more than 20,000 tons of oily sewage from ships, and assisted in dealing with water emergency accidents once. It has achieved great social and environmental benefits and provided strong support for the safety guarantee system of dangerous chemicals transportation in the Yangtze River. Through the design, construction and operation practice of the tank washing station, this paper summarizes the following design experience :

(1) The construction planning and site selection of inland waterway tank washing station should consider the long-term development in addition to the overall planning of the port. It should be considered to be arranged in the concentrated area of chemical terminals and chemical parks to save investment costs.

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(2) For the prediction of ship types of inland waterway tank washing station, in addition to the investigation of the arrival of dangerous chemical ships in the region, it is also necessary to investigate the tank washing needs of cargo ship owners and chemical enterprises to determine the type and quantity of tank washing. In particular, for the category of sewage with very little washing capacity, it can be considered to be transported to other specialized sewage treatment stations through tankers to save upfront investment.

(3) The layout of inland waterway tank washing station should be considered from the aspects of process, safety, environmental protection and economy, and the needs of later development should be reserved.

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