applied sciences

Editorial

Special Issue on "Ecotechnological Green Approaches to Environmental Remediation and Restoration"

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1. Introduction

Ecological technology (or ecotechnology for short) is an ecofriendly technology used to develop sustainable ecosystems that integrate human society with its natural environment for the benefit of both [1–3]. It is evolving rapidly and has proved its potential in addressing a wide spectrum of environmental problems as well as the plethora of pathological symptoms, indicating the degradation of biophysical resources, which plague our planet today. It relies on ecosystem components and works in accordance with ecological principles in tackling environmental problems and improving both the health of the ecosystem and human wellbeing [4–6]. Within ecotechnology, there is a commitment to using ecological principles and the complexity of living communities and ecosystems alongside technology to solve environmental problems, as opposed to depending on chemical, mechanical, or material technologies in problem solving, as is the case in environmental engineering [7,8]. Most conventional engineering processes seek to force their designs onto nature, even contradicting the essence of nature and damaging the fabric of her life. We can identify some problems associated with environmental engineering relying primarily on cleaning up pollution; firstly, it functions only as a 'quick fix'. Secondly, it may be deemed a 'shell game' being played with pollution, akin to removing one pollutant from the environment only to cause pollution somewhere else. The living library of nature—i.e., biodiversity comprising countless species of plants, animals, and microorganisms—is really an immense inventory of living tools and functional units of ecotechnology that can be used for reducing pollution loads, toxicant removal, contaminant remediation, biofuel synthesis, land reclamation, erosion control, wastewater treatment, bioregenerative reclamation, carbon sequestration, sanitization, etc. [9–12]. The diversity and best mix of species within new ecosystem designs represent a challenge for ecotechnologists. Ecotechnology advocates for bioremediation of contaminants through biodegradation or biological metabolism by miniscule microbes and other biological agents [13,14]. Ecotechnology tries to test the 'microbial infallibility' that states that no natural organic compound is totally resistant to biodegradation subject to appropriate environmental conditions. Ecotechnological methods mean to reduce the ecotoxicity of man-made synthetics/xenobiotics to the environment and facilitate the eco-assimilation of those compounds into ecological cycles, thus reducing the amounts of hazardous residues that otherwise end up in cost-intensive landfill and incineration facilities [15]. Ecotechnological processes help in reducing the ecological footprint of human waste and in combating global warming and climate change; they are carbon-positive, nitrogen-positive, low-cost, user-friendly and eco-friendly. Restoration of degraded ecosystem relies on the art, intuition, and scientific and objective knowledge of ecotechnologists [16,17].

The following ecotechnological approaches can be adopted to address different environmental problems: (1) Ecosystems are used to reduce or solve a pollution problem

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Citation: Biswas, J.K.; Sarkar, D. Special Issue on "Ecotechnological Green Approaches to Environmental Remediation and Restoration". *Appl. Sci.* **2024**, *14*, 1988. https://doi.org/10.3390/app14051988

Received: 9 February 2024
Accepted: 26 February 2024
Published: 28 February 2024

that would otherwise be harmful to other ecosystems; some examples of these systems are wastewater treatment and phytoremediation. (2) Ecosystems are imitated or copied to reduce or solve resource-related problems; some examples of these imitations are replacement wetland and forest restoration. (3) The recovery of ecosystems is supported after significant disturbance through processes such as lake restoration and mined land restoration. (4) The recovery of ecosystems is modified in an ecologically sound way to solve a given environmental problem; some examples of recovery processes are biomanipulation and selective timber harvest. (5) Ecosystems are used for the benefit of humankind without destroying ecological balance, for example, through multispecies aquaculture/polyculture, mixed culture, integrated farming, sustainable agriculture, and sustainable aquaculture. (6) Ecosystems' components are used for environmental remediation and the production of value-added products.

The papers in this Special Issue, contributed by scientists from Asia, America, and Europe, deal with remediation of degraded land, in situ electrokinetic remediation, the use of permeable reactive barriers, chemical manipulation of micronutrients and macronutrients for reducing toxicant load in crop plants, biodegradation of antibiotics, bioflocculation for heavy metal removal, biosurfactants for bioremediation of kerosene contamination in soil, biomonitoring of land use changes using enzymatic signatures, and biofuel feedstock production on metal-contaminated land. They represent a broad spectrum of ecotechnological processes involved in environmental remediation and restoration.

Deng et al. (contribution 1) describe how extracellular enzymatic (catalase, sucrase, urease and alkaline phosphatase) activities in soil show temporal variation subject to land-use change during different vegetative growth periods following afforestation, and can serve as excellent biochemical indicators of soil functions and ecosystem services. The results illustrated that soil enzyme activities increased significantly following afforestation due to characteristic microbial assemblages, associated activities and soil properties, and both alkaline phosphatase and sucrase were more sensitive to temporal variation than catalase and urease. These results highlight the importance of soil enzyme activities for maintaining soil nutrients in general, particularly dissolved organic carbon and dissolved organic nitrogen, which have immense importance in formulating fertilization and plantation management protocols in the Loess Plateau, China and elsewhere.

Kim and Han (contribution 2) evaluated the performance of in situ electrokinetic remediation (EK) and permeable reactive barriers (PRBs) filled with recyclable food scrap ash (FSA) of soil co-contaminated with heavy metal and organic contaminants. FSA was chosen as a PRB-filling material due to its high potential for adsorptive removal of contaminants. Acetic acid and Brij30 were used as enhancers on copper and phenanthrene, respectively, to improve EK remediation performance in removing heavy metals and organic contaminants. Copper adsorption to PRB accomplished a removal efficiency of up to 90%, whereas phenanthrene was hardly detected due to its low recovery rate in kaolinite; this indicates that further studies of pretreatment conducted on phenanthrene-contaminated kaolinite are needed.

The study of Boorboori et al. (contribution 3) delved into the bioavailability, uptake, accumulation, and toxicity of arsenic in rice plants and the impact of chemical manipulation (using two micronutrients and two macronutrients as fertilizer) in reducing As uptake and transport in rice. Adding micronutrients and macronutrients proved to offer dual benefits: it acts both to fertilize rice, improving the plant's growth and health, and to reduce arsenic uptake and toxicity. Other studies [18,19] have shown that significant amounts of As can be transmitted to rice shoots and grains depending on the genotype and soil conditions, and As partitioning and loading in different plant parts can be moderated by various agro-management interventions. Arsenite [As (III)] and methylated organic species enter rice using the Si and P transport routes. The use of Si in rice fields reduces the concentration of As (III) in rice, which is more toxic than As (V)]. Although removing Si from soil particles can increase the bioavailability of As, due to the common pathway of these two elements, when Si is added to the culture medium, the competition between them increases and thus reduces the uptake of As by rice. Phosphorus, a chemical analog of As, can control As motility in soil and As uptake in rice through competition for soil particle uptake sites, thanks to competition between P and As for uptake and the opposing effect of P on root-to-shoot As transfer. Se (IV) is transported to plant roots via phosphate and silicon transporters, and Se (VI) is transported to plant roots via sulphate transporters before competing with arsenic through the known routes. Ca participates in signaling various physiological and biochemical processes as a secondary messenger that mediates several cell and plant growth prospects and responds to various stresses including As toxicity.

Xue et al. (contribution 4) studied heavy metal (Cu, Pb, Cd, Cr, Ni and Zn) contamination in cropland soils, its spatial distribution, and its controlling factors in 12 different cities in Shandong Province, China,. The correlation analysis and factor analysis indicated that Cu/Ni/Zn and Pb/Cd were caused by a broad range of human activities, and that proper management of human activities is warranted to mitigate the risk of cropland soil becoming toxic and to ensure environmental health and safety.

Geiger et al. (contribution 5) showed that vetiver grass (*Chrysopogon zizianioides* L. Nash) can serve the dual purpose of phytoremediation and biofuel feedstock generation in metal-contaminated soils. In a greenhouse experiment, they assessed the effectiveness of vetiver grass in phytostabilizing copper (Cu)-contaminated soil as well as the potential of the harvested lignocellulosic biomass for downstream bioethanol production. The results obtained from the study with vetiver grass subjected to dilute acid pretreatment, enzymatic hydrolysis, and optimization of fermentation process parameters using response surface methodology (RSM) suggested that the lignocellulosic composition of the grass was altered suitably, showing an appreciable decrease in lignin but an increase in hemicellulose and cellulose content, which led to greater ethanol yield and volumetric productivity from the hydrolysates produced from the metal-stressed biomass.

Goswami et al. (contribution 6) investigated the use of extracellular biosurfactants (sophorolipids) derived from the yeast *Candida bombicola* CB2107 in the bioremediation of kerosene-contaminated soils for their subsequent potential application as a substitute for chemical surfactants, thus acting as "green" reagents for extracting petroleum hydrocarbons from contaminated soil. The results showed that although sophorolipids have the potential to replace synthetic surfactants, the properties and performance of the biosurfactants vary widely depending on the yeast species/strains and the growing conditions during production.

Biswas et al. (contribution 7) examined the potential of an extracellular polymeric substance (EPS) produced by *Bacillus licheniformis* strain KX657843 isolated from earthworm (*Metaphire posthuma*) gut in the adsorption of Cu(II) and Zn(II) from aqueous solution and in flocculation. The negatively charged functional groups of carbohydrates and protein moiety of the EPS were found to be capable of binding and removal of heavy metals through electrostatic interactions. Such a thermostable EPS from earthworm gut bacteria was championed as an effective agent for environmental remediation of heavy metals and as an emerging eco-friendly bioflocculant that can potentially replace synthetic flocculants in various applications, such as water/wastewater treatment and industrial waste treatment.

Chang et al. (contribution 8) assessed highly salinity-tolerant bacterial strains for the biodegradation of broad-spectrum antibiotics like sulfamethoxazole (SMX), which is extensively used in intensive coastal aquaculture (*Chanos chanos*) to fight bacterial infections. The antibiotics end up in fish (milkfish) pond sediments, resulting in pollution in rivers and oceans from the discharge of aquaculture wastewater. Aerobic and anaerobic batch experiments and continuous SMX addition experiments indicated that bacterial strains A12 (a strain of *Vibrio* sp.) and L (a strain of *Pseudomonas* sp.) could enhance SMX degradation in milkfish culture pond sediments, as revealed by phylogenetic analysis. Different compositions of the microbial community under aerobic and anaerobic conditions exhibited different SMX-degrading abilities. The results of this study suggest that bacterial strains A12 and L provide a solution for the treatment of wastewater and sediment from SMX-contaminated highly saline milkfish culture ponds. They can be used for the bioremediation of SMX-contaminated mangrove, estuarine, and coastal sediments.

2. Conclusions

The papers in this Special Issue demonstrate how ecotechnological practices are being incorporated into environmental remediation and restoration projects. With each passing day, many more tools are being made available to researchers; large-scale ecosystem creation, modification, and restoration practices will be possible in the near future. We hope that a new generation of researchers will follow in the footsteps of the authors of this Special Issue and diversify the scope and spectrum of ecotechnology in protecting the environment, thereby enhancing our economy, securing societal wellbeing, and fulfilling the triple-bottom-line principle of sustainable development. The challenge for ecologists and engineers alike is to break down the stereotypes of ecology and engineering and to build synergy, thus combining the strengths of both disciplines. Ecotechnologists can bridge the gap between ecologists and engineers by designing nature-friendly solutions to complex environmental problems.

Author Contributions: Conceptualization, J.K.B. and D.S.; writing—original draft preparation, J.K.B.; writing—review and editing, J.K.B. and D.S. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: As guest editors of the Special Issue "Ecotechnological Green Approaches to Environmental Remediation and Restoration", we would like to express our deep appreciation to all authors whose valuable works were published in this issue and thus contributed to the success of the current edition.

Conflicts of Interest: The authors declare no conflicts of interest.

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