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# Odour Treatment Method of Wastewater Treatment Plant Based on Biological Oxidation Process

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With the continuous increase of urban domestic sewage and production wastewater discharge, the odour treatment has been enhanced in the sewage treatment process. At present, the odour problem of wastewater treatment plant should be treated jointly by various technologies. In this paper, the biological process and oxidation process were mainly selected to study the odour treatment in wastewater treatment plants, and two sets of pilot equipment in biological process and oxidation process respectively were established for pilot test. The test results showed that the biological process has a very good effect on treating the odour in the sewage tanks, and the treatment effect of $N_2$ and $H_2S$ is relatively stable; the "alkali absorption + oxidation" method produces a stable effect on treating the odour gas produced by other adjusting tanks. At pH of 7.5-9, the potential of 700-850, and the liquid-gas ratio between 4.7L/m$^3$-6.0L/m$^3$, the best treatment effect can be achieved on the $H_2S$.

## 1. Introduction

As China's economic development speeds up and the industrialization process deepens continuously, the discharge of urban domestic sewage and production wastewater has been increasing. The discharge of urban sewage has a great impact on the lives of the general public and industrial production (Roman et al., 2015). In the city, odour is usually generated during the sewage treatment process, and no matter whether the odour is harmful or not, it is unbearable to the public. Thus, it has become a key issue in urban environmental protection on how to control odours and conduct effective governance (Antonopoulou et al., 2014). Now, China has enhanced the treatment of odours in the sewage treatment process, but the single treatment technology has been unable to effectively deal with the odour problem in the wastewater treatment plants. The combination of various technologies has become an important development direction of future odour treatment (Ghoreishi and Haghighi, 2003).

At present, a large number of scholars at home and abroad have conducted targeted research on the odour treatment and formed a series of research results. Some scholars proposed the use of chemical washing method, biological filtration method and other methods to deal with odour (Cowger and Labbe, 1965; Esplugas et al., 2004). Some scholars have conducted detailed research on the equipment and process of odour treatment (Ioannou- Ttofa et al., 2017; Silva et al., 2013); and some other scholars have studied the feasibility of some odour treatment projects (Beltrán et al., 2001; Moreira et al., 2015). This paper is mainly based on the biological oxidation process to study the odour treatment method of wastewater treatment plant, which has strong practical value (Rudina et al., 2018).

## 2. Related theory

### 2.1 Odorous substances

The production of odour is mainly related to the process and the system operation of sewage treatment. Sewage contains a large number of anaerobic organisms, which produce odours in the process of consuming

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organic matter (Holman and Wareham, 2003). The components of the odour are mainly composed of organic molecules and inorganic molecules, and the main inorganic gases are hydrogen sulphide ($H_2S$) and ammonia. Organic odours are often the activity result of the living organisms, which decompose organic matter to form a foul odour composed of various organic gases (Chuaha et al., 2018). The common odorous sulfur-containing compounds are shown in Table 1.

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

| Molecular formula | Odor characteristics | Critical value | Molecular weight |
|---|---|---|---|
| $CH_2$=CH-$CH_2$-SH | Strong garlic taste | 0.00004 | 75.31 |
| $CH_3$- $(CH_2)_3$-$CH_2$-SH | Rotten taste | 0.0006 | 107.64 |
| $C_6H_5CH_2$-SH | Intensely unpleasant | 0.00019 | 1276.58 |
| $CH_3$-CH=CH-$CH_2$-SH | The stink of the weasel | 0.000032 | 93.47 |
| $CH_3$-S-$CH_3$ | Rotten vegetable taste | 0.0005 | 64.18 |
| $CH_3$-$CH_2$-$SH_3$ | The rotten taste of cabbage | 0.00024 | 60.83 |

The odour is the sensation caused mainly by stimulating the taste organs in the nostrils. The common odour gas in sewage is mainly $H_2S$ hydrogen gas formed by bacteria reducing sulphur under anaerobic conditions (Lee, 2018).

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

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

With the pH of 9, over 99% sulfide will be dissolved in the water, and the sulfur will exist in the non-odour HS form. With the pH over 8, the hydrogen sulfide gas won't be released. With the pH below 8, it will be released from the sewage. With the pH over 9, ammonia gas will be released (Lee and Ahn, 2010).

### 2.2 Oxidation treatment

In the oxidation treatment of odours, various hypo-chlorites with strong oxidation properties are mainly used as oxidants (Benner et al., 2013). The cyano group is not easily decomposed, so it is usually accelerated by the 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 in formula (3) can occur instantaneously at any pH (Peter and Von, 2007). In order to convert cyanogen chloride (CNCI) into cyanate according to reaction (4) in time, the pH should be over 10.5, and then the reaction (4) can be completed in a few minutes. Reaction in formula (5) is mainly the oxidative decomposition of cyanate to nitrogen and carbon dioxide (Muñoz et al., 2013).

## 3. Odour treatment based on biological oxidation process

### 3.1 Biological process-based odour treatment

The odour treatment based on biological process is: organic pollutants are first contacted with water and dissolved in water; due to the differential concentration, the organic matter is further diffused from the liquid film into the biofilm after being dissolved in water, and then is absorbed by the microbes in the biofilm; afterwards, the microorganism through the metabolism can eventually turn the foul smell in the waste gas into the energy and carbon source, and decompose the organic matter into water and carbon dioxide; thus, the odour treatment is finally fulfilled. The whole process is shown in Fig.1.
Table 2 lists the instruments and materials required for biological process-based odour treatment.

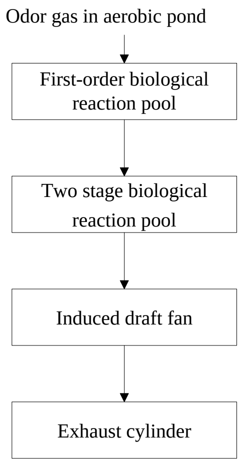


*Figure 1: Biological process flow chart*

*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 lists the related data recording and processing of biological process-based odour treatment.

*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% |

The experimental results in the table indicate that the biological process has a very good effect on the odour treatment in the sewage tank, and the treatment effects of $N_2$ and $H_2S$ are relatively stable. Among them, the average efficiency for treating $N_2$ is 95.38%, with the highest up to 97.08%; the average efficiency of $H_2S$ is 98.01%, with the highest up to 99.15%.

### 3.2 Oxidation process-based odour treatment

The oxidation process mainly uses the strong oxidizing property of hypochlorite to oxidize the organic matter, thereby achieving effective removal of the odour. In the wastewater treatment plant, with the high odour concentration, the concentration of the sodium hypochlorite solution is about 50-500 ppm, and the reaction is expressed as:

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

The oxidation process mainly uses the strong oxidant to make gas-liquid contact with the odour generated by the sewage treatment, and oxidizes the odour component in the gas, thereby eliminating the odour generated in the sewage treatment. Some odorous substances such as organic sulfur compounds and oxygen-containing hydrocarbons etc. can be treated by the oxidation method. The specific process of alkali absorption + oxidation method is shown in Fig.2.
Table 4 lists the data recording and processing of the oxidation process-based odour treatment.

*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 |

*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 |

The experimental data indicate that the “alkali absorption + oxidation” method has a stable effect on treating the odorous gas produced by other adjusting tanks. The average efficiency of $N_2$ treatment is 89.24%, with the highest up to 96.38%; the average efficiency of $H_2S$ treatment is 88.97%, with the highest up to 94.28%.

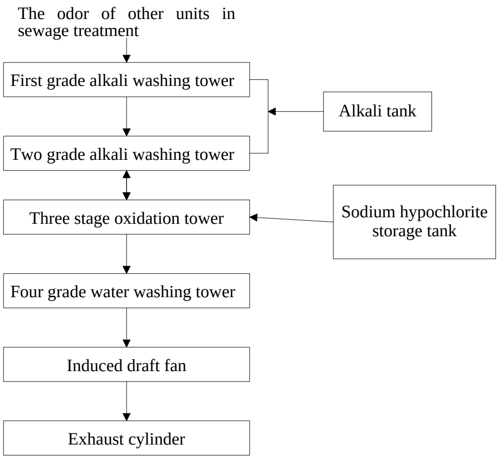


Figure 2: Process flow of alkali absorption+oxidation

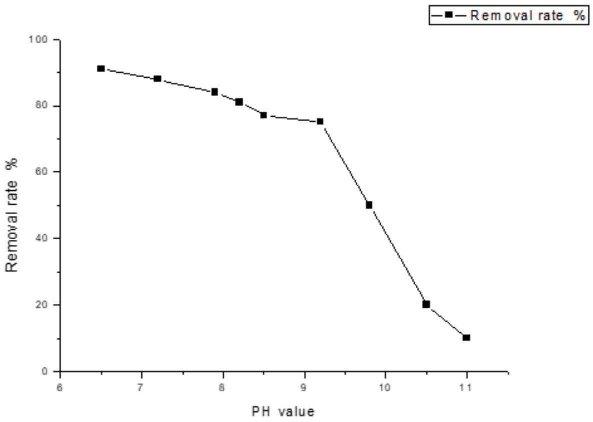


Figure 3: The change of hydrogen sulfide removal rate with pH value

It can be seen from Fig. 3 that as the pH value increases, the removal rate of $H_2S$ decreases continuously. When the pH value is over 9.5, the removal effect is greatly reduced; when the pH value is below 7.5, despite the higher removal rate, the outlet gas will have some chlorine smell, so, in the range [7.5, 9] of pH, the optimal treatment effect can be achieved.

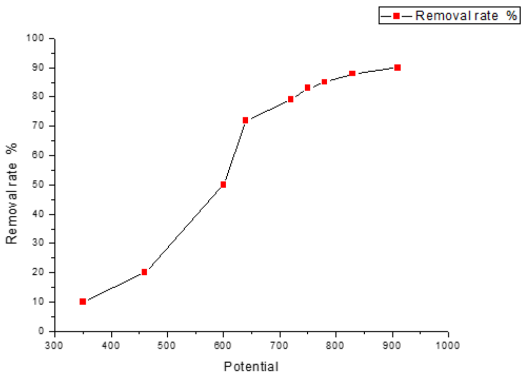


Figure 4: The change of hydrogen sulfide removal rate with potential

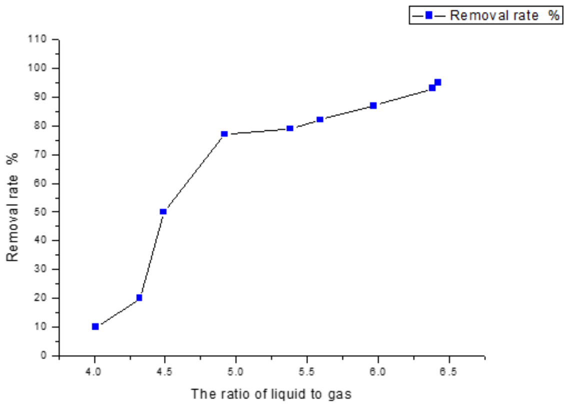


Figure 5: The change of hydrogen sulfide removal rate with the ratio of liquid to gas

It can be seen from Fig. 4 that as the potential increases, the removal rate of $H_2S$ also increases. When the potential is below 650, the removal effect is greatly reduced; when the potential is over 850, despite the higher removal rate, the outlet gas will have some chlorine smell, so in the range [700, 850] of potential, the optimal treatment effect can be achieved.

It can be seen from Fig. 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 at the liquid-gas ratio of [4.7, 6.0], the best treatment effect can be achieved.

## 4. Conclusions

(1) The biological process has a very good effect on the odour treatment in the sewage tank, and the treatment effects of $N_2$ and $H_2S$ are relatively stable. Among them, the average efficiency for treating $N_2$ is

95.38%, with the highest up to 97.08%; the average efficiency of $H_2S$ is 98.01%, with the highest up to 99.15%.

(2) The “alkali absorption + oxidation” method has a stable effect on treating the odorous gas produced by other adjusting tanks. The average efficiency of $N_2$ treatment is 89.24%, with the highest up to 96.38%; the average efficiency of $H_2S$ treatment is 88.97%, with the highest up to 94.28%. At pH of 7.5-9, the potential of 700-850, and the liquid-gas ratio between 4.7L/m$^3$-6.0L/m$^3$, the best treatment effect can be achieved on the $H_2S$.

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