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SUSTAINABLE LOW ENERGY TREATMENT OF MUNICIPAL SLUDGE THROUGH MESOTHERMOPHILIC AEROBIC ANAEROBIC PROCESSING

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Abstract

The sustainable management of municipal wastewater sludge remains a critical environmental and operational challenge, especially in rapidly urbanizing areas. Conventional sludge treatment methods such as open air drying and chemical dewatering are increasingly unsustainable because of high energy use, odor emissions, and limited opportunities for resource recovery. This study introduces a meso-thermophilic aerobic anaerobic treatment (AAMT) process designed to improve sludge stabilization and dehydration with minimal energy input and without chemical additives. A pilot scale thermally insulated reactor was constructed to process mixtures of raw sediment and excess activated sludge in different ratios. Laboratory results showed that optimal mixtures containing 25 to 35 percent raw sediment and 65 to 75 percent activated sludge achieved more than 70 percent water separation efficiency. The process operated at 38-41 °C, sustained by its exothermic microbial activity, which significantly reduced external energy demand. The activity of nitrites and nitrates actually helps reduce odor by oxidizing hydrogen sulfide (H_2S) and organic thiols, while aeration mainly serves for mixing rather than oxidation. Chemical analyses confirmed that the solid fraction retained valuable nutrients such as nitrogen, phosphorus, and potassium while meeting the heavy metal limits specified in EU Directive 86/278/EEC, making it suitable for agricultural use as a soil conditioner or fertilizer. The AAMT process reduces the need for flocculants, decreases the volume of sludge for transport and disposal, and extends the service life of dewatering infrastructure. Overall, the proposed method provides a sustainable and environmentally sound solution for wastewater treatment facilities aiming to lower operational costs, recover useful resources, and minimize ecological impacts. It combines energy efficiency, nutrient recycling, and odor control into a single approach that supports circular economy and green technology goals.

Keywords Municipal sludge; Meso-thermophilic aerobic anaerobic treatment; Low energy process; Wastewater management; Resource recovery; Circular economy; Sustainable sludge stabilization

1. Introduction

The treatment and disposal of sewage sludge generated in municipal wastewater treatment plants represent a growing environmental and economic concern worldwide. The large volume and high moisture content of sludge make it difficult and costly to handle, transport, and dispose

of. Conventional methods such as open air drying, mechanical dewatering, and chemical conditioning are energy intensive and may produce secondary pollution. In recent years, sustainable sludge management approaches have gained attention, aiming to minimize energy use while recovering nutrients and organic matter for agricultural or industrial reuse (Andreoli et al., 2007; Wu et al., 2020).

2. Materials and Methods

A pilot scale installation (Fig. 1) was designed for meso-thermophilic aerobic anaerobic sludge treatment. The reactor consisted of a thermally insulated cylindrical chamber equipped with an aeration unit and temperature monitoring system. Raw sediment and excess activated sludge from a municipal wastewater treatment plant were mixed at different ratios and introduced into the reactor. The temperature was maintained near 38-41 °C, sustained by biological heat generation. Samples were taken periodically to analyze physicochemical parameters including moisture content, nutrient composition, and heavy metal concentrations according to ISO and SM SR standards (ISO 5664:2007; SM SR EN ISO 6878:2011).

3. Results and Discussion

The AAMT process effectively enhanced sludge dewatering and stabilization. The optimal mixture of 25 to 35 percent raw sediment and 65 to 75 percent activated sludge achieved the highest water removal efficiency of over 70 percent. The meso-thermophilic conditions supported microbial activity while maintaining stable fermentation, resulting in a self-sustaining process with low energy input (Kim et al., 2002). The aeration phase reduced odors and promoted oxidation of organic matter, improving the quality of the final biosolid. The treated sludge exhibited nutrient-rich composition suitable for use as fertilizer, and heavy metal contents were below EU limits (Bożym and Siemiątkowski, 2018; Cao et al., 2020).

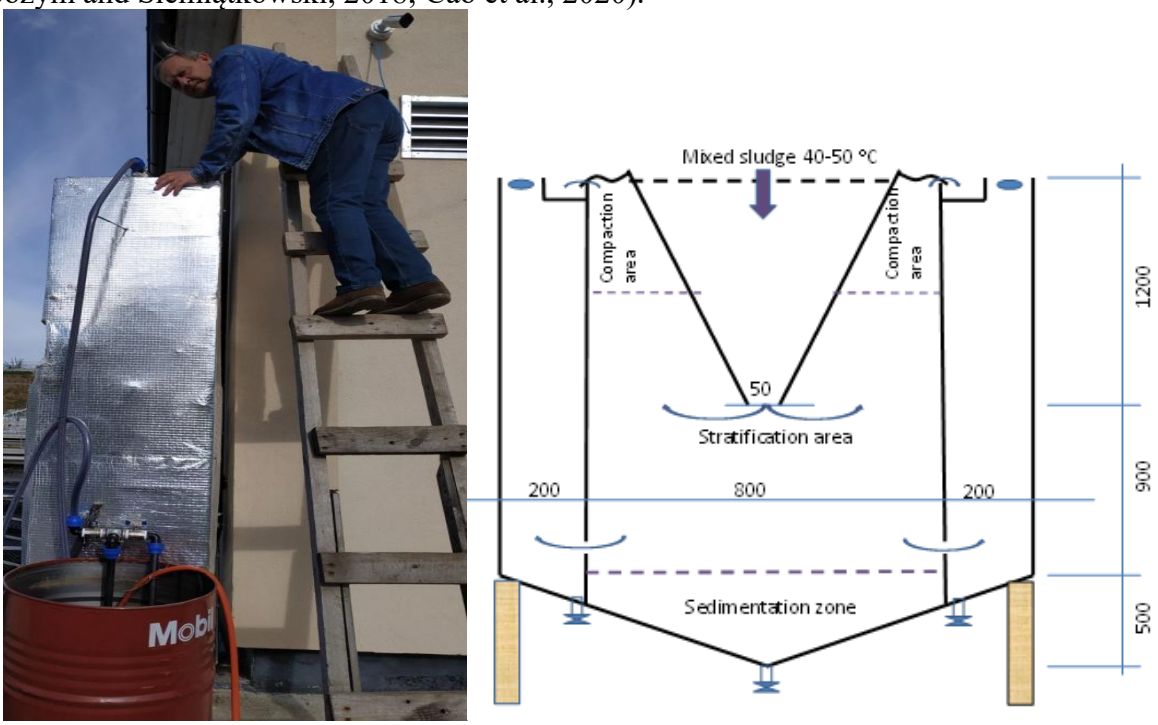

Fig. 1. A pilot scale installation designed for meso-thermophilic aerobic anaerobic sludge treatment.

4. Conclusions

The meso-thermophilic aerobic anaerobic treatment of organic wastewater sludge provides a sustainable, low energy, and cost-effective solution for municipal wastewater management. The method ensures efficient dehydration, odor control, and nutrient recovery while eliminating the need for chemical additives. The resulting stabilized sludge meets safety standards for agricultural reuse, offering an environmentally responsible option consistent with circular economy principles. Further research will focus on scaling up the technology and optimizing operational parameters under real-world conditions.

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OPTIMISATION OF A MICROWAVE PRETREATMENT OF ORANGE WASTES FOR IMPROVING BIODEGRADABILITY

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Among the various organic wastes generated by food industry, the residues from orange juice production constitute a significant technological and environmental problem. During the juice processing, more than half of fruit becomes a waste, which consists of seeds, fibres and peels. Due to significant organic content and high humanity, their properties deteriorate quickly; moreover, they contain essential oils that might hinder biological processes. Another problematic factor is the presence of lignocellulose that constitutes a complex structure which makes their further use difficult. On the other hand, orange wastes indicate a potential for energy production in the anaerobic digestion process. Therefore, this type of waste should be pre-treated to improve biomass structure, making it more susceptible to bioconversion. The pre-treatment strategy should reduce biomass crystallinity, eliminate lignin, prevent sugar degradation, and should not contribute to the formation of inhibitors. Additionally, the energy aspect should be considered.