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Case Study on the Design Engineering of Deodorization System in Coal Chemical Wastewater Treatment Plants in the New Era

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Abstract: *Since the beginning of the new era in China, environmental protection requirements have been continuously increasing, imposing higher demands on wastewater treatment in various industries. As a significant source of pollution, the coal chemical industry particularly emphasizes the design engineering of deodorization systems in wastewater treatment plants. This paper conducts an in-depth study on the design engineering of deodorization systems in coal chemical wastewater treatment plants in the new era. Through the analysis of deodorization standards, main treatment devices, and processes in coal chemical wastewater treatment plants, as well as discussions on specific engineering cases, optimization design strategies and key technical solutions are proposed, aiming to provide beneficial references for the design and implementation of similar projects.*

Keywords: *Coal chemical wastewater treatment plant; Deodorization system; Design engineering*

1. Introduction

The scale and quantity of urban sewage treatment facilities in China continue to increase, closely related to the continuous improvement of environmental standards. Among them, the discharge of wastewater from coal chemical industry is particularly prominent, containing more than a dozen harmful gases such as ammonia, hydrogen sulfide, sulfides, phenols, and volatile organic acids, which pose significant risks to the ecological environment and human health. Long-term exposure to these toxic and harmful gases can lead to digestive, respiratory, and other diseases among the population around the treatment plant, and in severe cases, may even result in acute poisoning and death. Therefore, relevant departments urgently need to optimize the design of deodorization system engineering in coal chemical wastewater treatment plants.

2. Common Deodorization Standards for Coal Chemical Wastewater Treatment Plants in the New Era

In recent years, with the rapid development of China's coal industry, the scale and quantity of construction of coal chemical wastewater treatment plants have been greatly increased. Against the backdrop of the new era, the country has put forward increasingly higher requirements for the discharge standards of coal chemical wastewater. Currently, coal mining enterprises in China are facing significant environmental pollution issues in wastewater treatment plants, and to ensure that the treated wastewater meets standard emission requirements, it is urgently necessary to adopt more advanced treatment processes.

The treatment of coal chemical wastewater is an important aspect of environmental pollution control, containing various odorous gases such as H_2S and NH_3, as well as acidic and alkaline gases such as methanethiol, methylamine, methyl mercaptan, benzene, and toluene. Typically, the concentrations of these odorous gases range from 0 to 300 mg/m^3 for NH_3, 0 to 150 mg/m^3 for H_2S, and 2000 to 8000 mg/m^3 for odor. According to current standards, gas emissions should comply with the secondary standards of "Limiting Concentration of Odorous Substances at Factory Boundaries" GB14554-93, as well as the requirements of "Pollutant Emission Standards for Urban Wastewater Treatment Plants" GB/T8175-1989 and the "Secondary Standards for Tail Gas at Enterprise Boundaries" GB18918-2002.

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3. Main Treatment Devices and Processes in Coal Chemical Wastewater Treatment Plants

The complete deodorization system in coal chemical wastewater treatment plants comprises odor hoods, pipeline transportation, chemical scrubbers, biofiltration ponds, discharge systems, and dosing and control systems. This system involves a novel type of odor source, with the following process flow: Firstly, to address potential sources of odor, a closed odor hood is installed indoors, and accumulated odorous gases are transported through pipelines to an acid-base chemical purification device [1] using a centrifugal fan. Clean water is sprayed in the purification tower to remove odorous solid impurities and adjust indoor temperature and humidity. This process also serves as a buffer to alleviate the impact of high-concentration pollutants on the environment. Subsequently, using acid-base media, a reaction occurs with toxic and harmful substances as a pretreatment before biological and chemical treatment. Treated odorous gases enter the biofiltration pond through a filter tower, where harmful gases in the smoke are adsorbed, absorbed, and degraded by microorganisms, transforming them into harmless substances. Finally, the treated exhaust gas is discharged into the atmosphere through an exhaust port, and in the event of an emergency, odors can also be rapidly expelled from the chimney.

There is a wide variety of pollutants in the exhaust gas, and based on their composition characteristics, various treatment methods such as adsorption, chemical oxidation, chemical scrubbing, catalytic combustion, direct combustion oxidation, soil treatment, plant liquid spraying, and biofiltration can be adopted. On this basis, by comparing the operating principles and characteristics of different processes, the optimal process for coal chemical wastewater treatment projects can be selected. Among them, the biofiltration pond exhaust purification technology achieves the best treatment effect, with the following treatment process:

The core of biofiltration deodorization technology is to utilize microbial metabolic activity in the filter chamber to degrade harmful gases. In this process, technicians first use a centrifugal fan to deliver the odorous gas to the bio tower. According to Henry's Law, toxic and harmful components are completely dissolved in water. Subsequently, the water solution containing harmful components passes through the packing layer, coming into sufficient contact and adsorption with specific microbial populations. Under appropriate conditions such as temperature and pH, microorganisms can transform organic pollutants in the water into beneficial organic substances for human health, such as water, nitrates, and sulfates. In this process, the degradation rate of microorganisms is as fast as traditional chemical reactions [2]. Finally, during the regeneration process, microorganisms absorb toxic components, converting them into sources of life energy and cell substances, achieving rapid reproduction. For example, sulfur-oxidizing bacteria can oxidize sulfur to sulfate, which in turn provides energy for microorganisms.

4. Analysis of Key Optimization Focuses in the Design Engineering of Deodorization System in a Coal Chemical Wastewater Treatment Plant in the New Era

4.1. Engineering Overview

A coal chemical project in a northern city of China is located within an industrial park. The project is tasked with pretreatment, biochemical treatment, and sludge treatment, with the complexity of odorous components in the exhaust gas posing significant processing challenges. Improper handling or direct discharge could have adverse effects on the local ecological environment. To address this issue, the project team proposes a new process combining alkaline scrubbing tower, biofiltration pond, and activated carbon absorption technologies. After treatment, the exhaust gas will meet the 15m exhaust emission standard stipulated in the "Odorous Pollutant Emission Standard" GB14554-201X and satisfy the corresponding limit requirements in the "Pollutant Emission Standard for Petrochemical Industry" GB31571-2015.

According to the wastewater treatment engineering design plan of this project, the total treatment capacity of the treatment plant is 120,000 Nm^3/h. Specifically, for high-concentration odorous gases, the treatment capacity of the device is 35,000 Nm^3/h; while for low-concentration odorous gases, the treatment capacity of the device is 85,000 Nm^3/h. Specifically, high-concentration odor pollutants mainly exist in the pretreatment and sludge treatment processes, while low-concentration odor substances mainly exist between the biochemical treatment process and the pretreatment system.

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4.2. Design of Odor Treatment Equipment

Firstly, designers can utilize an alkaline scrubbing tower to purify high-concentration exhaust gas, removing a significant amount of hydrogen sulfide and other acidic gases, effectively reducing the load on the terminal biofiltration pond. To ensure the normal operation of the alkaline scrubbing tower, alkali solution needs to be added to the supporting circulating water system. Secondly, the scrubbed tail gas can be mixed with a small amount of exhaust gas and then sent to the biofiltration pond. This equipment can deeply treat hydrogen sulfide, ammonia, volatile organic compounds (VOCs), and odorous gases in the tail gas, and combined with the circulating cooling water system, provide a favorable environment for microbial growth. On this basis, activated carbon (ACF) is used to adsorb hydrogen sulfide, ammonia, VOCs, and other substances in the tail gas to ensure compliance with emission standards. Additionally, the project needs to design a set of recovery devices to perform short-term desorption of activated carbon for recycling and reuse. After being treated by the alkaline scrubbing tower, biofiltration pond, and activated carbon adsorption tower, the tail gas is then sent into a 15m high exhaust pipe by an induced draft fan.

4.2.1. Pretreatment Section

Alkaline scrubbing is a chemical absorption method that transforms harmful gases into liquid or harmless gases. Currently, the most commonly used method is counterflow packed scrubbing tower, where the working principle involves spraying the absorbent from the top of the tower onto the packing layer, and then flowing upward along the gaps of the packing layer. This structure enables thorough contact between gas and liquid phases, efficiently adsorbing harmful substances. The packing material chosen is polygonal hollow polypropylene microspheres, which have a large specific surface area, wetting area, and gas-liquid mass transfer area, thereby enhancing adsorption performance [3]. Proper selection of packing ratio ensures uniform distribution of gas and liquid phases in the tower while reducing internal resistance. Maintaining an appropriate amount of liquid in the packing layer facilitates gas-liquid phase transfer. The packing material features resistance to acid and alkali and low resistance, which is conducive to gas-liquid phase mass transfer. During alkaline scrubbing, it is necessary to equip sodium hydroxide dosing equipment and use metering pumps for automated chemical cleaning. If the tail gas has a high sulfur content, such as hydrogen sulfide, methanethiol, etc., sodium hydroxide dosing equipment is employed for removal. The wastewater after scrubbing with alkali is intermittently discharged into the front end of the sewage treatment plant for subsequent treatment.

4.2.2. Biological Treatment Section

In the biological treatment section, technicians can adopt a two-stage series-connected biological deodorization process, where the synergistic action of various microorganisms is the key to deodorization. Different types of microorganisms are required for oxidation processes. Research results indicate that sulfur-oxidizing bacteria can efficiently oxidize hydrogen sulfide into sulfate ions in the presence of hydrogen sulfide. For odors produced by organic sulfides represented by methanethiol, organic sulfur needs to be converted into H_2S first, and then with the participation of autotrophic microorganisms, it is converted into sulfate ions. Taking ammonia nitrogen as an example, it first dissolves in water and then undergoes a series of processes involving ammonia-oxidizing bacteria, nitrite-oxidizing bacteria, and nitrate-oxidizing bacteria, ultimately transforming into nitrate. Under facultative anaerobic conditions, nitrate-reducing bacteria (NO3-) are the main functional microorganisms in the denitrification process [4]. To support this process, designers can choose corrosion-resistant, acid-resistant, high surface area, and high porosity fillers.

Due to its excellent antioxidant and biodegradable properties, as well as outstanding acid resistance, this filler maintains strong acidity while retaining its original shape and compactness without any impact. Its unique morphology and structure efficiently filter out odors while providing a moist and favorable growth environment for microorganisms. It effectively adsorbs odors, maintains appropriate pH levels, and enhances material corrosion resistance. Additionally, the filler exhibits excellent biological activity for odor removal. To further improve deodorization efficiency, this project can install a demister at the outlet of the deodorizer, which can prevent liquid splashing in the exhaust gas and reduce the loss of circulating water.

4.2.3. Deep Treatment Section

The core structure of the deodorization equipment in the deep treatment section includes adsorption, regeneration, tail gas cooling regeneration, filler drying, and inert gas protection. This system includes

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detailed designs for absorption pools, exhaust pipes, return air ducts, tail gas recovery pipelines, and drying and cooling pipelines to form a complete wastewater treatment process. This structural design ensures the continuous and stable operation of the system by immediately activating backup absorption pools when one absorption pool needs regeneration [5]. To better absorb multi-component exhaust gases, designers can use special graded carbon particle fillers inside the absorption tank.

4.3. Estimated System Operation Effectiveness

Once the wastewater deodorization system operates stably, it is expected to exhibit excellent treatment results. Experimental results demonstrate that the process operates efficiently, with influent indicators lower than the original design values. After 10 days of actual production, the indicators of the outlet gas all meet emission requirements (see Table 1), and the long-term removal efficiency of the process is expected to exceed 98%.

Table 1: Emission Indicators after Treatment

Control Item (mg/m3)	Actual Outlet Value (mg/m3)	Specification Requirement Outlet Value
Odor Concentration	480	<1000 (dimensionless)
Ammonia	0.38	0.6
Hydrogen Sulfide	0.045	0.06
Methanethiol	0.0032	0.006
Styrene	1.2	3
Non-methane Total Hydrocarbons	0.121	/

5. Conclusion

In the above example of the coal chemical wastewater treatment plant deodorization system design project, advanced biological filtration deodorization technology was employed, combined with alkaline scrubbing towers and activated carbon adsorption units, resulting in good operational performance. After stable operation verification, the emission indicators of the outlet odor met the emission standards, with a long-term removal efficiency consistently exceeding 98%. In future engineering practices, relevant enterprises need to further strengthen research and exploration of the design of deodorization system engineering for coal chemical wastewater treatment plants, continuously optimize design schemes, improve deodorization efficiency, reduce energy consumption and operating costs, thereby making greater contributions to protecting the living environment of residents.

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