

The Influence of Aeration on Atmospheric Environment during Sewage Treatment

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Abstract: This paper outlines the basic principles of wastewater treatment and highlights the important role of aeration technology. The working principle of aeration technology and its contribution to improving wastewater treatment efficiency are described in detail. The paper concludes with suggestions for reducing VOC emissions in wastewater treatment plants. In addition, this study analyzes the emission of volatile organic compounds (VOCs) and secondary pollution during the aeration process, highlighting their potential negative impacts on the atmosphere. Hence, it is suggested that to mitigate the effects of aeration on the atmosphere, the aeration equipment and technology should be enhanced along with better collection and treatment of the resulting gases.

Keywords: Aeration Technology; Atmospheric Impact; Vocs Emission and Secondary Pollution

1. Introduction

Water resource pollution has become an increasingly significant environmental issue globally, due to the rapid growth of industrialization and urbanization. Wastewater treatment has been identified as a crucial measure for mitigating this problem, and its efficiency and environmental impact have garnered widespread interest. Aeration technology, as a central component of wastewater treatment, has a significant impact on treatment efficiency and the environment. It is crucial, therefore, to ensure that aeration technology is objectively evaluated and its potential impact on the environment is mitigated through appropriate measures. It may lead to the release of volatile organic compounds (VOCs) and the creation of secondary pollution, which poses pressing concerns in the realms of environmental protection and engineering.

2. Overview of Sewage Treatment

With the rapid industrialisation and urbanisation, wastewater treatment technologies are gaining ever-increasing significance, particularly in preserving ecological balance and human health. The primary goal of wastewater treatment is to eliminate suspended solids, organic matter, pathogens and nutrients, etc., mostly accomplished through mechanical, biological, and chemical treatment procedures. Mechanical treatment involves screening, sedimentation, and filtration to remove large particulate matter, while chemical treatment utilizes chemical reactions to eliminate dissolved pollutants, such as phosphorus eliminated through chemical precipitation. Biological treatment is the most essential aspect of wastewater treatment and utilizes microorganisms to convert organic material into innocuous substances like water and carbon dioxide. Aeration involves adding air or pure oxygen to water, providing the required oxygen for microbial metabolism. This boosts the breakdown of organic matter and facilitates nitrogen and phosphorus removal from the water. Surface aeration and deep water aeration are conventional methods of aeration, each with its own suitability and effectiveness.

3. The Principle and Application of Aeration Technology

Aeration technology centres on supplying sufficient oxygen to the microorganisms in water, enabling them to efficiently decompose the organic pollutants within wastewater. Oxygen is introduced into the wastewater to provide aerobic microorganisms with the oxygen needed for respiration. These microorganisms convert organic material into carbon dioxide,

water, and energy, ultimately purifying the water. Surface aeration involves an aerator that generates bubbles at the water surface to facilitate oxygen transfer through the gas-liquid interface. Correspondingly, deep water aeration utilises minute bubbles generated by installing the aeration equipment at the pool bottom, thereby promoting oxygen solubility and surface area of contact in the water. Deep water aeration occurs when bubbles rise in water and remain in contact for a longer period, resulting in higher oxygen transfer efficiency compared to surface aeration^[1]. Aeration technology is commonly used in both municipal and industrial wastewater treatment facilities. By regulating the duration and volume of aeration, it is possible to effectively manage the growth and metabolic rate of microorganisms, thereby improving the sewage treatment process. It is important to note, however, that the aeration process presents certain challenges such as the possibility of elevated energy consumption, particularly when utilising conventional aeration systems. In recent years, research and engineering practice have progressively developed aeration techniques that are both energy-efficient and highly effective. For instance, utilizing high-efficiency aerators and optimizing bubble size to improve oxygen transfer efficiency are some of the leading techniques.

4. Impact of Aeration on the Atmosphere

4.1 Emissions of Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are a group of organic chemicals that easily evaporate at room temperature, comprising various hydrocarbons and halogenated hydrocarbons. The existence of VOCs in the environment poses a potential hazard to both atmospheric quality and human health. Therefore, their proper management and control are necessary steps towards enhancing environmental protection and public health. During the aeration process, VOCs are primarily emitted through two mechanisms. Firstly, the organic material present in the wastewater itself is released into the atmosphere due to physical agitation and bubble rise in aeration. Secondly, the organic compounds produced by microbial metabolism also contribute to VOC emissions. It is essential to consider both mechanisms to effectively control VOC emissions during wastewater treatment. Volatile Organic Compounds (VOCs), upon their release into the atmosphere, can take part in photochemical reactions to produce ozone and fine particulate matter. These can result in the deterioration of air quality, leading to haze and other environmental problems. The emission of VOCs is influenced by different factors, including the nature of the wastewater, the wastewater treatment process, and climatic conditions. Industrial wastewater tends to contain a much higher concentration of organics, and thus more VOCs may be generated during aeration. In response to this problem, current research focuses on the following issues: this problem, current research focuses on exploring methods to reduce the emission of VOCs during the aeration process. This involves enhancing the wastewater treatment process to lessen the volume of organic substances in the wastewater, upgrading aeration machinery to reduce gas emissions, and adopting closed aeration systems to decrease detrimental pollutants. Concurrently, methods for capturing and treating VOCs, including activated carbon adsorption and photocatalytic oxidation, are being explored with the aim of implementing a two-fold strategy to efficiently minimise VOC emissions both at their origin and during the discharge process.

4.2 Secondary Pollution Generation

The aeration stage in the wastewater treatment process could result in producing additional pollution, besides the potential release of volatile organic compounds (VOCs). Microorganisms increase and multiply through consuming organic material in the aeration process, and this, in turn, can potentially release nutrients, like nitrogen and phosphorus. While these nutrients are required for microbial growth up to a certain extent, their excessive quantities can result in eutrophication of the water body, inducing algal blooms that disrupt the ecological balance of the water body and precipitate water quality issues. Furthermore, other detrimental chemicals, such as ammonia and hydrogen sulfide, can emerge during the decomposition of organic matter in sewage by microorganisms. These gases, upon release into the atmosphere, not only threaten air quality but also impact human health. Optimizing the aeration and wastewater treatment processes is a crucial method in controlling secondary pollution. By regulating the amount of aeration and microorganism activity, the excessive release of nutrients can be reduced, thus mitigating the risk of water body eutrophication. An additional matter for consideration relates to the capture and treatment of the noxious gases generated during the wastewater treatment process. One approach involves employing chemical absorbents or biofilters to trap and purify these gases, which minimizes their harmful effects on the atmosphere. This measure not only enhances the quality of air but also bolsters the environmental proficiency of wastewater treatment plants.

5. Measures to Reduce the Impact of Aeration on the Atmosphere

5.1 Improvement of Aeration Equipment and Technology

Traditional aeration systems often rely on significant amounts of energy to produce adequate oxygen, but this method proves both unproductive and energy-consuming. More recent designs, such as microporous aeration systems, generate smaller bubbles, resulting in an increased contact area of water and oxygen. This microporous method enhances the dissolution rate of oxygen, creating a more efficient system. By monitoring water quality parameters and microbial activity in real-time, the amount of aeration can be adjusted according to actual needs, avoiding energy wastage and potential secondary pollution caused by over-aeration. This approach ensures efficient and sustainable wastewater treatment while preventing undesirable environmental impacts. For instance, through the utilization of sensors and an automated control system, the aeration intensity can be adjusted in real-time concerning the concentration of dissolved oxygen in wastewater. Integrating advanced material science and fluid mechanics principles has the potential to enhance the design of aeration equipment. For instance, using aeration membranes made of specialist materials can improve oxygen transmission efficiency and decrease maintenance demands and operational costs. Additionally, designing aerators optimized based on fluid dynamics can disperse oxygen more effectively and minimize energy loss. To enhance aeration efficiency, the application of nanotechnology and bioengineering to improve aeration materials warrants investigation. For instance, nanoscale bubble generators can generate minuscule bubbles to significantly enhance oxygen transfer efficiency, and microorganisms can be tailored through bioengineering techniques to perform effectively at lower levels of oxygen, thereby decreasing aeration prerequisites. By integrating intelligent management and big data analysis, optimized control of the aeration system can be achieved resulting in improved overall system performance and more environmentally friendly and efficient water treatment.

5.2 Collection and Treatment of Generated Gases

The collection of gases generally employs closed or semi-closed aeration systems for capturing the gases which are released during the aeration process. The design of the closed systems considers the dynamic flow properties of the gas to ensure its efficient capture and direction towards the treatment facility. Technical abbreviations will be explained when being used for the first time. Several gas treatment methods are available to eliminate or reduce harmful components while preserving as many useful components as feasible. One common gas treatment method involves adsorption technology, specifically activated carbon adsorption, which proves to be effective in eliminating harmful gases, including VOCs. The large number of micropores and high surface area of activated carbon efficiently adsorb and immobilise organic vapour molecules. Additionally, biofiltration also provides an effective approach to gas treatment. Biofilters contain microorganisms that can break down organic matter and convert harmful gases into harmless substances through metabolic action, such as water and carbon dioxide. This method is environmentally friendly, cost-effective and especially appropriate for treating low concentrations of VOCs. Chemical scrubbing is another method for treating gases, particularly those that contain acidic or alkaline components. By exposing harmful gas components to specific chemical reagents, they can be converted into harmless or easily treatable compounds. Additionally, advanced technologies such as catalytic combustion are being investigated for gas treatment. This method employs catalysts to promote the oxidative decomposition of harmful gases at lower temperatures, which can significantly reduce pollutant emissions^[2].

6. Summarize

Aeration in wastewater treatment has considerable implications for the atmosphere, as it results in the release of volatile organic compounds (VOCs) and secondary pollutants. Therefore, advancing aeration technology and equipment and implementing efficient gas collection and treatment remains crucial in reducing the impact of wastewater treatment on the environment. These measures represent not only technological advancements but also a heightened awareness of the environment. By following these strategies, it is feasible to uphold the effectiveness of wastewater treatment while reducing its detrimental effects on the environment and advancing sustainable and eco-friendly water management practices.

References

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