water

Editorial

Advances in the Management of Solid Waste and Wastewater Treatment

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The management of solid waste and wastewater treatment is an ever-pressing concern for countries around the world. The proper treatment of these residues to preserve the environment for future generations must be the main objective in environmental engineering, chemistry, and microbiology.

In the treatment of solid waste, reuse and valorization are considered the priority in the European Union, with the aim of achieving the minimal emission of greenhouse gases in order to prevent climate change. In documents published by the European Environmental Agency in 2015 and 2020 [1,2], the target of achieving a 30% reduction in greenhouse gas emissions by 2030 was set, and in this regard, not only are various industries, vehicles, and home heating systems included in this target but solid waste landfills and wastewater treatment plants must also reduce their greenhouse gas emissions. Indeed, some research laboratories are specifically focusing their endeavors on reducing greenhouse gas emissions in solid waste landfills and solid waste and wastewater treatment plants.

Another important challenge in the management of solid waste is the transformation/degradation of plastics and microplastics found in many natural environments, not only in marine water and organisms [3] but also in many rivers in Europe [4]. Although the biodegradation of plastics by bacteria has been known for several decades, more recently, it has been considered as a promising method for the removal of plastics from the environment and several genera of bacteria that are able to carry out this process have been identified [5]. Many organic pollutants can be found in groundwater due to their anthropogenic origin, and among them, n-alkanes are dominant because oil spillages are a frequent issue around the world [6]. At present, the biodegradation of oils, especially alkanes, is considered one of the most suitable methods for the treatment of petroleum and its derivatives [7].

Metals and metaloides appear in groundwater and are an important target for reductions in solid waste, landfill leachate, and sewage, with particular focus on waste originating from wastewater treatment plants. Microbes can once again play an important role here because of the enhancement of bioremediation via biosorption or other co-processes [8].

In wastewater treatment plants, due to strict regulatory legislation in natural waters, research on nutrient removal has continued, even after many decades of research on a topic on which many articles have been published. The most efficient processes actually developed in wastewater treatment plants (anammox [9]) and the most economic strategies have been studied deeply for they have been the main research themes in many laboratories [10]. Nutrients, as is widely known, result in the eutrophication of natural waters and their reduction is currently one of the main objectives in most countries, in the form of optimizing the actual processes and proposing and providing new systems.

Pharmaceuticals have been detected not only in wastewater but also in natural waters [6], and effective methods for their removal (adsorption and electrochemical degradation) have been developed [11].

The aim of this Special Issue is to describe actual effective/sustainable processes for the treatment of solid waste, landfill leachate, and wastewater and proposals for reducing

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greenhouse gas emissions and water use in accordance with the objectives proposed in the legislation of different countries. Of the eight articles published herein, seven cover different areas of engineering (civil, chemical, environmental, industrial, and hydrology) and one covers the field of zoology.

This Special Issue is mainly focused on new proposals for the treatment of emerging contaminants (micro- and nano-plastics in Contribution 4 and fluoride in Contribution 3), the reduction in greenhouse gas emissions in solid waste landfilling (Contribution 5), the reduction in water consumption via sewage treatment and reuse (Contribution 8), and the proposal of special treatment for recalcitrant pollutants (crude oil in Contribution 2, landfill leachate in Contribution 7, and cosmetics in Contribution 6).

We note the remarkable use of sustainable resources (indigenous plants) for the purification of drinking water in Contribution 1 and the treatment of wastewater in Contribution 3 and landfill leachate in Contribution 7.

In Table 1, a synthesis of the eight articles published herein is presented, with the research area, topic of the work, type of contribution, and the country of submission listed.

Table 1. Special Issue contributions and synthesis of concepts.

nº	Research Area	Topic	Type of Research	Country
1-	Engineering	Purification of drinking water with natural plants	Laboratory	Italy
2-	Chemical Engineering	Oil biodegradation by bacteria in bioreactors	Laboratory involving reactors	Spain
3-	Environmental Health Engineering	Wastewater treatment: fluoride removal by plants	Laboratory	Iran
4-	Zoology	Degradation of microplastics by bacteria	Review	India
5-	Civil Engineering	Greenhouse gas emissions from solid waste landfills	Field data	Jordan
6-	Industrial Engineering	Wastewater treatment: cosmetic effluents	Industrial data	Brazil
7-	Civil Engineering	Wetlands for wastewater treatment: industrial and landfill leachate	Laboratory involving pilot plants	Iran
8-	Hydrology	Sewage treatment for the reduction of water use	Field data and laboratory	China

Contribution 1 is an article in which *Aloe vera*, a natural plant, is used as a coagulant for obtaining drinking water of high quality, as a substitute for traditional coagulants, sulfates of aluminum and iron. The use of 0.1 mL/L of liquid mixture/drinking water (the liquid mixture was extracted from the plant using distilled water) can reduce turbidity by 87.8% (initial value: 13 NTU), and the authors compared this natural coagulant with other vegetable coagulants described in the literature. Due to the higher turbidity reduction achieved compared to other vegetable adsorbents, the authors propose the use of this natural product to improve the quality of drinking water.

Biological treatment in laboratory bioreactors of light crude oil used in Europe for gasoline and lubricants production (Arab Light) using two oleophilic bacterial strains (*Bacillus licheniformis* and *Pseudomonas putida*) is studied in Contribution 2. The authors analyzed GC-FID petroleum alkanes over time in bioreactors and achieved 95% biodegradation within 35 days (8.6 g/L petroleum measured as TPH). First-order kinetic coefficients were calculated with the objective of the bioremediation of petroleum-contaminated sites, and the high values obtained (0.082 and 0.098 d^{-1}) demonstrate the strong oligotrophic potential of these microorganisms.

Two natural plants (*Syzygium cumini* and *Psidium guajava*) are proposed in Contribution 3 for fluoride removal in drinking water via adsorption. The surface of the adsorbents was investigated via SEM and the changes in adsorbents after adsorption were studied via FT-IR. The monolayer adsorption process was modeled, and the experimental data were statistically analyzed via ANOVA and finally described using a Langmuir isotherm. The removal of fluoride by the two natural biosorbents reached values of 72.5 and 88.3% for 6 mg/L initial F^- concentration and 8 and 6 g/L adsorbent concentration, respectively. The maximum adsorption capacities of both natural adsorbents were measured as 1.14 mg/g for SC and 1.50 mg/g for PG.

Contribution 4 is a review of micro- and nano-plastics of anthropogenic origin via degradation in the environment and the microorganisms able to degrade them. After classifying the different types of plastics, the authors cite bacteria that can degrade them and focus on synthetic plastic polymer-degrading enzymes and the phylogenetic relationships between plastic-degrading bacteria. The use of natural and genetically modified bacterial strains is discussed therein in order to compare the risks and benefits of modified microorganisms in the bioremediation of pollution produced by plastic residues.

An evaluation of the use of landfill gas generated from the landfilling of solid waste in Jordan for energy production is presented in Contribution 5 with the objective of reducing greenhouse gas emissions. The authors use four first-kinetic degradation models of solid waste to evaluate the amount of landfill gas produced and they conclude that 1–6% of the renewable energy produced in the country can be produced using landfill gas, reducing CO_2 emission by 18 million tons within ten years.

An economic study on the implementation of a wastewater treatment plant for a cosmetic factory is described in Contribution 6, with the authors analyzing the effluent concentrations that align with current legislation in this regard. The treatment plant involves a hybrid membrane–bioreactor process comprising biological treatment followed by microfiltration, and the authors discuss the viability of this wastewater treatment plant from an economic perspective and the benefits of the plant to the environment. In the study, very high levels of efficiency were obtained for heavy metal removal: 95.0–99.8% for Ba, B, Cu, Cr (III), Fe, Mn, and Zn, 91.5% for Ni, and 80.0% for Pb, and in light of the economic and environmental benefits presented, the authors highly recommend the implementation of this wastewater system.

A comparative analysis of five different wetlands constructed at a laboratory scale with different materials used for wastewater and landfill leachate treatment is provided in Contribution 7. The authors use life cycle assessment (LCA) as a statistical tool for the evaluation of the results in the reduction in pollution parameter concentration using different materials in laboratory treatment plants. The configuration of these wetlands is formed by two units: the first one is a PVC pipe filled with different materials (cement, brick, and sugarcane bagasse) and the second one simulates an open lagoon with two species of plants (*Phragmites australis* and *Canna indica*). The reduction in COD and metals is evident in this study, especially with regard to the cement and brick materials, and the authors evaluated the environmental benefits of these wastewater treatment systems by focusing on household gas emissions (in the construction of filling materials), ecotoxicity, toxicity to humans, and eutrophication reduction.

Contribution 8 is a comparative study of 10 rural domestic sewage samples in two regions of China (Zhejiang Province) treated using a portable device consisting of biological treatment followed by electrochemical/UV disinfection for application in crop irrigation and landscape and ecological water supplements during the non-irrigation period. The use of the sewage treatment device resulted in a significant reduction in COD (86.7%), SS (69.8%), coliforms (97.7%), and nitrogen (89.4%), with it reaching the standards for agricultural water and landscape water for nitrogen (COD $\leq$ 60 mg/L, SS $\leq$ 15 mg/L, coliforms $\leq 2\ 10^4$ NMP/L, and TN $\leq$ 15 mg/L). The authors annually evaluated the reduction in the use of water ($2.5\ 10^5$ tons), nitrogen (5.6 NH_3-N tons), and carbon emissions (134 tons) through the reuse of treated sewage.

Advances in the management of solid waste and wastewater treatment include landfilling, the composting of organic matter, reductions in greenhouse gas emissions and methane production, physicochemical wastewater treatment, biological wastewater treatment, nutrient removal, oxidation/reduction processes, the removal of heavy metals, and other topics derived from them or new approaches. To propose topics for future research is not an easy task in this wide-ranging field of research; however, we can focus on recent legislation and recommendations in developed and developing countries.

One of the main problems faced at present in countries in South Europe and North Africa (and also in Western Asia) is the reduction in rainfall due to climate change. Research conducted to preserve water through the reuse or post-use of wastewater will be a priority in these areas. Effluents from wastewater treatment plants could be used for the irrigation of crops, gardens, or trees, and for this purpose, more efficient strategies need to be applied to the treatment of wastewater. Strategies aimed at nutrient removal, focusing on the performance of the most economic methods (anammox, for example), will continue to be developed.

Hydrocarbons (especially n-alkanes and PAH) are present in many different environments [6]. The frequency and severity of large-scale accidents in petroleum transportation by sea have decreased significantly in the last three decades [12] because modern ships are much safer. However, it must be noted that petroleum is always present in the surroundings of refineries, oil transportation pipes, harbors, storage deposits, etc.; thus, transportation accidents will inevitably still occur. The effects of these "environmental tragedies" have to be minimized as much as possible. Petroleum is one of the priority pollutants in the European Union [2] and research focused on the optimization of petroleum biodegradation by bacterial strains, via in situ and ex situ bioremediation, is of great interest at present.

Plastic (micro- and nano-) biodegradation is one of the other future concerns in environmental engineering and microbiology. Of late, a connection between alkane-degrading and plastic-degrading bacteria has been noted, and because hydrocarbons are present in many marine environments, exploring extreme marine niches for obtaining novel microbial resources presents a fascinating challenge to be addressed in the future [13]. The use of genetically modified microbes could be proposed to degrade plastics and produce high-value products [5,14].

The use of textile dyes in clothing production results in high levels of pollution in rivers in the developing countries in which production facilities are located. Pollution in waters originating from textile dyes causes significant harm to ecosystems and great efforts must be made to minimize such detrimental effects. Due to the chemical structure of textile dyes, coagulation–flocculation [15] and also biological treatment [16] seem to be the most suitable methods for their removal from the environment. The study of the toxicity to the environment and also the bacteria or consortia of different bacterial strains that can remove them are intriguing topics and priority challenges to be addressed in order to protect the environment [17].

Metals of anthropogenic origin in groundwater and rivers are present in low concentrations but are incredibly extensive in range. They must be treated at the site of origin, and a wide research field has opened within this topic not only because metals can be removed from water via oxidation, precipitation, or electrolysis but also in light of recent findings in that microorganisms can be used to reduce metal concentrations via adsorption or assimilation [8]. The exact process associated with the decrease in metal concentration in water induced by microorganisms is not clear at present and further research is needed to elucidate the exact mechanism involved. In addition, the equilibrium between the toxicity of heavy metals to bacteria capable of degradation and the adequate concentration for biodegradation [18] depends on the metallic element and strain in question and this particular issue needs to be clarified further [19].

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