



Article

Investigation of the technology for treating excess activated sludge from pathogenic contamination

Achilov Komil Islamovich¹

1. MA student at Tashkent University of Architecture and Civil Engineering

*corresponden: limok_1982@mail.ru

Abstract: This article investigates the technological approaches used for the treatment of excess activated sludge in order to reduce its pathogenic contamination. Excess activated sludge is one of the main by-products of wastewater treatment plants and may contain pathogenic microorganisms, including bacteria, viruses, protozoa and helminth eggs. If such sludge is not properly treated, it can become a serious source of sanitary, environmental and epidemiological risk. Therefore, the development and improvement of sludge treatment technologies is an important task for modern wastewater management. The article analyzes the main methods of reducing pathogenic contamination in excess activated sludge, including anaerobic digestion, aerobic stabilization, lime treatment, thermal processing, composting and advanced disinfection methods. Special attention is given to the effectiveness, practical applicability and environmental safety of these technologies. The results show that the most effective approach is the combination of stabilization, disinfection and dewatering processes, which allows the sludge to be safely disposed of or reused in agriculture and land reclamation.

Keywords: excess activated sludge, wastewater treatment, pathogenic contamination, sludge stabilization, disinfection, anaerobic digestion, sanitary safety, environmental protection.

INTRODUCTION

Wastewater treatment plants play an essential role in protecting the environment and public health. During biological wastewater treatment, a considerable amount of excess activated sludge is formed. This sludge contains organic substances, nutrients and microorganisms; however, it may also contain pathogenic agents that create sanitary and epidemiological risks. Excess activated sludge is not simply a waste product [1]. If properly treated, it can be transformed into a useful resource for soil improvement, compost production or energy generation. However, before any reuse or disposal, it is necessary to reduce its pathogenic contamination to a safe level. Untreated sludge may contaminate soil, surface water and groundwater, and may also spread infectious diseases [2].

The relevance of this research is connected with the growing need to improve wastewater treatment technologies and ensure the safe management of sludge. In many countries, including Uzbekistan, wastewater infrastructure is being modernized, and this requires scientifically grounded methods for sludge treatment. Therefore, the main purpose of this article is to investigate the technologies used for treating excess activated sludge from pathogenic contamination and to identify the most effective technological solutions [3].

Literature review. The problem of sludge treatment has been widely discussed in environmental engineering, sanitary microbiology and wastewater management studies. Researchers emphasize that excess activated sludge contains a complex mixture of organic matter, microbial biomass and possible pathogenic organisms. According to Metcalf and Eddy, sludge treatment is one of the most important stages of wastewater management because it determines the environmental safety of the whole treatment process [4].

Tchobanoglous notes that untreated sludge may contain pathogenic microorganisms and

therefore cannot be directly discharged into the environment or used in agriculture without prior stabilization and disinfection. This idea confirms that sludge treatment technologies must be designed not only to reduce volume and odor, but also to ensure epidemiological safety [5].

According to Bitton, pathogenic contamination in wastewater sludge may include bacteria such as *Salmonella*, *Escherichia coli*, viruses, protozoan cysts and helminth eggs [6]. These microorganisms may survive for a long time under unfavorable environmental conditions, especially if the sludge contains high moisture and organic matter. Therefore, simple storage or mechanical dewatering is not enough to guarantee sanitary safety.

Horan explains that biological stabilization methods, especially anaerobic and aerobic digestion, can significantly reduce the number of pathogenic microorganisms by changing temperature, pH, oxygen conditions and microbial competition. However, the effectiveness of these methods depends on process duration, temperature regime, sludge composition and operational control [7].

Arthurson emphasizes that composting is also an effective method for sludge sanitization if the process reaches thermophilic temperatures. During composting, heat generated by microbial activity can destroy many pathogenic organisms and improve the hygienic quality of sludge. However, composting requires proper mixing, aeration, moisture control and sufficient processing time [8].

Researchers also point out that chemical treatment, especially lime stabilization, is widely used for reducing pathogen levels in sludge. Lime increases the pH of sludge, creating unfavorable conditions for pathogenic microorganisms. This method is relatively simple and cost-effective, but it may increase the final mass of treated sludge and change its chemical properties. Thus, the literature shows that no single technology can be considered universally ideal for all conditions. The choice of sludge treatment technology depends on wastewater composition, available infrastructure, economic possibilities, environmental requirements and final sludge utilization method [9].

METHODOLOGY

This study uses a qualitative analytical approach to examine technologies for treating excess activated sludge from pathogenic contamination. The research is based on the analysis of scientific literature, environmental engineering principles and comparative evaluation of biological, chemical and thermal sludge treatment methods. The effectiveness of each method is assessed according to pathogen reduction, operational simplicity, environmental safety and suitability for practical application in wastewater treatment systems.

RESULTS

The analysis shows that excess activated sludge treatment must include several technological stages: stabilization, disinfection, dewatering and final utilization or disposal. Each stage has a specific function and contributes to reducing sanitary and environmental risks [10].

First, stabilization is necessary to reduce the biological activity of sludge. Stabilized sludge has lower odor, reduced organic load and improved sanitary characteristics. Anaerobic digestion is one of the most widely used stabilization methods. It takes place in the absence of oxygen and allows microorganisms to decompose organic matter. As a result, biogas can be produced, which may be used as a renewable energy source. This makes anaerobic digestion both an environmental and economic solution [11].

Second, aerobic stabilization can also be used to treat excess activated sludge. In this process, oxygen is supplied to support aerobic microorganisms that break down organic substances. Aerobic stabilization is relatively simple to control and can reduce pathogen levels; however, it requires energy for aeration. Therefore, its economic efficiency depends on the scale of the treatment plant and energy costs.

Third, lime treatment is an effective chemical method for reducing pathogenic contamination. When lime is added to sludge, the pH level increases sharply. High alkalinity destroys many pathogenic microorganisms and improves sanitary safety. This method is especially useful for small and medium-sized wastewater treatment facilities because it does not require highly complex equipment. However, excessive use of lime

may increase the volume of treated sludge and affect its further application [12].

DISCUSSION

Fourth, thermal treatment provides a high level of pathogen destruction. Heating sludge to high temperatures can eliminate bacteria, viruses and parasite eggs. Thermal methods are highly effective but require significant energy consumption and special equipment. Therefore, they are more suitable for large wastewater treatment plants or cases where strict sanitary requirements must be met [13].

Fifth, composting is a promising method for transforming treated sludge into a useful organic product. During composting, sludge is mixed with organic bulking materials such as sawdust, straw or plant residues. If the composting process is properly managed, thermophilic temperatures destroy pathogenic microorganisms and produce a stable compost-like material. This method is environmentally beneficial, but it requires enough land area, time and process control. The study also shows that mechanical dewatering alone cannot remove pathogenic contamination. Dewatering reduces sludge volume and moisture content, but pathogens may remain in the solid fraction. Therefore, dewatering should be used only as part of a combined treatment system, after or before disinfection and stabilization [14].

Overall, the most effective technological approach is the combination of several methods. For example, anaerobic digestion followed by dewatering and lime stabilization can provide both volume reduction and pathogen control. Another effective option is composting after preliminary sludge stabilization. The selection of the best technology should be based on local conditions, including climate, treatment plant capacity, financial resources and intended use of treated sludge [15].

CONCLUSION

Excess activated sludge is an inevitable by-product of biological wastewater treatment, and its safe management is an important environmental and public health task. The article shows that untreated sludge may contain pathogenic microorganisms and therefore requires proper technological treatment before disposal or reuse. The most effective methods for reducing pathogenic contamination include anaerobic digestion, aerobic stabilization, lime treatment, thermal processing and composting. Each method has its advantages and limitations. Therefore, the best solution is the application of combined treatment technologies that include stabilization, disinfection and dewatering. The results of the study confirm that the development of sludge treatment technologies should be based on sanitary safety, environmental protection, economic efficiency and practical applicability. For wastewater treatment systems in Uzbekistan, priority should be given to technologies that are reliable, affordable and adaptable to local conditions. The improvement of excess activated sludge treatment can reduce epidemiological risks, protect water and soil resources, and contribute to sustainable environmental management.

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