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Overview of modern methods of treatment and disposal of sewage sludge

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Abstract. This article provides a brief overview of current methods for the treatment and disposal of sewage sludge, such as soil application, landfill, incineration and anaerobic digestion. Municipal sewage sludge is an acute problem in both developed and developing countries. Researchers are conducting many experiments to solve this problem. They are many methods of disposal, neutralization or reuse of sediments after neutralization. The review of methods in this article will provide more information and further make the most appropriate and cost-effective choice for the use of sewage sludge.

1 Introduction

Municipal sewage sludge is a by-product of municipal and industrial wastewater treatment. Depending on the source of the wastewater, sewage sludge may contain pathogenic organisms, antibiotic-resistant microorganisms, and inorganic and organic contaminants such as polycyclic aromatic hydrocarbons, dioxins, furans, heavy metals, and pharmaceutical compounds, among others. Consequently, the disposal of sewage sludge can pose a risk to the environment and human health. Because of these concerns, the direct use of sludge for agricultural purposes has been restricted or banned in many countries, especially in Western Europe. Among the limited disposal options available, (co)incineration is emerging as the most viable alternative to final sludge disposal. However, this is more expensive than other traditional treatment options, such as the reuse of stabilized sludge in agriculture.

2 Materials and methods

Sewage sludge, an inevitable by-product of urban wastewater treatment plants, is a key concern in many countries due to its increasing volume and the impact associated with its disposal.

One of the key components for maximizing resource recovery in a wastewater treatment plant is the sewage sludge generated from the primary and secondary treatment stages, as well as an anaerobic digester (AD), if available. The sludge is not only rich in organic matter with valuable nutrients, including nitrogen (N) and phosphorus (P), but also contains

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significant energy (higher heating value (HHV) 15–20 MJ/kg dry sludge), thus becoming optimal stream to implement waste-to-energy and nutrient recycling strategies.

However, few of the current methods of sewage sludge disposal are designed to recover resources (and even if they do, recovery parameters are very difficult to control).

In 2015, approximately 55% of the 7.2 million dry tons of sewage sludge produced in the US was landfilled, while landfill (30%) and incineration (15%) accounted for most of the remaining shares.

Although some of these traditional methods contribute to the partial recovery of nutrients and energy (Fig. 1), they cannot fully exploit the potential of the sludge.

In addition, the presence of harmful substances in the sludge, such as pathogens, hormones, antibiotics, heavy metals and persistent organic pollutants, serves as an additional deterrent against the further use of some modern methods of disposal.

The use of sludge in the construction industry is another well-known area with specific applications including co-firing as heating oil, cement kilns for mortar production, and stabilization by mixing with wet cement.

These routes provide additional economic benefit in the disposal of sewage sludge over some other traditional methods. However, the presence of heavy metals and additional laws limit the maximum economic value that can be obtained from the sludge using these methods.

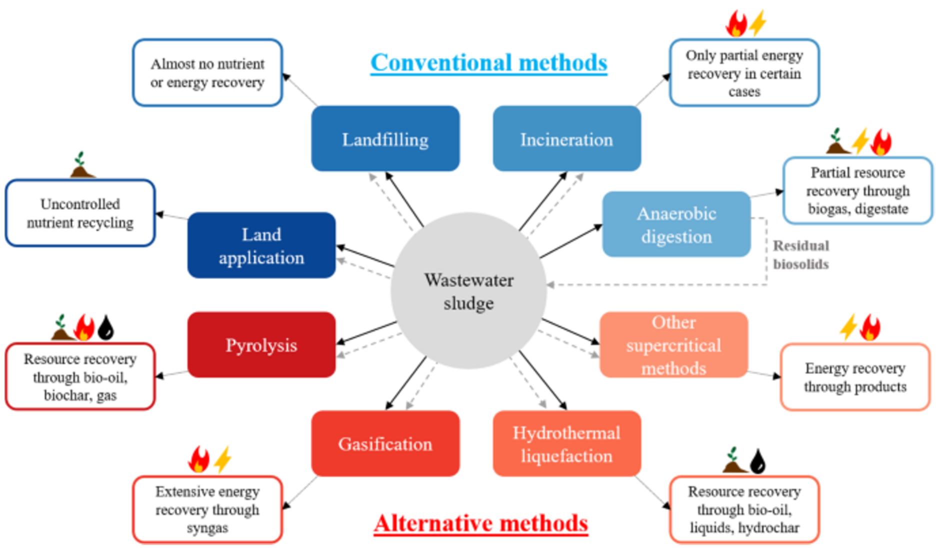

Fig. 1. Traditional and alternative thermochemical methods for the conversion of sewage sludge, as well as the degree of recovery of energy and nutrients.

3 Results and discussion

Intermediate steps such as drying and post-processing steps are not shown in this representative figure. Dotted lines in gray represent residual biological solids derived from AD, which can then be used for any other method. Symbols: seedlings, nutrient processing; flame, energy (heat); lightning, electricity; drop, bio oil.

According to studies by Eva Kochbek [1] Microwave (MW) drying is recognized as a suitable sludge treatment technology. However, microwave drying systems exhibit high energy costs due to (i) unnecessary heating of the resonator and other system components, (ii) inefficient extraction of condensate from the resonator for irradiation, and (iii) inefficient use of microwave radiation. energy, including questions.

This study examined the performance of a new experimental MW sludge drying system specifically designed to overcome the shortcomings described previously.

The performance of the system for drying household centrifuged waste, activated sludge at an output power of MW from 1 to 6 kW was evaluated and the drying speed of the system and exposure time, specific output power, MW generation efficiency, overall energy efficiency and specific energy consumption were evaluated.

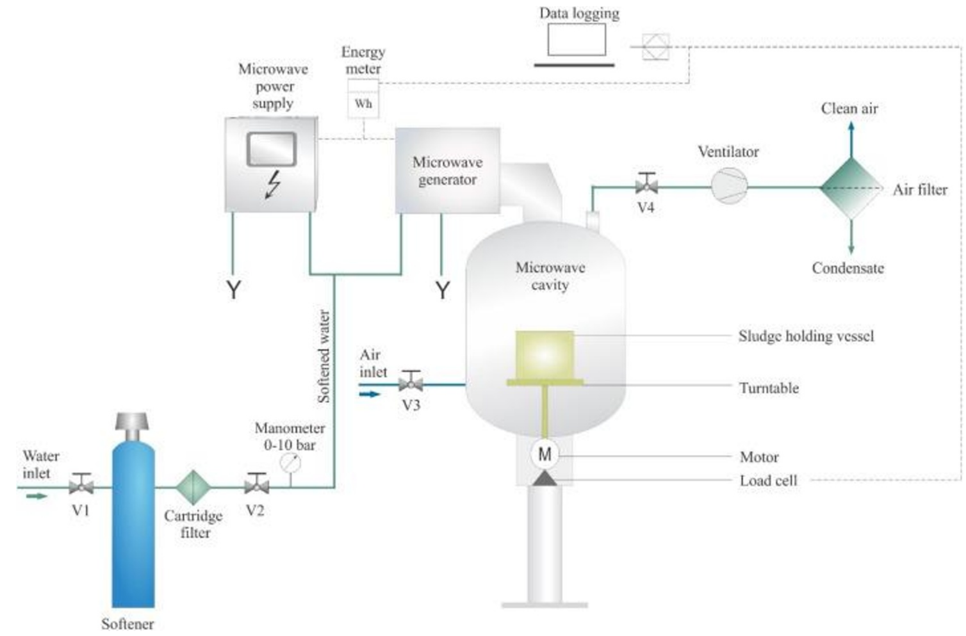

Fig. 2. Schematic representation of the MW experimental system on a pilot scale.

The results showed that MW drying significantly increased the duration of the constant rate drying period associated with the evaporation of free water from the sludge, a phase associated with low energy consumption for water evaporation. In addition, the higher the MW output power, the higher the sludge power absorption density and the MW generation efficiency.

It is reported that the generation efficiency of MW is as high as 70%. The higher the power absorption density, the lower the probability of energy loss, in the form of reflected power and / or energy dissipated in the MW system.

Specific energy consumption can be as low as 2.6 MJ l -1 (0.74 kWh l -1), which is quite comparable to conventional thermal dryers. The results obtained in this study provide enough evidence to conclude that the modifications made to the new MW pilot system have mitigated the shortcomings of existing MW systems and that the technology has great potential for efficient and effective drying of municipal sewage sludge.

According to the results of a study by Vesna Pancevska, Afrodita Zendelska [2], sewage sludge from wastewater treatment plants continues to create environmental problems in terms of volume and method of valorization. Thermal treatment of sewage sludge is seen as an attractive method for reducing the volume of sludge while at the same time generating reusable by-products.

Wastewater sludge from wastewater treatment plants is carbonaceous in nature and rich in organic matter, so it can potentially be converted into activated carbon.

The conversion of sewage sludge into activated carbon, due to the high content of organic components, not only solves the problem of sewage sludge disposal, but also turns solid waste into a useful material in the production of an adsorbent for sewage treatment.

In this study, sludge-based activated carbon was obtained using sewage sludge from the Volkov wastewater treatment plant in Skopje by chemical activation using a 25% ZnCl2 solution and carbonization at 6000C for 50 minutes. The precipitate-based activated carbon obtained was characterized using a scanning electron microscope, an X-ray diffractometer, and well-known standard methods such as ash and moisture content, and adsorption capacity using the iodine number method.

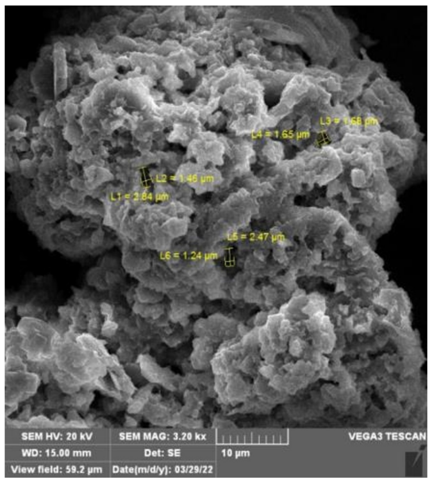

Fig. 3. Micrograph of the sample obtained as a result of SEM analysis

The resulting sludge-based activated carbon has a macroporous structure and interchangeable cations, making it suitable as an adsorbent for wastewater treatment.

According to the results of studies by Aminuddin Ab Latif, Annamaria Nazarudin, Nur Safwan Muhammad [3], the use of sewage sludge ash as a replacement for cement in the production of concrete is considered. Sewage sludge ash is a powdery material that contains a high percentage of SiO2, Al2O3, Fe2O3, CaO, P2O5 and SO3 and is moderately reactive in terms of pozzolanicity. Most researchers have burned sewage sludge at temperatures between 600 °C and 900 °C to produce sewage sludge ash. Partial replacement of cement with sewage sludge ash contributed to an increase in the compressive and bending strength of concrete.

Table 1. Optimum sludge content as a substitute for cement in concrete

Researchers	Compressive Strength	Flexural Strength
Jamshidi et al. (2012)	5%	5%
Ing et al. (2016)	5%	-
Fontes et al. (2016)	5%	5%

Meanwhile, replacing 5% of sewage sludge ash per weight of cement was considered to be the optimal content to obtain the best mechanical performance of concrete. In addition, the workability of concrete after 28 days was improved with the addition of sewage sludge.

Shufeng Huang et al. [4] conducted research on the dewatering of sewage sludge by electricity. Electro-dewatering is a sludge reduction technology with significant potential. However, its use is limited by low economic benefits, partly due to the energy required to heat the sludge. When the DC electro-dewatering mode is selected, a significant amount of energy is wasted heating the poorly conductive dry sludge in the late stage of the electro-dewatering. Decreasing the electrical resistance of the sludge can weaken for electro-dewatering (constant current at 1A) in this study with different dosages (0%-12% dry sludge weight) tested and compared. The results show that all anthracite treated groups with 2-12% anthracite dry sludge added to the sludge consumed less energy than the blank group when the moisture content was reduced to 60%. The economic benefit, quantified by the KsiEDW score, was improved by conditioning with anthracite compared to all conditioned groups and the blank group. The optimal addition was 6% dry sludge in the study as the group had the lowest energy consumption (0.128 kWh/KGS) and KsiEDW (1.71 (kWh/Kgf)•(h/KGS)). Anthracite also improved dewatering efficiency - all conditioned groups had a lower final moisture content than the blank group at the same final voltage (60V), with 51.5% being the lowest (6% in the dry sludge group).

4 Conclusion

The problem of disposal of sewage sludge remains unresolved today. The relevance of this problem is due, on the one hand, to active processes of urbanization, and on the other hand, the emergence of new scientific data on the processes of interaction between precipitation components and the environment. An analysis of scientific publications indicates the need for an integrated approach to the disposal of excess sludge, taking into account specific conditions and factors.

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