Research Progress of Influencing Factors of Biological Contact Oxidation Method

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Keywords: Surface Water Pollution, Sewage Treatment, Biological Contact Oxidation Method.

Abstract: The biological contact oxidation method has the advantages of low operating cost, stable treatment effect, and good effluent quality, and is widely used to treat domestic and industrial sewage. Based on a large amount of literature, this research expounds the origin, development, and decontamination mechanism of the biological contact oxidation method. The main factors affecting the biological contact oxidation method and its research progress were systematically analysed to provide a reference basis for the further development of this technology.

1 INTRODUCTION

In recent years, with the acceleration of urbanization, the contradiction between the rapid development of agriculture and water pollution has intensified, and it is urgent to solve the problem of rural water pollution (Ma, 2021). Traditional water treatment technology has not adapted to the current requirements of rural sewage treatment. As a new and high-efficiency water treatment process, the biological contact oxidation method has the characteristics of activated sludge method and biofilm method and the advantages of stable treatment effect, impact load resistance and simple management (Hu, 2015). Since the late 1970s, the biological contact oxidation method has been widely used in China, and many scholars have studied the biological contact oxidation method and made certain achievements (Jiang, 2013).

2 THE ORIGIN AND DEVELOPMENT OF BIOLOGICAL CONTACT OXIDATION

Biological contact oxidation method is a kind of biofilm method, which is developed on the basis of biological filter. At the end of the 19th century, Blaring first proposed the concept of biological contact oxidation, and Closs applied for a related patent in Germany in 1912. Before the 1950s, due to the small specific surface area of the filter material, low filter load, large floor space, high cost of spraying water, and high energy consumption, the practical application of this method was limited, and it was not a mainstream water treatment technology [4]. By the 1960s, with the development of plastic technology, the filler of the biofilm method was made into honeycomb or foam, which has the advantages of light weight, easy processing and molding, and large specific surface area. It has been widely used in the contact oxidation process. In the 1970s, Japanese scholars studied the biological contact oxidation method in depth, further improved the contact filler, and promoted the engineering application of the process. At present, the biological contact oxidation method is widely used in sewage, water supply purification treatment and river ecological restoration (Li, 2008).

3 POLLUTANT REMOVAL MECHANISM

Biological contact oxidation method is an efficient biological treatment technology that organically combines activated sludge method and biological filter technology. It is composed of tank body, filler,

Wu, L., Wang, Z., Guan, R. and Liu, X.
Research Progress of Influencing Factors of Biological Contact Oxidation Method.
DOI: 10.5220/0011186300003443
In *Proceedings of the 4th International Conference on Biomedical Engineering and Bioinformatics (ICBEB 2022)*, pages 95-99
ISBN: 978-989-758-595-1

water distribution system and aeration system (Figure 1). Biological contact oxidation method is also called submerged biological filter, which evolved from biological filter and contact aeration oxidation. The biological contact oxidation method is to fill the pond with a certain density of fillers and aerate through the air from the bottom of the pond. The sewage immerses all the fillers and extensively contacts with the biofilm on the fillers to achieve the purpose of purifying sewage under the function of microbial metabolism. Following the law of microbial growth cycle, the biofilm purification effect is not good during the decay period. At this time, under the impact of wastewater and gas, the biofilm on the filler falls off quickly and is discharged from the reactor with the water flow. At the same time, the biofilm is replenished and updated in time. As a result, the system can stably and efficiently remove pollutants in the water body during the entire operation process (Zhang, 2012).

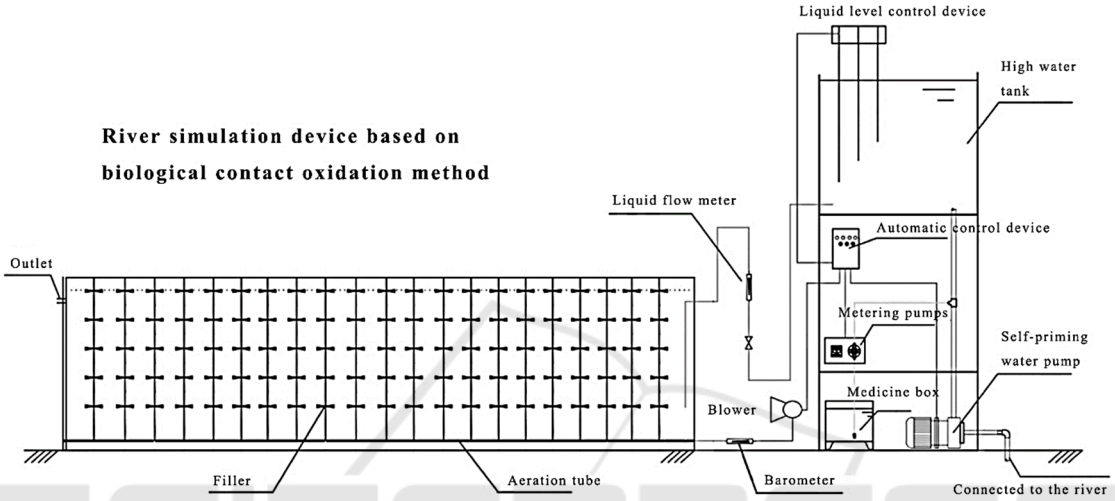

Figure 1: River simulation device based on biological contact oxidation method.

4 FACTORS AFFECTING THE REMOVAL OF POLLUTANTS

The pollutant removal effect of biological contact oxidation method depends on the biological quantity and activity of the biofilm. The factors affecting the treatment effect of biological contact oxidation method mainly include water temperature, pH value, DO, filler properties, gas-water ratio, organic matter load, and hydraulic load.

4.1 Water Temperature

Water temperature mainly affects biological reactions in two aspects: on the one hand, it affects the rate of enzyme-catalysed reactions; on the other hand, it affects the rate of matrix diffusion into cells. In the process of nitrification, the suitable growth temperature of nitrate bacteria is 35~42℃, and that of nitrite bacteria is 35℃. Temperature affects the effect and rate of nitrification reaction of nitrifying bacteria. The suitable temperature range for the nitrification reaction is 15~35℃. When the temperature is lower than 10℃, the nitrification will be significantly inhibited. The influence of temperature on nitrogen removal is significantly higher than that on phosphorus removal, but the decrease of temperature will change the phosphorus release and absorption rate of phosphorus accumulating bacteria (Helmer, 1998).

4.2 pH Value

The pH value is of great significance to the growth of microorganisms. For most bacteria, the optimal pH range is 4~7. The pH value is too high or too low, not only restricts the osmotic function of the microbial cell surface, but also inhibits the enzymatic reaction inside the cell. Biological contact oxidation method has good adaptability to pH. According to the research results of Villaverde S., the suitable pH range for the growth of microorganisms in the biological contact oxidation method is 5~9. When the pH=8.2, the microorganisms grow in the best condition, and the maximum amount of biofilm will be obtained in this case (Villaverde, 1997). In the actual operation of

sewage treatment, if the pH value is not in the range of 5~9, the pH should be adjusted first.

4.3 Dissolved Oxygen

The biological contact oxidation method uses an aeration device to aerate the water body of the reactor, which has three main functions: 1) Provide oxygen for the oxidation of microorganisms and synthesize endogenous respiration; 2) Stirring to maximize water turbulence and improve the mass transfer effect between biofilm, pollutants, and oxygen; 3) Promote the renewal of biofilm, improve biological activity, prevent filler blockage, and improve treatment effect. Therefore, to improve the ability of the biological contact oxidation reactor to remove pollutants, it is necessary to ensure that the dissolved oxygen concentration in the system is maintained above the minimum concentration level required for bacterial metabolism. With the increase of dissolved oxygen concentration, the ability of nitrification reaction to remove NH_3-N increases significantly, and tends to a stable level when the dissolved oxygen concentration is 7 mg/L. When the dissolved oxygen concentration in the system is lower than 0.5 mg/L, the nitrification reaction basically stops.

4.4 Filler Properties

Filler is one of the important design parameters of the biological contact oxidation method. The performance, quantity, and layout of the filler not only directly affect the effect of the contact oxidation method in treating sewage, but also affect the economic cost of the project. The filling rate of the filler is between 30% and 70% of the effective volume of the filter. Insufficient fillers will affect the removal of pollutants. Too much filler will not only increase the construction cost, but also hinder the oxygen transfer rate. The physical and chemical characteristics of common biological contact oxidation fillers are shown in Table 1 (Zhang, 2015).

4.5 Gas-Water Ratio

The gas-water ratio is the key to the design of the application of biological contact oxidation technology, and it plays a decisive role in the treatment effect, the project investment, and the operating cost. The gas-water ratio must be maintained in a reasonable range, too high or too low, it will have an adverse effect on the system. When the air-to-water ratio exceeds a certain threshold, long-term high-intensity aeration will cause turbulence in water flow, produce a large shear force to act on the biofilm, cause the biofilm to fall off more seriously, and increase system operating costs. When the air-to-water ratio is too low, the DO content and mass transfer power in the system will be insufficient, which will adversely affect the metabolic activity of the aerobic community and cause the system effluent water quality to not meet the standard. The death of aerobic microbes and the proliferation of anaerobic microbes caused by insufficient aeration will produce metabolic gas (H_2S, NH_3, etc.), resulting in more voids in the biofilm, significantly weakened biofilm adhesion, and even large areas of biofilm shedding, which will eventually lead to the quality of treated water deteriorated. Nitrogen and phosphorus removal in bioreactors is a continuous and complex reaction mechanism (Liu, 2003). Existing research results show that, during the intermittent aeration operation of the biological contact oxidation system, the gas-water ratio is preferably in the range of 5:1 to 10:1.

4.6 Volume Load of Influent Pollutants

The volume load of influent pollutants is one of the important parameters that affect the design and operation of the contact oxidation process. In the biological treatment process, it comprehensively reflects the concentration of organic matter in the influent water and the hydraulic retention time. There will be an optimal balance between influent load, pollutant treatment effects and economic benefits. When the volume load increases within a certain range, the concentration of organic matter in the sewage is relatively high, and the advantage of easy cultivating bacteria has a strong metabolic effect, thereby promoting the biodegradation of pollutants (Ge, 2015). The small-scale trial study of Zhang et al. with Xiaosha River sewage as the treatment object in Shandong Province has similar results (Zhang, 2012). When the volumetric load of COD_{Cr} increases to a certain range, it may change the dominant bacteria in the reactor to heterotrophic bacteria, inhibit the nitrification reaction, and ultimately affect the removal effect of NH_3-N (Lin, 2015).

Table 1. Physical and chemical properties of various fillers.

Compare items	Honeycomb packing	Soft filler	Semi-soft material	Combination packing	Elastic filler	Suspended packing
Factory-supplied specific surface area (m^2/m^3)	150~200	500~700	150~200	200~300	200~300	150~250
Use specific surface area (m^2/m^3)	SAB[a]	SAC[b]	SS[c]	SS	SL[d]	SL
Increase oxygenation rate	-5%	-10%	30%~40%	25%~35%	70%~100%	1%~30%
Water and air distribution performance	Poor	Poor	General	Better	Good	Better
Film performance	General	Good	General	General	Good	General
Drag film performance	Poor	Poor	General	General	Good	General
Blockage	More serious	No	No	General	No	No
Clumping and broken wire	No	More serious	General	No	No	No
Service life	4~6 years	1~2 years	5~8 years	5~8 years	7~10 years	5~8 years
Replacement of filling	INC[e]	INC	INC	INC	INC	CON[f]
Support	CON	CON	CON	CON	CON	INC
Transport	INC	CON	CON	CON	CON	INC
Price (Yuan/m^3)	700	100	220	200	250	1000

[a] SAB: Small after blockage
[b] SAC: Small after clumping
[c] SS: Slightly smaller
[d] SL: Slightly larger
[e] INC: Inconvenient
[f] CON: Convenience

4.7 Hydraulic Load

Hydraulic load is the amount of wastewater treated per unit volume of filter media per day and is an important parameter for the design and operation of sedimentation tanks and biological filters. Studies have shown that for treatment systems of different sizes, when the hydraulic load increases within a certain range, it has little effect on the performance of the biological contact oxidation system COD_{Cr} and NH_3-N. As the hydraulic load further increased, the removal rate of COD_{Cr} and NH_3-N decreased significantly. This also shows that the biological contact oxidation method has better resistance to hydraulic load impact.

5 CONCLUSION

At present, surface water sources are generally polluted, which has become a major factor threatening the quality of water supply. The improvement of the traditional treatment process and the introduction of biological contact oxidation treatment technology into the water treatment process has gradually become an effective means to treat micro-polluted source water and improve the quality of drinking water. This research expounds the origin, development, and decontamination mechanism of biological contact oxidation method by consulting many literature, and systematically analyses the main factors affecting biological contact oxidation method, including water temperature, pH value, DO, filler properties, gas-water ratio, organic matter load, and hydraulic load. Biological contact oxidation method has become one of the main technologies for wastewater treatment in China. This study provides a reference for the further development of this technology.

ACKNOWLEDGEMENTS

This work was supported by the National key research and development plan special (No. 2018YFC0407702), the National Natural Science Foundation of China (No. 51879279, 51879278) and the Ministry of Water Resources Department Project (No. 12630100100020J002).

REFERENCES

Ge J., Hu X., Pang Y., Huang T., Teng Q. (2015). Research on Purifying Lightly Contaminated Water in Baihe River by Gravel Contact Oxidization Process. Research of Environmental Sciences. 28, 816–22.

Helmer C. and Kunst S. (1998). Low temperature effects on phosphorus release and uptake by microorganisms in ebpr plants. Wat. Sci. Tech.. 37.

Hu P. (2015). Experimental research on fine bubble aeration and biofilm treatment of rural sewage. Master Thesis. China Institute of Water Resources and Hydropower Research.

Jiang R., Yu Z., Li J., Pan B., Sun W., Wang F. (2013). Research Situation of Bio-contact Oxidation Process. Environmental Science and Management. 38, 61-63+93.

Li L., Wen D., Zhang H., Xie S. (2008). Pilot Experiment on the Treatment of the River Wastewater by a Step-Feed Biological Contact Process. Environmental Science. 29, 2227–2234.

Li L., Zhang H., Xie S., Wen Donghui. (2008). Experimental Study on Treatment of River Wastewater by Biological Contact Oxidation Process. China Water & Wastewater. 24, 25-28+33.

Lin J. L., Tu Y. T., Chiang P. C., Chen S. H., Kao C. M. (2015). Using aerated gravel-packed contact bed and constructed wetland system for polluted river water purification, A case study in Taiwan. J. Hydrol.. 525, 400–8.

Liu J., Wang B., Pan D., Li S., Wang P. (2003). Study on the denitrification route in aerobic denitrification process. Industrial Water Treatment. 23, 53–56.

Ma B., Guan R., Liu L., Huang Z., Qi S., Xi Z., Zhao Y., Song S., Yang H. (2021). Nitrogen Loss in Vegetable Field under the Simulated Rainfall Experiments in Hebei, China. Water. 13, 552.

Villaverde S. (1997). Influence of pH over nitrifying biofilm activity in submerged biofilters. Water Research. 31, 1180–1186.

Zhang X. (2015). Experimental Study on Small Integrated Biological Contact Oxidation Device for Processing University Campus Sewage. Master Thesis. Xinjiang Agricultural University.

Zhang Y., Xie B., Zhang Z., Wang H. (2012). Feasibility Study on Treatment of River wastewater by Biological Contact Oxidation Process. Technology of Water Treatment. 38, 51–54.