

Editorial

Special Issue on Promising Research and Strategies in Wastewater Treatment, Sludge Management, and Valorisation: Volume I

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1. Introduction

Rapid urbanization and industrialization, together with new contaminants arising from many different sources, make it necessary to move forwards with research to face future challenges regarding water pollution.

Conventional wastewater treatment plants (WWTPs) are designed primarily to remove organic matter and nutrients. For this reason, in many cases, these treatments are inefficient for the removal of specific pollutants, with the consequent risk that this entails.

Emerging contaminants (ECs) represent a wide group of potentially hazardous compounds that have been classified into various categories, including pharmaceutical and personal care products (PPCPs), per- and poly-fluoroalkyl substances (PFAS), flame retardants, surfactants, endocrine-disrupting chemicals (EDCs), and microplastics (MPs) [1]. Recently, it has been highlighted that chemical and plastic pollution has surpassed global boundaries, resulting in harmful effects, not only for the environment, but also for the humanity [2].

Furthermore, large amounts of sludge—the main residue originating from WWTPs—are produced every year. The management of this waste leads to high costs, both in economic and environmental terms, so exploring alternatives for its valorisation is essential. Residue reduction and reuse of wastewater seem to be an excellent option to achieve a circular economy, lessening the environmental impacts associated with wastewater treatment processes. In addition, different efforts to valorise agricultural by-products to treat wastewater have been conducted, which also meets sustainability goals.

In view of the current situation, this Special Issue aimed to compile the latest research on relevant wastewater treatment concerns, such as EC occurrence and removal in WWTPs, novel technologies for wastewater and sludge treatment, sludge valorisation, transformation of agricultural residues into materials for wastewater treatment, etc.

Of the papers submitted to this Special Issue, eight were finally accepted and published. These articles can be organized into three different topics, as synthesized below.

2. Occurrence and Fate of Emerging Contaminants in WWTPs

WWTPs have been reported as one of the main sources for the release of ECs into the environment. Accordingly, gaining an in depth knowledge of the occurrence and fate of these potentially harmful contaminants is a topic of great interest. In this context, Kumar et al. [3] studied the incidence of 15 pharmaceutically active compounds (atenolol, amlodipine, bisoprolol, carbamazepine, citalopram, diazinon, fluoxetine, ketoconazole, metformin, metoprolol, oxazepam, paracetamol, propranolol, risperidone, and sertraline), 18 antibiotics (ciprofloxacin, clarithromycin, clindamycin, doxycycline, erythromycin, ofloxacin, linezolid, metronidazole, moxifloxacin, norfloxacin, tetracycline, trimethoprim, amoxicillin, ampicillin, benzylpenicillin, fusidic acid, rifampicin, and sulfamethoxazole),



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and one stimulant (caffeine) in the largest treatment facility in Jordan (Assamra WWTP). These authors also analysed the presence of these compounds in the Zarqa River, where the treated water is discharged. This study concluded that Assamra WWTP is efficient in removing caffeine and pharmaceutically active compounds (except for bisoprolol and carbamazepine) with overall efficiencies higher than 80%, whereas the wastewater treatment process was not able to eliminate antibiotics. Additionally, Zarqa river water was shown to be contaminated with pharmaceutically active compounds and antibiotics, and the origins of this pollution were the effluent discharges from Assamra WWTP and side-inputs from the areas surrounding the river.

Menéndez-Manjón et al. [4] remarked that WWTPs also represent a major indirect source of microplastics released into the environment and analysed, as a case study, the performance of a WWTP sited in Southwest Europe for one year. They observed that the majority of MPs detected in wastewater and sludge samples were fragments and fibres. Regarding the chemical composition of these micropollutants in the water samples, polyethylene (PE), polyethylene terephthalate (PET), and polypropylene (PP) were the most common microplastics, whereas, in the sludge samples, the main polymers were PET, polyamide (PA), and polystyrene (PS). No significant variations were found between months and the results showed that removal efficiencies were between 89% and 95% during study the period. Moreover, most MPs (88%) were eliminated in the secondary treatment stage, being entrapped in the sludge.

3. Agricultural Residue Valorisation for Wastewater Treatment

It has been estimated that approximately 998 million tons of agricultural wastes are generated each year. In the search for economic and eco-friendly alternatives to management, agricultural residues have been proposed as biosorption materials for the removal of water pollutants [5].

Mamera et al. [6] reviewed the literature published on the potential use of biochar, a carbon-rich adsorbent produced from different organic biomass, in faecal sludge management in developing countries. This work determined that biochar is a viable option for faecal sludge management due to its capacity to bind different inorganic and organic pollutants. Incorporating biochar as a low-cost adsorbent in pit latrine sludge management could lead an improvement in the quality of water resources and, in addition, biochar-amended sludge could be repurposed as a useful economical by-product.

Bouhcain et al. [7] obtained activated carbon from argan nutshells by means of chemical activation. Once this material was characterized, it was assayed as an adsorbent for the removal of two emerging contaminants employed as model pollutants, a stimulant (caffeine) and an anti-inflammatory drug (diclofenac). The highest adsorption capacity was about 126 mg and 210 mg per gram of activated carbon, for diclofenac and caffeine, respectively. The adsorption process was described by a pseudo-second-order kinetic model and the thermodynamic parameters indicated that this process was spontaneous and exothermic for diclofenac and endothermic in the case of caffeine.

Samir et al. [8] employed date stems as a precursor to prepare activated carbon (AC) by calcination. The AC was modified by a hydroxylation strategy to increase the hydroxyl groups over the surface, resulting in AC-OH. In addition, to ensure that photodegradation took place, AC was impregnated into TiO₂ solution to produce AC-TiO₂. The obtained materials were evaluated to remove pharmaceutical contaminants based on atenolol (AT) and propranolol (PR). Results showed that the removal of AT and PR reached 92% by adsorption, while 94% was obtained by photodegradation. Comparing both processes, adsorption proved to be more suitable for removing pollutants from water, since it presented low energy consumption, which revealed AC-OH as a low-cost and environmentally friendly material suitable for wastewater treatment on an industrial scale.

4. Removal of Recalcitrant Compounds

Biodegradation is a cost-effective and practical solution for removing contaminants from different environments, including wastewater, where microorganisms play a key role. However, biodegradation of recalcitrant pollutants is particularly problematic due to the lack of efficient microbial metabolic traits [9]. A fundamental aspect of biodegradation is the C:N ratio. Staninska-Pięta et al. [10] assessed the impact of nitrogen compounds during the process of biological decomposition of hydrocarbons, confirming the positive effect of properly optimised biostimulation. Nevertheless, when excessive biostimulation was employed, negative effects on the biodegradation efficiency were observed. Certain effluents from the food industry, such as the olive sector, contain lignocellulosic organic matter and phenolic compounds, which are difficult to eliminate using conventional biological methods. Díaz et al. [11] evaluated *Phanerochaete chrysosporium* to treat “alperujo” (olive pomace), a by-product composed of pulp waste, ground stone, and skin, together with vegetation waters. COD (Chemical Oxygen Demand) and colour removals of around 60%, and 32% of total phenolic compounds degradation, were achieved in this work, showing the interest of this fungi in recalcitrant compound treatment.

Furthermore, Fuller’s earth was proposed as an environmentally green material to be employed as a catalyst in heterogeneous Fenton oxidation technology [12]. Fuller’s earth was chemically and thermally activated, and the obtained catalysts were employed to treat synthetic wastewater polluted with Levafix Dark Blue dye. Optimal results were observed when 818 and 1.02 mg/L of Fuller’s earth and hydrogen peroxide were used, respectively. Specifically, it was possible to achieve a removal efficiency of 99% and, in addition, after a six-cycle test, a reasonable percentage of dye (73%) was still removed. This underlines the potential of this material to be applied in textile wastewater effluent treatment.

5. Future Prospects

Approximately, 80% of the world’s wastewater is still discharged into the environment untreated. With an increasing scarcity of freshwater available, mainly due to a growing population and the unsustainable use of natural resources, the treatment and recycling of wastewater is a topic of great interest. Moreover, the occurrence of emerging pollutants in wastewaters, such as pathogens, pharmaceuticals, and microplastics, has become a progressively serious issue. Although conventional contaminants may be feasibly removed using established methods, many hazardous compounds, for example, polyfluoroalkyl substances, antibiotics, endocrine-disrupting chemicals, etc., are resistant to typical biological treatments, which leads to a severe threat, not only for aquatic environments, but also for human health.

According to the United Nations, it is very likely that water will be the most critical natural resource in the decades to come. Certainly, universal access to clean water and sanitation is one of the 17 Sustainable Development Goals (SDG 6) that should be achieved by 2030 [13]. This makes it essential to develop novel green alternatives to address wastewater purification in the present context of sustainability.

Moreover, following circular economy principles, valorisation of wastes is mandatory today; this requires, for instance, the use of agricultural residues in wastewater treatment processes, the use of sewage sludge as soil amendment, or the recovery of compounds of interest from different industrial wastes.

Thus, the current defiance of the wastewater sector could be summarised as the need for sustainable and cost-effective technology development. More efforts are required from the scientific community to tackle scientific, political, and societal aspects regarding wastewater concerns in the context of demanding environmental conditions and challenges of the future.

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