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Design of Initial Rainwater Collection and Treatment Process in Port Stacking Aera

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Abstract: Bulk cargo in ports is usually stacked in the open. The initial rainwater in the region contains a large amount of suspended solids such as coal powder and mineral powder, which easily causes pollution to the surrounding water bodies. In order to meet the increasingly strict environmental requirements and national policies, this paper introduces the collection and treatment process design of the initial rainwater in the bulk pile area in a port of China, and the selection and arrangement of the main structure. The content of suspended matter in the initial stage of rainwater after treatment can meet the standards of "The reuse of urban recycling water-Water quality standard for urban miscellaneous use (GB/T 18920-2020)". This article provides reference for similar projects.

1. Introduction

The coal transportation in the coastal ports accounts for more than 3/4 of the total dry cargo transportation in China. Most coastal ports have bulk areas for stacking and loading of coal powder, mineral powder and other materials. At present, most of the bulk cargo stacked in ports are placed in open areas to facilitate the loading, unloading and transportation of the goods, but this kind of piling method has a high risk of environmental pollution. In the rainy season, a large amount of rainwater containing coal powder, mineral powder and suspended matters is discharged into the nearby, and the content of suspended matter is up to 1000 ~ 3000 mg/L [1], which easily leads to water pollution. In order to meet the relevant requirements of environmental protection, the initial rainwater in the storage yard should be collected and treated according to the regulations, and discharged or reused after meeting the standards. This paper introduces the design and equipment arrangement of the rainwater collecting system in the bulk material area of a port in China, and discusses the attention to the system operation.

2. The Volume Calculation of Initial Rainfall

For this project, the scope of rainwater collection was the bulk material area, mainly including yard, loading area and road, and the rainwater collection area was about 1.5×10^5 m^2. At present, there was no unified regulation on the calculation of initial rainfall volume. In many literatures, the

definition of initial rainfall is 5~20 min from the stare of rainfall, and the value varies according to different occasions. According to the "*Design Code for Water Supply and Drainage System of Petrochemical Enterprises (SH/T3015-2019)",* the total amount of polluted rainwater should be calculated as the product of the initial rainwater collection area and the initial rainwater depth, and the initial rainwater depth is generally 15~30 mm [2]. According to the *"Code for Environmental Protection Design of Water Transportation Engineering (JTS149-2018)"*, the precipitation depth of the initial rainwater at the port should be 0.01m. However, considering the port mainly collects the initial rainwater in the bulk and heap area, the level of pollution was more serious than that of the ordinary road surface, and a certain amount of treatment allowance is reserved. Hence the design value of the initial rainwater collection in the bulk and heap area of this port is 2000 m^3.

3. The Collection Method of Initial Rainwater

For the collection of initial rainwater on the ground of bulk cargo terminal, drainage ditches are usually set up. That is, the terrain slope could help the initial rainwater to be quickly collected through the drainage ditches [3]. In this project, the longitudinal span of the initial rainwater collection area was about 1.03×10^3 m. The transverse span was about 120 m, covering a long and narrow area, and there was a certain slope in the transverse direction. Taking into account the timeliness and effectiveness of rainwater collection in the initial stage, the project set up collecting channels and basins around the bulk piling area, which could not only prevent the disorderly discharge of rainwater in the initial stage into the sea, but also not hinder the bulk cargo stacking and handling operations in the port. In this project, a longitudinal rainwater collection channel was set at the lowest elevation side of the bulk material area, 7.0 m away from the pier shore. The rainwater collection tank was set at the lowest point of the rainwater collection canal. Figure 1 shows the initial rainwater collection canal arrangement in the bulk area.

According to the "*General Design Specification for Industrial Enterprises (GB50187-2012)*", the depth of the starting point of the general open trench should not be less than 0.2m, and the width of the bottom of the rectangular open trench should not be less than 0.4m; The longitudinal slope of open gully should not be less than 0.3%, and it should not be less than 0.2% in difficult areas with flat terrain. The top of the open trench calculated by flow should be more than 0.2 m above the calculated water level. According to the requirements of "*Water Supply and Drainage Design Manual*", the section of ground type dark ditch should not be too small, the width of the starting ditch should not be less than 0.5m, and the depth of the ditch should not be less than 0.6m. In this project, the initial rainwater collecting canals in the bulk material area were designed according to the concrete rain grate drainage gutter. The width of the starting ditch was 0.5m, the depth of the starting ditch was 0.6m, and the longitudinal slope of the drainage ditch was 0.2%.

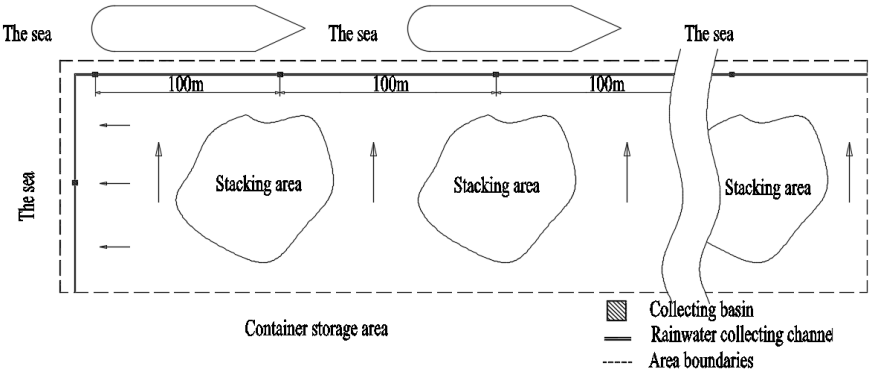

Figure 1: Drainage plan for initial rainwater collection in stacking area

4. Collection Tank Design

Considering the layout form of the initial rainwater collection area and the principle of uniform catchment, the collection tank should be set into multiple pools, and the structural form of the collection tank is steel structure or concrete structure. A certain slope should be set at the bottom of the collection tank, so that the slag precipitated to the bottom of the tank can be concentrated in the suction inlet of the sewage pump, which was conducive to the discharge of large particles of sediment [4,5]. A manhole should be set above the collecting pool so that operators can enter the pool to clean or maintain the water pump. Considering the loading and unloading operation in the area, the manhole was usually covered with steel cover plate. The steel cover plate can be of different types such as light or heavy, depending on whether there was a vehicle passing through it. Steel grille was set before the rainwater collection canal enters the catchment to reduce the blockage of the water pump caused by large particle cinder or other debris.

According to the terrain of the bulk material area and the characteristics of production operation, the rainwater collection area in the initial stage of the project is divided into 8 sub-areas, and each sub-area is equipped with 2 catchments, each with a volume of about 19 m3 and a catchment size of 2.5m × 2.5m ×3.0m. In order to ensure smooth drainage, each catchment pool is equipped with two unblocked submersible pumps. The setting principle is one for use and one for backup. The flow rate of submersible pumps is 250 m^3/h, and the resistance loss along the pipeline is calculated according to the pipeline transmission length. Submersible sewage pump is equipped with stirring function to prevent blockage of pump channel. The submersible pump will collect the initial rainwater through the pipeline to the integrated treatment tank for treatment, as the rain proceeds, the clean rainwater will overflow into the sea through the overflow weir of the catchment tank.

In order to prevent silting in the outlet pipeline of submersible sewage pump, backwash ports were set every 50 m. The pump outlet was equipped with a quick closed check valve, and the pressure relief valve was installed on the pipeline to prevent the "water hammer" effect to the system.

5. Integrated Treatment Tank Design

5.1. Process Flow Design

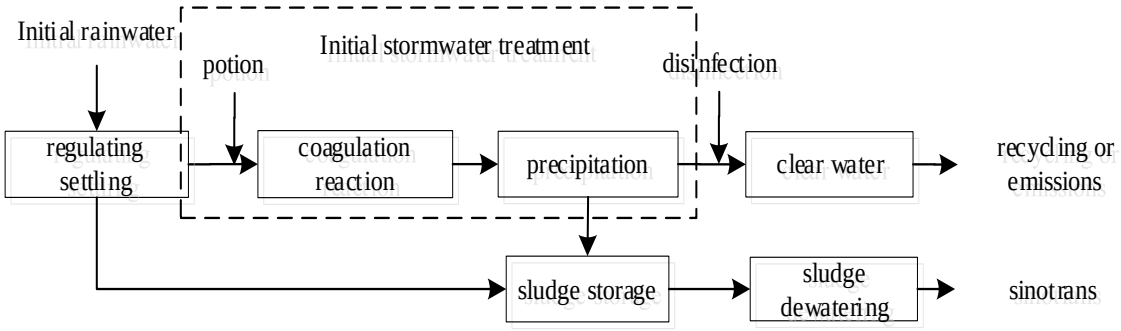

Figure 2: Process Flow of initial rainwater treatment

Figure. 2 shows the initial process flow chart of rainwater treatment. As showing in figure 2, in the initial stage, rainwater flows to the collecting wells by itself through pipes and canals, and when the volume of the rainwater collected in the wells reached the set level, collecting well lift pump should start to work and the initial rainwater was lifted to the regulating settling tank. The rainwater in the precipitation area was initially precipitated, and the pulverized coal and ore powder with large particle size were quickly precipitated and removed. The dispersed particles that cannot be

precipitated enter the coagulation reaction tank with the rainwater. After precipitation through coagulation reaction, the precipitation stability and polymerization stability of dispersed particles in rainwater were removed, and the dispersed particles condense and flocculate into aggregates to be removed. After treatment, the clean water was disinfected and stored temporarily in the clear water pool. The clean water in the clear water pool was reused for vehicle flushing, fog cannon and ground sprinkling, and the remaining part is put into the sea after the water quality reaches the standard.

The sludge in the regulating sedimentation tank and coagulation sedimentation tank was transported to the sludge storage tank by pump, and the sludge was conditioned and concentrated in the sludge storage tank and transferred to the plate and frame filter press for dehydration. The dehydrated sludge was shipped out and entrusted to qualified units for treatment.

5.2. Treatment Unit Design

5.2.1. Regulating Settling Tank

The purpose of setting a regulating sedimentation tank was to remove relatively dense particles, and then reduce the concentration of suspended solids in the initial rainwater, and has the role of temporarily storing the initial rainwater and regulating the amount of water treated [6]. According to the initial rainwater treatment scale, the total volume of regulating sedimentation tank set in this project was 2500 m^3, regulating sedimentation tank adopts semi-underground steel concrete structure, the main structure was set up precipitation area and regulating area respectively. The sludge pump was set in the sedimentation area to transport the initially precipitated particulate sludge to the sludge storage tank. The sludge pump was an onshore non-blocking pump. The flow rate of the sludge pump was 25 m^3/h and the head was 10m according to the calculation of the content of suspended solids in the inlet water. The mixing intensity is 8 W/m^3, and the power of the mixer was set as 5.0 kW to prevent the sludge deposition at the bottom of the pool caused by the sedimentation of the remaining suspended matter, which leads to the poor operation of the system. At the same time, a lifting pump was set to transport the initial rainwater to the subsequent coagulation reaction tank. The lifting pump flow of the regulating tank was 120 m^3/h and the head is 8 m.

5.2.2. Coagulation Tank

By adding coagulant and flocculant, under sufficient stirring and mixing reaction, the suspended particles with a specific gravity less than 1 which were difficult to precipitate in the initial rainwater would be removed. The coagulation tank body was semi-underground steel concrete structure [7,8]. The coagulation reaction time was designed to be 10~15 min. The coagulation tank was equipped with a mixer, which power was 2.2 kW and stirring speed was 30~60 rpm.

5.2.3. Sedimentation Tank

The sedimentation tank precipitates the large particles generated in the process of coagulation reaction to realize the separation of mud and water. After purification, the initial rainwater overflow to the clean water pool, which can be reused for fog cannon, dust removal and vehicle flushing in the port. The coagulation sedimentation tank was Semi - underground steel concrete structure. The designed treatment capacity of the coagulation tank in this project was 100 m^3/h, and the surface load was 1.5 $m^3/(m^2$ ћ). Inclined pipe packing was set in the tank to precipitate the suspended impurities in the water. Water flows upward along the inclined plate or inclined pipe, and the sludge at the separation point slides down to the bottom of the pool under the action of gravity along the inclined pipe, and then was centralized and eliminated. The incline tube packing was increased the precipitation efficiency by 50%~60%, and the treatment capacity was increased by 3~5 times in the

same area. The mud scraper of sedimentation tank adopts truss type, which was convenient for later maintenance and operation. The configuration power was 1.1 kW. A sludge hopper was set at the inlet of the sedimentation tank to discharge the precipitated sludge. The sludge pump flow rate in this project was 25 m^3/h with a head of 10m.

5.2.4. Clear Water Pool

The main function of the clean water tank was to regulate the amount of rainwater after treatment and transport it to the water point through the pump. The residence time of the clean water tank was designed to 3~5 h. The clean water tank in this project was designed with a full volume of 500 m^3, two reuse pumps with a flow rate of 200 m^3/h and a head of 15 m were setted. If the treated water should meet the higher standards, sodium hypochlorite disinfection would be required [9,10], and the disinfection contact time was designed not less than 30 minutes.

5.2.5. Sludge System

The precipitated sludge generated in the initial rainwater treatment process was transported to the sludge storage tank by the pump for temporary storage, and then enters the plate and frame filter press system for dehydration treatment. The dehydrated sludge moisture content was less than 60%. In this project, the filtration area of plate and frame filter press was 100 m^2. The filtrate water generated in the filtration process was transported to the regulating sedimentation tank, and the sludge was transported to outside for treatment.

6. Analysis of Operation Effect

Table 1 shows the Removal rate of suspended solids in each section. During the initial stage of rain, a large number of fine suspended particles were often entrained, which was not easy to settle. Large coal particles are gradually deposited along with the flow of the collecting channel, so cleaning and maintenance should be designed. The concentration of small suspended matter is generally 1000-3000mg/L. As showing in table 1, after further purification and precipitation of the initial rainwater treatment facility, the drainage index of this project has meet the standards of *"The Reuse of Urban Recycling Water-Water Quality Standard for Urban Miscellaneous Use (GB/T 18920-2020)"*, and the drainage turbidity is less than 10 NTU [11,12].

Table 1: Removal rate of suspended solids in each section

Number	Structure	Concentration of suspended solids in influent (mg/L)	Concentration of suspended solids in effluent (mg/L)	Removal rate (%)
1	Collection Tank	3000	2700	10
2	Regulating Settling Tank	2700	2430	10
3	Sedimentation Tank	2430	50	98

7. Conclusion

In order to meet the relevant requirements of environmental protection, the initial rainwater in the storage yard should be collected and treated according to the regulations. According to the topographic characteristics of the bulk piling area of the port and considering the timeliness and effectiveness of the initial rainwater collection, this project selects a reasonable treatment process to remove the suspended matter in the initial rainwater. The collection of initial rainwater in the bulk

area of the port is a difficult point in the design of the project. The uniform water collection was fully considered and initial rainwater collection channels and supporting collection pools were designed to be separated and played an efficient role in the actual operation.

The concentrations of suspended matter in initial rainwater, which content of coal and mineral powder, was as high as 1000-3000 mg/L. In this project, the coagulation-precipitation process was used for suspended matter treatment. The clean water after treatment meets the reuse water quality requirements and was reused for fog cannon, dust removal and vehicle washing in the port, which achieves the purpose of saving water and reducing emissions.

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