Editorial: Environmentally friendly (bio)technologies for the removal of emerging organic and inorganic pollutants from water

As the saying by Leonardo Da Vinci goes, ‘Water is the driving force in nature.’ Needless to say, water is an inevitable part of our day-to-day activities, and access to safe water and sanitation is a major concern in many developing countries and countries in transition. At the United Nations Sustainable Development Summit held in 2015, ‘ensuring availability and sustainable management of water and sanitation for all’ was set as one of the global goals for sustainable development. Water scarcity is a global issue due to the following reasons: (i) population growth, (ii) expanding urban environments, (iii) agricultural land use patterns, (iv) variation in water consumption approaches, and (v) climate change. According to recent statistics, a major proportion of living habitats is in crisis because reservoirs and aquifers have dried up, and approximately one in seven people on the planet lack access to safe drinking water. In contrast, flooding is another serious global issue in many water-sensitive regions, primarily because of: (i) rising temperatures, (ii) increased levels of sediments, nutrients, and pollutants present in rivers (both transboundary and national), and (iii) failure of sewers, storm water drains as well as water and wastewater treatment facilities.

This special issue on ‘Environmentally friendly (bio)technologies for the removal of emerging organic and inorganic pollutants from water’ highlights the impacts of emerging pollutants (both organic and inorganic) in water bodies and the role and performances of different water and wastewater treatment approaches that are presently being employed in the field of environmental engineering. Some of these approaches are focused on ‘end-of-pipe’ treatment, while most of these approaches are focused on the application of novel physio-chemical and biological techniques for wastewater treatment and reuse.

The presence of organic and inorganic pollutants in water bodies has caused serious health and environmental problems. For example, pharmaceutical and personal care products (PPCPs) are a new type of widely produced trace pollutant that have become a global environmental problem in developing as well as developed nations. A study by Feng et al. (2018) addresses the performance of a physico-chemical process, i.e., adsorption of norfloxacin (NOR) from wastewater by biochar derived from luffa sponge. Luffa is widely cultivated in temperate and tropical regions around the world. Mature luffa forms a net fiber, called luffa sponge, that can be used for scrubbing and wet cleaning purposes as well as for medicinal use because of its diuretic properties. The authors prepared biochar from luffa and used it to adsorb NOR from synthetically prepared wastewater. The prepared biochar was characterized based on its surface structure, specific surface area, porous structure, and Fourier-transform infrared (FTIR) spectrum. Optimization of adsorption processes and conditions such as initial NOR concentration, pH, biochar dose, temperature, and contact time were also carried out in that study and the authors reported a maximum adsorption capacity of 250 mg NOR/g biochar.

In a study that was related to the presence of persistent organic pollutants (POPs) in atmospheric environments, Zhu et al. (2018) predict the low-density polyethylene–air partition coefficients using theoretical linear solvation energy relationships. The presence of these compounds in water bodies can be easily measured using modern analytical instruments; however, in the case of atmospheric POPs, it is rather difficult to determine a suitable technique to monitor the fate of these pollutants due to atmospheric dispersion and their interactions with sunlight/precipitation that lead to the formation of secondary pollutants. Recently, some progress has been made in the development and application of passive atmospheric sampling (PAS) technology. The authors have developed a theoretical linear solvation energy relationship (TLSER) model with the help of quantum chemical descriptors for predicting poly-ethylene–air partition coefficients. The TLSER models were based on a large data set, including 97 compounds, comprising the most commonly reported hydrophobic organic compounds (HOCs), within the applicability domains, to reduce...
Experimental cost and time. The McGowan volume, chemical hardness, and dipole moment were screened as the most relevant variables and the authors have shown, that by estimating the log $K_{PE,a}$ values for complex molecules, the concentrations of a wide variety of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and organochlorine pesticides (OCPs) in the atmosphere can be predicted.

Heavy metal pollution in water is another major concern because of deleterious health and environmental impacts. In the last five decades, there have been increasing ecological and global public health concerns associated with environmental contamination due to the presence of heavy metals in the environment (air, water, soil, and sediments). Human exposure has risen several-fold because heavy metals are used in a wide variety of processing industries as well as in the field of agriculture. In another, similar approach, Rai et al. (2018) prepared microporous activated carbon from almond shell powder activated with H$_3$PO$_4$ and the adsorbent was used for the removal of hexavalent chromium [Cr(VI)] from water. The authors carried out batch experiments to study the effects of contact time, solution pH, adsorbent dose, initial Cr(VI) concentration, and temperature on removal performance. The Cr(VI) removal was found to be 100% at an initial pH of 2.0. The results from thermodynamic studies revealed the spontaneous, endothermic, and increased randomness nature of the adsorption process, and the maximum adsorption capacity achieved was 202 mg Cr(VI)/g adsorbent. In another novel approach, Jiang et al. (2018) prepared a magnetic plant polyphenol (PP)-coated Fe$_3$O$_4$ material (Fe$_3$O$_4$/PP) to remove Cd(II) from water. The authors studied the effect of different parameters (e.g., pH, initial metal ion concentration, contact time, adsorbent dose, agitation speed, and coexisting ions) on the adsorption process; and after fitting the experimental data to the well-known Langmuir isotherm, the adsorption capacity of Cd(II) was shown to be 0.951 mg/g. Concerning the role of process parameters, the adsorption capacity increased with increasing pH (3.0–8.0), and unlike NO$_3^–$ and SO$_4^{2–}$, common coexisting cations such as Na$^+$, K$^+$, and Mg$^{2+}$, as well as Cl$^–$, negatively affected the Cd(II) adsorption onto Fe$_3$O$_4$/PP. With respect to practical applications of this work, the authors have highlighted the role of reusing the Fe$_3$O$_4$/PP and reported stable removal of Cd(II) from water.

Cerium is the most abundant rare earth element (REE) in the Earth’s crust and is commonly used in fluorescent devices, polishing compounds, magnetic substances, and alloys. Cerium oxide is part of the catalyst in catalytic converters that are used to clean up vehicle exhausts. Due to its overuse in the electronic industry, cerium can be accumulated in the human body by inhalation and ingestion which can damage the kidneys and lungs. In the study by Serunting et al. (2018), cerium(III) was removed by using sodium alginate-coated magnetite (Alg-Fe$_3$O$_4$) nanoparticles having an average diameter of 13.7 nm. The authors showed that the optimum conditions for the adsorption process were pH 4.0, contact time 4 h, and adsorbent dose 0.15 g, resulting in a maximum adsorption capacity of 31.8 mg cerium(III)/g of nanoparticle. As well, this novel adsorbent also showed good performance in reusability, where it was able to sustain its performance for three cycles of adsorption–desorption using 0.01 M HNO$_3$ as the desorption agent.

In addition to the presence of heavy metals in water bodies, the levels of nutrients (N, P, K) are also alarming due to intense agricultural practices and the use of fertilizers and pesticides. High concentration of biogenic substances, such as phosphorus, can invigorate the algal bloom and anoxic conditions can trigger the growth of cyanobacteria, reduce dissolved oxygen content, suffocate fish populations, form murky water, and complicate water purification. Deteriorating quality of water in water bodies are very often directly related to the evolution of eutrophication-like conditions. Hamzah et al. (2018) have ascertained the performance of thermally treated rice husk as an efficient adsorbent for phosphate removal from water. The adsorbent was prepared via chemical activation using NaOH followed by heat treatment at 450 to 750 °C. The authors have carried out batch adsorption tests to study the effects of pH, contact time, adsorbent dose, and initial phosphate concentration on the adsorption performance. The maximum phosphate removal achieved was 97%, at an initial phosphate concentration of 2 mg/L and at pH 9.0. According to the authors, the results from this study can be a platform in designing eco-friendly adsorbent-based columns for water and wastewater treatment, mainly in poor countries, since the chemical treatment of wastewater is costly.
Transboundary waters, i.e., when rivers, lakes, dams, and other water resources are shared between two or more countries, have been one of the main sources of livelihood for many people in the world. Efficiently managing these water resources is very important for international cooperation and to promote circular economy in these regions. One such case study has been demonstrated by Zhang et al. (2018), in which the Nen River was considered as the model river. This river flows through Inner Mongolia, Heilongjiang, and Jilin provinces in China, which form the neighboring sections at the border of the provinces. The authors ascertained 10 water quality parameters covering 11 sites in the region, using cluster analysis (CA) to determine the spatial variation of water quality parameters in the Nen River. The results were interpreted to identify low, moderate, and highly polluted areas of the river. The authors also used statistical tools such as grey relational analysis (GRA) combined with principal component analysis (PCA) and pairwise correlation analysis to reveal the fact that NH$_4$+N and TP were principal factors influencing the water quality of the Nen River. According to the authors, the results obtained from this study will serve as the source for a provincial government document that will help to develop policies for water pollution control and water environment management for this transboundary river.

According to a recent WHO report, control of the microbial quality of drinking water should be a priority in all countries, given the immediate and potentially devastating consequences of waterborne infectious diseases. For instance, most cases of diarrheal illness and death occur in developing countries, with an estimated annual incidence of 4,600 million episodes and causing 2.2 million deaths every year. A UNICEF report suggests that hand pump fitted boreholes are still among the main sources of drinking water for communities in many developing countries in Asia and Africa. Globally, the number of people using hand pump fitted boreholes grew from 1 billion in 1990 to 1.4 billion in 2018 in both urban and rural areas of these countries. In a case study from Ethiopia, Bekuretsion et al. (2018) assessed the bacteriological quality of drinking water from hand pump fitted borehole sources and determined the associated risk factors involved and antimicrobial susceptibility patterns. The authors reported that 11 (15%) hand pump fitted borehole sources were not suitable for drinking as per the WHO recommended guideline values for drinking water. As well, the water also contained elevated levels of Escherichia coli, Enterobacter, Klebsiella, Citrobacter, Salmonella and Pseudomonas spp. The recommendations from the authors were as follows: (i) incidences of microbial contamination should be identified well in advance for remedial action to be taken by the responsible government bodies; and (ii) there should be regular maintenance and rehabilitation of hand pumps or boreholes in the region.

According to Belding & Boopathy (2018), in the modern healthcare industry, antibiotic resistant bacteria (ARB) infections have become one of the most insidious epidemics seen throughout the world. The authors have identified the presence of ARB and antibiotic resistance genes (ARG) in coastal recreational waters of southeast Louisiana, USA. The two recreational coastal water sites chosen by the authors were located downstream from waste disposal and had high human activity. The main aim was to analyze the water quality in terms of total coliform and fecal coliform bacteria in the coastal water samples in order to monitor the water chemistry of coastal waters and to ascertain the presence of ARB and ARG. The authors found that the two sites had significantly different salinity levels, allowing more variety of bacterial species between the sites, and fecal and total coliform data confirmed that microbial life was plentiful at both sites. Based on the Kirby-Bauer assay data, the authors have shown that a considerable number of drug-resistant isolates, with up to one-third of some species, were resistant to the same drug. Some isolates were resistant to two or even three of the antibiotics used, and the presence of ARG in the samples clearly showed a major public health concern for recreational users of these water bodies.

A case study from Taiwan (the Love River basin) by Ma et al. (2018) focused on the development of water and sediment quality management strategies for an urban river basin. In that study, the authors performed river water analyses, sediment quality investigation, and water quality modeling in order to determine the impacts of pollutant load on the Love River and develop a strategy to manage the river basin. The authors carried out a desk study as well as field tests, and with the help of the geoaccumulation index and enrichment factor evaluations, it was reported that high levels of heavy metals (Cu, Zn, Ni, Cr, and Pb)
posed a major threat to river water quality. The authors also used the Water Quality Analysis Simulation Program (WASP) model to carry out water quality modeling, and the results showed that sewage discharge from a sewage trench caused significant impairment to the quality of river water. Interesting results were also shown from a test bed demonstration site, where the authors built an on-site aerated gravel-packed contact bed (CB) along the river bank to treat 10% of the water flow from the river. The CB system was able to remove 52% of ammonia nitrogen (NH\textsubscript{3}-N) and 64% of biochemical oxygen demand (BOD) from the river. The authors recommended that the authorities construct a treatment system for preventing the entry of sewage into the river, and carry out sediment dredging and excavation in the affected areas of the river in order to preserve sediment and river water quality.

Another case study, by Tang et al. (2018), demonstrated at the Shedu River port (China), highlighted the importance of monitoring river water quality (physical, chemical, and biological parameters) as well as the construction of concrete river bank systems to promote natural microbe-mediated water purification effects. In river basins, as applied in many countries, to meet the safety requirements, hard concrete bank systems are usually constructed to ensure flood control, bank protection and waterway traffic. Besides these benefits, the construction of the hard concrete bank system also causes negative effects on the river ecosystem. In some instances, hard bank construction not only destroys aquatic and amphibian habitats, but also causes deterioration of the river’s ecological and natural landscapes. The authors evaluated the effectiveness of ecological restoration of hard bank rivers and promoted the use of porous concrete templates to cover the river hard bank works in the Shedu River and to enhance its ecological restoration effects. Experiments were performed in different seasons and microbial community variations, and the structure of biofilm on the surface of porous concrete templates was studied. The results from that study proved that porous concrete templates were able to provide a suitable natural habitat for the growth and reproduction of microbial, floral, and faunal species, where the highest microorganism abundance index of \(3.27 \times 10^7\) cell/cm\(^2\) was noted and the highest water purification capacity was achieved during the autumn season.

According to a consensus study report, the function of a water distribution system is to deliver drinking water to all customers, in sufficient quantity, and to provide water for fire protection purposes, at the appropriate pressure, with minimal loss of safe and acceptable quality, and as economically as possible. In engineering terms, a drinking water distribution system (DWDS) is a system designed and operated to meet the water demand of consumers by supplying water of desirable quality and quantity, at the right time of need. In many developing countries, as well as in some developed countries, DWDSs are operated in an intermittent manner. The operation of DWDSs relies upon conventional disinfection processes like chlorination to destroy microorganisms and to prevent water quality degradation during distribution. Mohan et al. (2018) reported the results of batch studies that were aimed at determining the response of chlorine in water induced by sewage intrusion and an uncontrolled microbial contamination situation. The authors also proposed a generalized kinetic relationship between chlorine and microbial contaminants and, according to the authors, the kinetic model can be used to investigate how the chlorine demand of water changes in DWDSs during real-world sewage intrusion events. It was observed that the chlorine response to uncontrolled contamination (sewage intrusion) can be classified into three reaction phases: rapid response phase (~ up to 5 min), slow response phase (between 5 and 15 min), and a very slow response phase (>15 min). Again, the authors also have stated that no single-order kinetic model can represent the reaction kinetics of chlorine during events of uncontrolled microbial contamination, such as sewage intrusion, and thus an empirical method is required for the estimation of kinetic parameters induced by a specific contaminant load under a given chlorine concentration. One recommendation to overcome this limitation is to incorporate wall-zone reactions (within the pipe) in order to understand the kinetics of chlorine disappearance in pipelines of real-world DWDS.

The application of membrane bioreactor (MBR) technology for the treatment of tapioca wastewater was tested by Truong et al. (2018). In industrial situations, an activated sludge process can be combined with membrane filtration as it produces high quality treated effluent without suspended solids (SS). The authors tested a novel aerobic granular sludge membrane bioreactor (AGMBR) for the treatment
of tapioca processing wastewater and its performance (COD and NH₄-N removal) was compared with that of a traditional MBR. The reactors were operated at a low organic loading rate (OLR) of 2.5 kg COD/m³, for 14 days. The authors ascertained the membrane fouling mechanism through filtration resistance analysis and scanning electron microscopy (SEM) images of the fouled membrane surfaces. The main fouling factor in the AGMBR was found to be pore blocking, which accounted for 50% of the total resistance, while cake blocking was the main fouling factor in the MBR. The authors recommended that, under optimal OLR, more vigorous stability tests as well as microbial community analysis should be conducted on the mature granules in order to understand the activity of the microbes and prolong the performance (i.e., longevity) of the AGMBR.

Three review articles in this special issue addressed the modeling aspects as well as the removal of pollutants (organic, nitrate, and selenium) from wastewater in different (bio)reactor configurations. Dutta et al. (2018) summarized the characteristics of anaerobic processes, with eventual emphasis on the upflow anaerobic sludge blanket (UASB) reactor and its performance under various operating conditions. According to the authors, modeling of any bioprocess will be very helpful to engineers and plant managers in making design decisions, and emphasized that specific consideration should be given to the anaerobic digestion model 1 (ADM1) due to its potential to be integrated with other activated sludge models (ASM). Thus, a single framework can be used to describe aerobic post-treatment of the effluent from the UASB. The authors presented adequate literature information regarding the treatment of different sources of wastewater in UASB, the effect of temperature, organic loading rate, mixing conditions, and pH on reactors’ performance and reviewed the application of dimensional as well as biokinetic models to UASB reactors. Furthermore, the authors also presented a real case study on the application of the modeling strategy to a semi pilot-scale upflow UASB reactor treating primary municipal sludge at Waterleau R&D centre, Wespelaar (Belgium).

Huno et al. (2018) reviewed available groundwater nitrate treatment technologies, the important process parameters and conditions used and their performances. The following aspects were addressed by the authors: biological processes of nitrate reduction in groundwater, effect of process conditions on groundwater denitrification, heterotrophic-autotrophic biofilm-electrode denitrification, membrane bioreactors, physico-chemical methods of nitrate reduction from groundwater, and in situ nitrate removal from groundwater using the pump and treat method. Finally, the authors also provided practical recommendations concerning the treatment of nitrate contaminated water: (i) post-treatment might be required due to the formation of secondary pollutants during nitrate treatment; and (ii) a thorough understanding of the groundwater flow regimes and contaminant transport properties are crucial for the successful application of permeable reactive barriers for nitrate remediation.

Stefaniak et al. (2018) presented an overview of the different physico-chemical and biological technologies used for the removal of selenium (Se) from contaminated water. The contamination of the environment by Se compounds can originate from various sources that include agricultural drainage water, mine drainage, residues from fossil fuel, thermoelectric power plants, oil refineries, and metal ores. In this review, the authors mentioned the advantages and limitations of technologies such as adsorption, biosorption, membrane separation, coagulation/floculation, biological oxidation-reduction, and phytoremediation. The application of microbial biocatalysts (fungi, bacteria, and yeast) as biosorbents were also surveyed. Furthermore, the authors also presented different challenges encountered during Se adsorption from water bodies containing different organic pollutants, competing ions, dissolved solids, and other metals/metalloids, and suggested future directions in Se removal technologies. In such situations, the authors recommended applying a hybrid or two-step process, in which the Se oxyanions can be selectively adsorbed onto the active sites of a sorbent material (e.g., first stage adsorption) and, subsequently, in the second stage (e.g., bioreactor), the remaining non-treated pollutants can be removed.

The goal of this special issue is to present the emerging technologies and trends in the field of water and wastewater treatment. The papers in this special issue provide clear proof that environmentally friendly (bio)technologies are becoming more and more important and playing a critical role in removing a wide variety of organic and inorganic pollutants from water. It is also believed that the papers will further the research on new best practices and directions in this emerging research topic.
This special issue required substantial devotion from the authors and the reviewers to meet the high scientific standards of quality maintained by the *Journal of Water Supply: Research and Technology—AQUA*. We would like to thank them for their efforts. Finally, we thank and appreciate the continuous support and invaluable guidance received from Ms Emma Gulseven, the Publishing Manager and her team at IWA Publishing in making this special issue possible.

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