

# Advanced Wastewater Treatment and Biomass Energy

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## 1. Introduction

This Special Issue titled “Advanced Wastewater Treatment and Biomass Energy” aims to compile the latest research and challenges in the field of wastewater treatment and energy production to reduce the impact of human activities on the environment. Solutions are presented for the improvement of the performance of wastewater treatment processes and management of waste streams with the rules of circular economy.

In this Special Issue, methods of optimizing wastewater treatment processes were presented, both in lab-scale and full-scale studies focused on the improvement of nitrogen compound removal by dosing external carbon sources or optimization of reactor operation to increase deammonification rate and reduce energy consumption. The results of studies on the mechanisms of micropollutant removal from wastewater were reported. A number of aspects related to circular economy assumptions in wastewater treatment were discussed. The potential of application of composted waste sludge for phytostabilization of polluted soils was assessed. The possibilities of increasing biogas production were investigated by using organic waste as co-substrate during fermentation and by increasing the availability of organic compounds in the fermented substrate via hydrodynamic cavitation. Finally, biopolymer recovery from waste sludge was discussed.

## 2. An Overview of the Contributions to This Special Issue

The paper by Kowal et al. [1] deals with possibility of enhancement of nitrogen removal efficiency by the addition of external organics to a biological part of a wastewater treatment system. The experiment was conducted at a full-scale wastewater treatment plant and, as a source of organics, fusel oil, a byproduct from the distillery industry, was applied. The addition of fusel oil increased nitrate utilization rates at nearly 2-times and mitigated the variability of nitrate concentrations in the effluent from the anoxic reactor. The addition of fusel oil did not reflect a stringent selective pressure on bacterial community structure but stimulated denitrifying bacteria activity. The authors concluded that the application of fusel oil creates opportunities for WWTPs to meet effluent standards and reduce operational costs. Moreover, the application of fusel oil for wastewater treatment provides additional benefits for the distillery industry to optimize waste management.

In the next paper, Al-Hazmi et al. [2] used mathematical modeling to evaluate the effect of intermittent aeration strategies for achieving high and stable deammonification in wastewater at decreasing temperatures. Intermittent aeration with a prolonged non-aerated phase helped maintain high and stable deammonification performance at decreasing temperatures (14–22 °C). Extending the non-aerated phases increases energy savings and, thus, makes this technological solution an attractive option for the treatment of high-nitrogen wastewater. Molecular results indicated the high abundance of *Candidatus Brocadia* in biomass and, thus, favorable conditions for the deammonification system to operate under low temperatures. A decrease in temperature from 26 °C to 14 °C promoted the growth of *Nitrosomonas* sp. At temperatures below 12 °C community reorganization and an increase in biodiversity was observed.



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Understanding the metabolic pathways connected with a removal of micropollutants may help to better design effective wastewater treatment processes. In paper three by Cydzik-Kwiatkowska et al. [3], changes in gene expression in an aerobic granular sludge (AGS) community exposed to bisphenol A (BPA) were investigated. Metatranscriptome analysis of AGS exposed to BPA indicated that direct biodegradation was the main mechanism of BPA removal from wastewater. The expression of genes coding chaperon proteins and proteins involved in biofilm formation in the BPA-exposed biomass indicated that exposition to BPA stimulated aggregation of microbial cells. The presence of BPA in wastewater changed nitrogen metabolism because it was mainly used as an energy source. Exposition to BPA stimulated expression of gene-coding proteins responsible for xenobiotic degradation, including enzymes responsible for benzoate degradation. These presented results increased knowledge about the metabolism of BPA in multi-species communities in wastewater treatment plants and indicated that AGS technology is a suitable solution for BPA removal from wastewater.

Excess sludge is produced in large amounts during wastewater treatment and costs of its management pose a serious position in each WWTP budget. In the next paper of this Special Issue, Radziemska et al. [4] focused on the possibilities of the application of composted municipal sewage sludge (MSSC) for aided phytostabilization applied on soils containing heavy metals (HMs). The application of MSSC increased the production of plant biomass and soil pH and significantly reduced Ni, Pb, and Zn contents in soil after the experiment. The application of MSSC for remediation of soil environment allowed maintaining nutrient cycling in the ecosystem. It was concluded that MSSC can support immobilization of HMs and ensure adequate biomass increase in aided phytostabilization.

The current trend in wastewater treatment is to achieve energetical self-sufficiency. One of the concepts is to use organic-rich waste as co-substrates for methane fermentation. The paper by Wilińska-Osowska et al. [5] investigated the effect of co-fermentation of flotate in wastewater treatment plants treating fish products and a mixture of vegetables on biogas production and nitrogen concentration in reject water. Co-fermentation of waste significantly increased both the production of biogas and the content of methane in biogas. On the other hand, the addition of waste increased the fraction of dissolved organic nitrogen, which may negatively affect biological conversions by increasing nitrogen loads in the biological part of wastewater treatment plants. Energy balance calculations were performed, which took into account the production of electric energy and oxygen supply for oxidation of nitrogen in reject water. For all calculation variants, a positive energy balance was obtained; the minimum energy profits for the flotate and vegetable mixture were approximately 60% and 30% higher in relation to the primary sludge.

In the next paper, Lebiocka et al. [6] evaluated the usefulness of mature landfill leachate as a carrier allowing hydrodynamic cavitation of brewery spent grain. During evaluations, two aspects were taken into account, namely the enhancement of biodegradability and formation of potentially toxic byproducts of hydrodynamic cavitation. Hydrodynamic cavitation of brewery spent grain suspended in leachate increased the availability of organics for anaerobic digestion but resulted in the formation of byproducts such as aromatic compounds that may negatively affect subsequent biological treatment. Considering this, the authors suggested further studies evaluating other carriers for hydrodynamic cavitation of brewery spent grains such as agro-industrial wastewater or digester supernatant.

Finally, the paper by Cydzik-Kwiatkowska [7] summarizes the possibilities of recovering biopolymers from waste sludge. As a source of biopolymers, aerobic granular sludge (AGS) was analyzed because AGS technology for wastewater treatment ensures better quality effluent and higher process sustainability than wastewater treatment systems based on activated sludge. The review summarizes up-to-date information on the composition of extracellular polymeric substances (EPS) in AGS, the effect of operational parameters of wastewater treatment on EPS production, and the effects of EPS in biomass on wastewater treatment and sludge management. Additionally, the possibility of polymer recovery from AGS is presented together with information regarding potential applications based on the

newest findings. It is stressed that extraction methods must be optimized to obtain high amounts of biopolymers with well-defined characteristics. The concluding remarks are that the re-use of AGS-derived polymers increases the sustainability of wastewater treatment processes by rendering them more economical and reducing the amount of sludge that requires management.

As observed from the above summary, in this Special Issue, many problems have been addressed and different technologies were critically evaluated to successfully treat wastewater and manage waste sludge. The involvement of many scientific units and research centers provides this Special Issue the unique value that comes from combining different experiences and research methodologies for solving complex environmental problems.

### 3. Conclusions

This Special Issue presents innovative solutions for wastewater treatment focused on effluent quality, cost-efficiency, and removal of chemicals of emerging concern such as micropollutants. Possibilities of increasing the recovery of bioproducts and energy from waste streams generated in wastewater treatment plant or other plants are also presented.

Coming to the end of this preface, as the guest editor, I thank all the authors for their submissions of such high-quality manuscripts and reviewers for evaluating the manuscripts and providing helpful suggestions. I believe that the publications presented in this Special Issue are a source of valuable knowledge and inspiration for improving existing solutions related to wastewater treatment and bioenergy production.

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