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Editorial: Decentralized wastewater treatment technologies

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Editorial on the Research Topic
Editorial—Decentralized wastewater treatment technologies

This Research Topic focuses on decentralized technologies as an alternative and complement to conventional centralized wastewater treatment processes. Decentralized wastewater treatment solutions are being considered as an option to becoming a standard under certain conditions as their systems have broader practical applications.

Decentralized wastewater management is a significant area of focus for many researchers and a highly topical global issue. Decentralized treatment systems face different challenges than centralized processes, and in recent years, several new technologies have been developed worldwide that demonstrate more effective and reliable processes for water and nutrient recycling, and for the safe end-use of treated sewage sludge and water fractions. The research on decentralized wastewater treatment systems can cover all the fractions or only focus on one of them, and, in order to be implemented, the different treatment alternatives need to be combined with each other so as to enable treatment of all the wastewater flows generated in a household. Many of the decentralized wastewater treatment systems rely on source separation, i.e., treating each individual wastewater stream according to its composition. Source separation has great potential for more effective resource recovery as it can treat the different fractions according to their composition. In this Research Topic, we received seven contributions that look at different aspects of decentralized wastewater treatment methods.

One contribution (Engstler et al.) focused on mixed wastewater and evaluated the performance of small-scale wastewater treatment plants in Austria. The authors evaluated the treatment performance of approximately 2,500 small wastewater treatment plants with a capacity of ≤50 PE (population equivalent) using external monitoring data from 2009 to 2018. The main technologies represented were Sequencing Batch Reactor plants, conventional activated sludge plants, and vertical flow wetlands. The evaluation showed that all technologies met the regulatory requirements for BOD_5, COD, and NH_4-N effluent concentrations. There was no evidence of significant degradation in treatment performance with age for any of the technologies, but many of the plants showed increased variability in

performance with increasing time in operation. The vertical flow wetlands proved to have significantly more stable performance over time compared to the other treatment systems.

Several studies focused on the treatment of one of the fractions. One of the studies (Aicher et al.) focused on treatment by vertical green systems for graywater treatment. The researchers conducted a field study with four modules using synthetic graywater fed hourly for 18 weeks and monitored the performance in terms of COD, total P, ortho-P, total N, NH_4-N, and NO_3-N removal. The modules using agricultural residues for treatment are promising, with up to 92% COD reduction together with a high reduction of N and P. The modules using wooden chips had a lower reduction, reaching only 67% COD removal and a lower reduction of N and P compared to the agricultural residue filter.

Two studies (Randall et al.; Simha et al.) focused on source-separated human urine and the effect of alkaline stabilization, the impact of selected alkalizing chemicals, and how drying conditions affect the pH of the solution. (Randall et al.) presented the chemical kinetics of CO_2 entering the alkalized urine from the evaporation air during dehydration. The rate constant increased with temperature, and the effect of pH on the chemical urea hydrolysis rate in alkalized urine was negligible (>11). Their computer simulations showed that CO_2 dissolution was the main cause of the pH decrease, but $CaCO_3$ precipitation and NH_3 volatilization fostered the pH decrease. Residual, undissolved $Ca(OH)_2$ was shown to significantly delay the pH decrease. Overall, this work provided valuable insights into the CO_2-induced pH decreases and into the mechanisms of urea hydrolysis in alkaline urine dehydration. The second contribution (Simha et al.) used alkaline earth hydroxides to prevent urease activity in source-separated urine. The authors investigated and simulated the solubility of $Mg(OH)_2$ and the factors affecting its dissolution in different types of urine, both real and synthetic. They found that it took 6–16 min for $Mg(OH)_2$ to dissolve. When fresh urine was supersaturated with $Mg(OH)_2$ (650 mgL^{-1}), the pH increased to >10.5. The high pH inhibited the enzymatic degradation of urea for >14 days. When 95% of the water was removed, the solubility of $Mg(OH)_2$ increased to 16,240 mg L^{-1} and the pH dropped below 10.

In another contribution (Wang et al.), a review was conducted on technologies for the recovery of nutrients from blackwater. Nutrient recovery and recycling are of great importance in sustainable development. Blackwater (BW) refers to toilet wastewater containing feces, urine, water, and toilet paper from flushing toilets. The highly concentrated nutrients of BW could be collected through source separation and treated appropriately for efficient and economic recovery. This review provided an overview of the characteristics of BW and different techniques for recovering nutrients and other valuable substances. A number of these technologies are currently being developed or tested at the laboratory or pilot level. The outlook for BW nutrient recovery technologies is very positive due to their great potential for resource recovery. There is still a long way to go to develop commercial technologies and valuable products for the application of resource-based sanitation infrastructure and systems.

Another study (Häfner et al.) used field experiments to evaluate the fertilizer potential and nitrogen value of three novel and safe recycling products. The researchers fertilized white cabbage grown in three soil types (sand, loam, or silt) with two nitrified urine fertilizers and a fecal compost, applied alone or in combination. The control was fertilized with organic fertilizer vinasse. In addition to growth, the uptake of pharmaceuticals was assessed for treatments with compost application. The two nitrified urine fertilizers had a similar fertilizing effect as vinasse, producing up to 72 t ha^{-1} of white cabbage. Plant uptake of pharmaceuticals (carbamazepine) was higher in sand than in loam, with lower concentrations in the edible part compared to the outer leaves. The researchers found that nitrified urine fertilizer was a promising alternative in horticultural food production.

The final paper to conclude this Research Topic looked into "Emerging dynamics and prospects in France". The authors (Joveniaux et al.) presented a study investigating source separation sanitation as an alternative to conventional sanitation management. They looked at environmental conditions and agricultural use. In France, source separation systems were previously found mainly in single households in rural areas. However, since the 2010s, source separation has been introduced on a larger scale in urban areas. The researchers performed a cross-sectional analysis of experimental projects in three cities (Paris, Bordeaux, and Grenoble). Their analysis showed that source separation is still in an emerging phase in France and is currently being experimented with through diversified projects and approaches, both in terms of socio-technical choices and forms of territorial embeddedness. The authors pointed out that, beyond technical issues and shared social values, stakeholder alignment issues and organizational challenges are essential. They also considered possible directions for future development, ranging from the spread of a homogeneous solution to the continuation of a diversity of approaches in different territories.

To summarize this Research Topic, it can be seen that the contributions covered several aspects of decentralized wastewater treatment systems and that most of them focused on systems with separate treatment of different wastewater fractions with a view to resource recovery and the challenges with the different treatment alternatives that are available when decentralizing sanitation.

Author contributions

BV wrote the editorial together with ZL with inputs from other authors.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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