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The Odor Treatment Methods of Wastewater Treatment Plant Based on Biological Oxidation Process

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With the continuous increase of urban domestic sewage and production sewage discharge, China has enhanced the treatment of odors in the sewage treatment process. At present, the odor problem of sewage treatment plants needs to be treated jointly by various techniques. In this paper, biological and oxidation methods are selected to study the odor treatment methods of sewage treatment plants, and two pilot plants of biological method and oxidation method are established for the pilot tests. The test results showed that: using biological method to treat the odors in the sewage tanks has a good treatment effect, and the treatment effect of N_2 and H_2S is relatively stable; using the "alkali absorption + oxidation" method to treat the odors produced by the other regulating tanks has a relative stable treatment effect. The H_2S treatment efficiency is best when the pH is 7.5-9, the potential is 700-850, and the liquid-gas ratio is between 4.7L/m^3-6.0L/m^3.

1. Introduction

As China's economic development constantly speeds up and the industrialization process continues to deepen, the discharge of urban domestic sewage and production sewage continues to increase. The discharge of urban sewage has a great impact on the lives of the general public and industrial production. In the city, odor is usually generated during the sewage treatment process, and whether the odor is harmful or not, it is unbearable for the people. How to control the odors and conduct effective treatment has become a key issue in urban environmental protection (Antonopoulou et al., 2014). At present, China has enhanced the treatment of odors in the sewage treatment process, but single treatment technology has been unable to effectively deal with the odor problem of sewage treatment plants. The combination of various technologies has become an important development direction of future odor treatment (Ghoreishi and Haghighi, 2003; Sed et al., 2018).

At present, many scholars at home and abroad have conducted targeted research on the treatment of odors and formed a series of research results. Some scholars have proposed to use chemical washing method, biological filtration method and other methods to deal with the odors (Cowger and Labbe, 1965; Esplugas et al., 2004). Some scholars have conducted detailed research on the equipment and process of odor treatment (Ioannou-Ttofa et al., 2017); and some scholars have studied the feasibility of odor treatment in some projects (Beltrán et al., 2001; Moreira et al., 2015). This paper is mainly based on the biological oxidation method to study the odor treatment method of sewage treatment plant, which is of great practical value (Mazzelli et al., 2018).

2. Introduction of relevant theories

2.1 Substances that produce odors

The generation of odors is mainly closely related to the treatment process of sewage and the operation of the treatment system. Sewage contains a lot of anaerobic organisms, which produce odors when they consume the organic matters (Holman and Wareham, 2003). The components of the odors are mainly composed of organic molecules and inorganic molecules, and the main inorganic gases are hydrogen sulfide and ammonia. Organic odors are often the result of the activity of living organisms, which decomposes the organic matters to

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form a foul odor composed of various organic gases. The common odor-causing sulfur compounds are shown in Table 1.

Table 1: Identification of sulfur-containing odor compounds in sewage treatment facilities

Molecular formula	Odor characteristics	Critical value	Molecular weight
CH2=CH-CH2-SH	Strong garlic taste	0.00004	75.31
CH3-(CH2)3-CH2-SH	Rotten taste	0.0006	107.64
C6H5CH2-SH	Intensely unpleasant	0.00019	1276.58
CH3-CH=CH-CH2-SH	The stink of the weasel	0.000032	93.47
CH3-S-CH3	Rotten vegetable taste	0.0005	64.18
CH3-CH2-SH3	The rotten taste of cabbage	0.00024	60.83

The odor is mainly due to the sensation caused by stimulating the olfactory organs in the nostrils. The common odor gas in sewage is mainly the hydrogen sulfide gas which is formed by bacteria reducing sulphur under anaerobic conditions (Lee, 2018).

$$\mathrm{SO}_4^{2-} + Organic\ compound \rightarrow S^{2-} + H_2O + CO_2 \quad (1)$$

$$S^{2-} + 2H^{+} \rightarrow H_2S \quad (2)$$

If the pH value reaches 9, 99% or more of the sulfide is dissolved in the water, and the sulfur exists in the form of HS that has no odor. When the pH exceeds 8, the hydrogen sulfide gas won't release. If the pH value is less than 8, the hydrogen sulfide gas will be released from the sewage. When the pH exceeds 9, it will release ammonia gas (Lee and Ahn, 2010).

2.2 Oxidation treatment

In the oxidation treatment of odors, various hypochlorites are mainly used as oxidants to utilize their strong oxidation properties (Benner et al., 2013). The cyano group is not easily decomposed, so it is usually accelerated by a strong oxidation method. The basic ion reaction formula is as follows:
Local oxidation:

$$\mathrm{CN}^- + \mathrm{HOCI} \rightarrow \mathrm{CNCI} + OH^- \quad (3)$$

$$\mathrm{CNCI} + 2OH^- \rightarrow CNO^- + CI^- + H_2O \quad (4)$$

Complete oxidation:

$$2CNO^- + 3OCI^- + H_2O \rightarrow 2CO_2 + N_2 + 3CI^- + 2OH^- \quad (5)$$

Reaction (3) can occur instantaneously at any pH conditions (Peter and Von, 2007). In order to be able to convert cyanogen chloride (CNCI) into cyanate according to reaction (4) in time, a pH value that is higher than 10.5 is required, and at this time, the reaction can be completed in a few minutes (4). Reaction (5) is mainly the oxidative decomposition of cyanate into nitrogen and carbon dioxide (Raúl et al., 2013).

3. Biological oxidation odor treatment

3.1 Biological odor treatment

The biological odor treatment process is: at first, the organic pollutants contacted with the water and dissolved in it. Due to the difference in concentration, after the organic matters dissolved in the water, they further diffused from the liquid film into the biofilm, and then had been absorbed by the microbes in the biofilm. Through metabolism, the microbes will eventually turn the stinks in the odors into energy and carbon source, and decompose the organic matters into water and carbon dioxide. Eventually, effective treatment of odor is achieved. The whole process is shown in Figure 1.
The equipment and materials needed for the biological treatment of odors are shown in Table 2.
The data recording and processing of the biological odor treatment are shown in Table 3.
Through the experimental results in the table, it can be found that using biological method to treat the odors in the sewage tanks has a very good treatment effect. The treatment effects of N_2 and H_2S are relatively stable. Among them, the average efficiency of N_2 treatment is 95.38%, the highest can reach 97.08%; the average efficiency of H_2S treatment is 98.01%, and the highest can reach 99.15%.

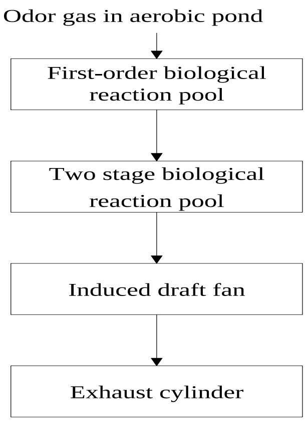

Figure 1: Biological process flow chart

Table 2: Experimental instruments and equipment

Number	Device name	Specifications	Texture of material
1	First-order biological reaction pool	1m*1.5m*1.5m	Plexiglass
2	Two stage biological reaction pool	1m*1.5m*1.5m	Plexiglass
3	Induced draft fan	15KW	Glass fiber reinforced Plastics
4	Flowmeter	$100m^3/h$	
5	air sampler	TH-110F	Carbon steel
6	Bullous absorption tube		Glass
7	Ultraviolet spectrophotometer	UV743-GD	
8	Analytical balance	FA2008	
9	Portable acidity meter	PHB-2	
10	Electromagnetic air compressor	ACO-310	
11	Glass rotor flowmeter	LZB-5	Glass
12	Gas flowmeter	LZB-3WB	
13	Water circulating pump	HJ-984	Carbon steel

Table 3: Data analysis of experimental results in biological system

Serial number	Flow (m^3/h)	Monitoring index	Import	Export	Removal rate (%)
1	80	$N_2(mg/m^3)$	10.52	0.64	93.75%
		$H_2S(mg/m^3)$	18.94	0.18	98.47%
2	80	$N_2(mg/m^3)$	15.32	0.46	97.08%
		$H_2S(mg/m^3)$	19.07	0.17	98.97%
3	80	$N_2(mg/m^3)$	12.39	0.52	96.37%
		$H_2S(mg/m^3)$	13.16	0.47	95.79%
4	80	$H_2S(mg/m^3)$	19.32	0.39	99.15%
5	60	$H_2S(mg/m^3)$	15.74	0.58	97.15%
6	60	$H_2S(mg/m^3)$	14.98	0.74	95.96%
7	60	$H_2S(mg/m^3)$	17.57	0.38	98.43%
8	60	$H_2S(mg/m^3)$	18.31	0.23	97.45%
9	60	$H_2S(mg/m^3)$	16.93	0.29	98.05%
10	60	$H_2S(mg/m^3)$	16.85	0.41	98.49%
11	60	$H_2S(mg/m^3)$	18.02	0.32	97.34%
12	60	$H_2S(mg/m^3)$	18.45	0.36	98.57%
13	40	$H_2S(mg/m^3)$	16.82	0.41	95.75%
14	40	$H_2S(mg/m^3)$	17.43	0.38	96.37%
15	40	$H_2S(mg/m^3)$	19.35	0.26	98.52%
16	40	$H_2S(mg/m^3)$	18.54	0.37	97.09%

3.2 Oxidation odor treatment

The oxidation method mainly uses the strong oxidizing property of hypochlorite to oxidize the organic matter, thereby achieving effective removal of the odors. In the sewage treatment plant, when there is a high concentration of odors, the concentration of the sodium hypochlorite solution is about 50-500 ppm, and the reaction formula is expressed as:

$$\text{NaOCI} + H_2O \rightarrow HOCI + NaOH \quad (6)$$

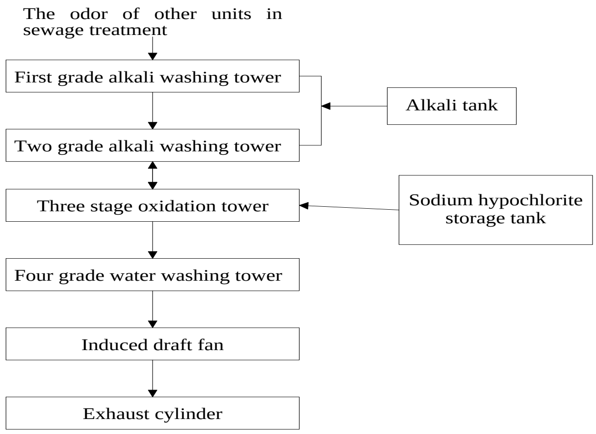

Figure 2: Process flow of alkali absorption + oxidation

Table 4: Data analysis of pilot test results of "alkali absorption + oxidation" system

Serial number	Monitoring index	Import	Export	Removal rate (%)
1	N_2(mg/m^3)	4.25	0.34	96.38
	H_2S(mg/m^3)	2.56	0.29	87.25
2	N_2(mg/m^3)	4.56	0.84	81.93
	H_2S(mg/m^3)	2.27	0.41	83.46
3	N_2(mg/m^3)	5.03	0.57	90.04
	H_2S(mg/m^3)	2.97	0.68	80.24
4	N_2(mg/m^3)	4.47	0.41	89.56
	H_2S(mg/m^3)	2.38	0.27	94.28
5	N_2(mg/m^3)	2.96	0.41	92.63
	H_2S(mg/m^3)	4.89	0.37	85.19
6	N_2(mg/m^3)	4.74	0.37	91.27
	H_2S(mg/m^3)	2.89	0.71	79.82
7	N_2(mg/m^3)	4.62	0.32	85.76
	H_2S(mg/m^3)	2.95	0.27	85.39
8	H_2S(mg/m^3)	2.74	0.31	79.32
9	H_2S(mg/m^3)	2.84	0.25	84.76
10	H_2S(mg/m^3)	2.69	0.37	85.27
11	H_2S(mg/m^3)	2.76	0.29	90.01
12	H_2S(mg/m^3)	2.19	0.51	89.53
13	H_2S(mg/m^3)	2.06	0.36	85.78
14	H_2S(mg/m^3)	2.84	0.26	87.51
15	H_2S(mg/m^3)	2.63	0.37	88.63
16	H_2S(mg/m^3)	2.59	0.43	89.27

The oxidation method mainly uses strong oxidants to make gas-liquid contact with the odors generated by the sewage treatment, it oxidizes the odor component in the gas, so as to eliminate the odors generated in the sewage treatment. Some odorous substances such as organic sulfur compounds, oxygen-containing hydrocarbons, and the like can be treated by the oxidation method. A specific flow chart of the alkali absorption + oxidation method is shown as Figure 2.

The data recording and processing of the oxidation odor treatment are shown in Table 4.

From the experimental data, it can be found that the effect of the treatment of odorous gases produced by other regulating tanks by the "alkali absorption + oxidation" method is relatively stable. The average efficiency of N_2 treatment is 89.24%, and the highest can reach 96.38%; the average efficiency of H_2S treatment is 88.97%, and the highest can reach 94.28%.

It can be seen from Figure 3 that as the pH value increases, the removal rate of H_2S decreases continuously. When the pH value is greater than 9.5, the removal effect is greatly reduced. When the pH is lower than 7.5, although the removal rate is high, the outlet gas will have some chlorine smell, so the pH range when the treatment effect is optimal is [7.5, 9].

It can be seen from Figure 4 that as the potential increases, the removal rate of H_2S also increases. When the potential is less than 650, the removal effect is greatly reduced; when the potential is higher than 850, although the removal rate is higher, the outlet gas will have some chlorine smell, so the potential range when the treatment effect is optimal is [700, 850].

It can be seen from Figure 5 that as the liquid-gas ratio continues to increase, the removal rate of H_2S will also increase. When the liquid-gas ratio is less than 4.7L/m^3, the removal effect is greatly reduced; when the liquid-gas ratio is higher than 6.0L/m^3, the removal effect is not significantly improved, so the liquid-gas ratio range when the treatment effect is optimal is [4.7, 6.0]

Table 5: The relationship between the removal rate and the control parameters

PH value	Removal rate (%)	Potential (mV)	Removal rate (%)	Circulatory volume (m^3/h)	Liquid to gas ratio (L/m^3)	Removal rate (%)
7	89.31	400	10.94	11	3.8	10.28
7.5	87.62	500	20.63	12	4.1	20.74
8	85.37	600	50.38	13	4.2	50.49
8.5	81.94	650	70.04	14	4.5	75.34
9	75.32	700	78.92	15	4.9	82.51
9.5	71.64	750	83.64	16	5.2	83.64
10	51.09	800	85.39	17	5.6	85.03
10.5	20.18	850	87.62	18	6.2	87.38
11	10.69	900	89.93	19	6.5	90.29

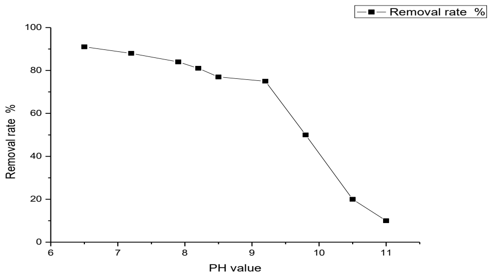

Figure 3: The change of hydrogen sulphide removal rate with pH value

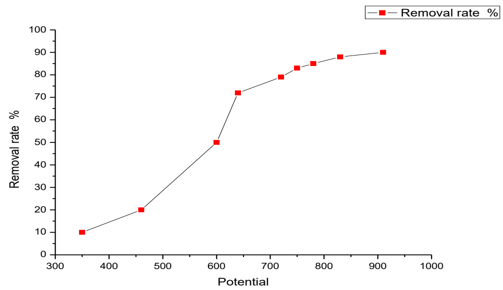

Figure 4: The change of hydrogen sulfide removal rate with potential

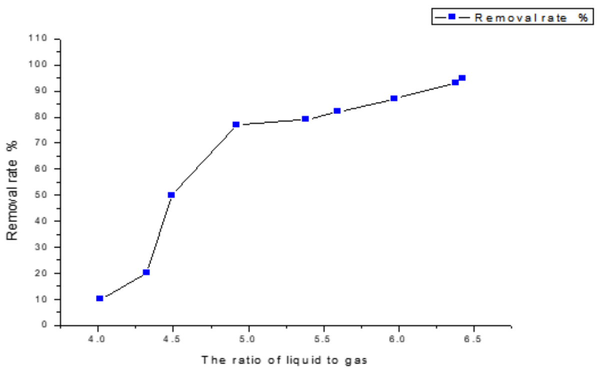

Figure 5: The change of hydrogen sulfide removal rate with the ratio of liquid to gas

4. Conclusion

4.1 The biological method is used to treat the odors in the sewage tanks, and the treatment effect is very good. The treatment effects of N_2 and H_2S are relatively stable. Among them, the average efficiency of N_2 treatment is 95.38%, the highest can reach 97.08%; the average efficiency of H_2S treatment is 98.01%, and the highest can reach 99.15%.
4.2 The effect of the treatment of odorous gases produced by other regulating tanks by the "alkali absorption + oxidation" method is relatively stable. The average efficiency of N_2 treatment is 89.24%, and the highest can reach 96.38%; the average efficiency of H_2S treatment is 88.97%, and the highest can reach 94.28%. The H_2S treatment efficiency is best when the pH is 7.5-9, the potential is 700-850, and the liquid-gas ratio is between 4.7L/m^3-6.0L/m^3.

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