Editorial: Sustainable eco-technologies for water and wastewater treatment

One of the major challenges in the world is to provide clean water and sanitation for all. With 3% fresh water reserves in the earth, there are more than 1 billion people who still lack access to clean drinking water. The declining water quality has not only reduced the life expectancy of humans, but it has also contributed to the deleterious negative impacts on aquatic/marine life, flora, fauna and the ecosystem. However, with rapid technological advancements and the availability of advanced scientific instruments, there has been substantial improvement in the design and operation of water and wastewater treatment systems. Recently, these sustainable eco-technologies have been designed and operated to offer the following advantages: (i) a smaller footprint, (ii) less maintenance, (iii) >99% removal of contaminants, (iv) provides the option for resource recovery, (v) less energy consumption, (vi) minimal use of chemicals, and (vii) less investment and operational costs.

Although these eco-technologies have proven to be reliable to treat water and wastewater containing a complex mixture of pollutants, the development and application of innovative hybrid processes and concepts are still needed in order to meet the stringent pollutant control regulations. Besides, due to changing lifestyles, such as the use of numerous health care products, cosmetics and pharmaceutical compounds, the challenges faced by the treatment systems have become increasingly complex. In the last decade, there has been a marked rise in the occurrence of emerging/persisting contaminants and antimicrobial resistant bacteria in the majority of drinking water sources. Due to the development of sophisticated detection techniques and analytical instruments, the detection and monitoring of very low concentrations of these compounds have been made possible by researchers. From the perspective of wastewater treatment, the conventional technologies such as activated sludge process, trickling filters, sequencing batch reactors, ponds and lagoons, among others, are not designed to remove these pollutants. In such cases, stand-alone technologies such as membrane filtration, ultrafiltration (UF), nano-filtration (NF), reverse osmosis (RO), ozone and catalytic oxidation, and membrane bioreactors (MBRs) could only partially remove some these emerging/persisting contaminants from water or wastewater. Thus, researchers have also focused on the development of hybrid eco-technologies that combine the operational advantages of advanced technologies or physico-chemical treatment systems and conventional biotechnologies (e.g. activated sludge process + a membrane filtration unit, or adsorption column + a biotrickling filter) in order to reduce the level of these pollutants to the desired regulatory standards.

This special issue on 'Sustainable eco-technologies for water and wastewater treatment' highlights the technologies used for the removal of pollutants such as dyes, uranium, cyanotoxins, faecal contamination and P/N compounds from water environments. Several case-studies from landfills, bioretention systems, membrane bioreactors and pumping stations are also covered in this special issue. Figure 1 shows a representative infographic of the different ecotechnologies used worldwide for water, wastewater treatment and resource recovery.

Numerous anthropogenic sources such as the metal finishing industry, electroplating processes, mining extraction operations, textile industries, and nuclear power plants, as well as natural sources such as soil erosion, urban runoff, aerosols, and particulates contribute to the deposition of metals or metallic elements in water bodies. The need for environmentally friendly biotechnologies for the removal of organic and inorganic water pollutants has been the focus of many published reports in recent years, with the focus on sustainably produced adsorbents for removal of water pollutants. In this regard, Baltrėnaitė *et al.* (2019) identified the characteristics of accumulated metallic elements ligneous biomass and related it to the adsorptive properties of the biochar derived from such modified biomasses. The authors of this paper investigated the forms and quantities of metallic elements present in the biomass and their transformation to biochar. The results from their study suggest that additional syngenetical present metallic elements increases the adsorptive properties of the resultant biomass-derived biochar. When compared with a reference biochar, i.e. commercially available biochar, the lignin biochar showed a higher amount of ash content and higher electrical conductivity values. The mean concentrations of metallic elements in lignin biochar were higher than in reference biochar: 4 times for Pb, 70 times for Cu, 10 times for Ni, 38

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Figure 1 | Representative ecotechnologies used for water, wastewater treatment and resource recovery. Most of these technologies use naturally available resources (e.g. micro-organisms or packing material or plant species) for treating the pollutant.

times for Cr, 1.7 times for Mn, 3.5 times for Zn and 3.8 times for Cd, respectively. In another study, Zeng *et al.* (2019) collected anaerobic granular sludge from a citric acid wastewater treatment plant and enriched the sludge under sulfate-reducing conditions. Thereafter, the authors used the biomass for the removal of high uranium concentrations (20 mg/L) from synthetic wastewater. The authors also identified the dominant microbial communities involved in removing uranium from wastewater. The Bacteroidetes phylum had the largest part in the composition, which accounted for 42.25% with 3,504 reads. The second most dominant phylum was Firmicutes (26.55%) followed by Proteobacteria (20.66%). Accordingly, the sulfate-reducing granular sludge exhibited high (>90%) removal efficiencies during four feeding operations, lasting for a total of 24 days from synthetically prepared 20 mg/L uranium acid mine drainage. The interesting results obtained from this study proved that the microbial community plays an important role in uranium recovery from contaminated sites, which is also beneficial for the control of uranium contamination.

Among the emerging pollutants reported in many water bodies worldwide, microcystins (MCs) are one of the common and highly potent hepatotoxins formed during algal blooms. Accidental exposure to MCs via skin contact, inhalation, or ingestion of toxin-contaminated water sources can lead to breathing problems, nausea, diarrhoea, skin irritation, and even acute liver damage at a high level of exposure. MCs

are difficult to physically detect in water due to their colourless, odourless, and tasteless characteristics. According to Ponnusamy *et al.* (2019), the complete removal of cyanotoxin could be a challenging process for conventional water treatment plants as there is a possibility of dissolved extracellular toxins passing through the treatment process. The authors ascertained the MC-LR removal efficiency at varying ozone dosages and initial toxin concentrations and tested the effectiveness of the MC-LR removal using a novel peroxone process. The experimental results showed that ozone and peroxone can be used to effectively remove MC-LR in drinking water; however, the oxidant dosages were governed by the initial toxin concentrations and the organic carbon content present in the water samples. The authors observed that higher total organic content values led to poor removal of MC-LR, presumably due to competition kinetics between the toxin and organic carbon during the oxidation process. From a practical viewpoint, the authors recommended that, as toxin concentration in real cases exists at extremely low concentration, an ozone dose of 0.75 mg/L would be sufficient to degrade MC-LR.

Nanotechnologies have prominent applications in the field of science and technology owing to their size-tuneable properties, providing a promising approach for the degradation of various pollutants. Nickel ferrites due to their relatively dry and more compact physical structure than ferric hydroxide considerably reduce sludge volume in ferrite formation. In a study by Vijay *et al.* (2019), nickel ferrite was used as the model heterogeneous photo-Fenton catalyst. The authors tested the effect of nickel ferrite nanoparticles on the degradation of Irgalite violet dye by Fenton's reaction using oxalic acid as an oxidizing agent in the presence of sunlight. The effect of pH and adsorbent dosage on the rate of dye degradation was evaluated and 99% dye degradation was achieved under the following conditions: catalyst dosage – 0.2 g, dye concentration – 400 mg/L, oxalic acid dose – 2.0 mM, pH – 3.0 and contact time - 60 min. In another similar study, Valappil *et al.* (2019) tested the photocatalytic potential of Co_3O_4 nanoparticles for the treatment of RB220 (dye) at different time, pH, dye concentration (mg/L), and nanoparticle concentration (mg/L). The authors determined the decolourization efficiency of Co_3O_4 nanoparticles and elucidated the mechanism and kinetics of RB220 decolourization. According to the results, a maximum dye concentration of 10 mg/L of RB220 was decolorized, at Co_3O_4 nanoparticle dose of 150 mg/L.

Apart from dyes and heavy metals, nonpoint source (NPS) pollution also leads to different water quality problems. NPSs of contamination may be attributed to urban and agricultural runoff, leakage from septic or sewer systems, and storm water runoff. Martinez *et al.* (2019) developed methods in which certain microorganisms were used to indirectly identify probable sources of anthropogenic faecal pollution in the Bayou Lafourche area, USA. This is known as microbial source tracking (MST). The overall goal of that study was to investigate the correlations between optical brighteners (OBs), faecal coliforms (FC), *E. coli*, and polymerase chain reaction (PCR) data in selected contaminated sites in Upper Bayou Lafourche and to determine if there was any correlation among these parameters to identify the source of faecal contamination. According to the authors, the OB readings, FC, *E. coli*, and *M. smithii* were found not to be good indicators of human faecal contamination. Therefore, the authors had recommended using the two anthropogenic sewage markers HB and HPyV in order to obtain reliable results from specific water contaminated locations. In another study related to water quality, Senevirathna *et al.* (2019) discussed the problems faced due to the primary and secondary water quality of eight water distribution networks in New South Wales (NSW), Australia. Based on the analysis of a large number of drinking water samples (more than 11,000), the authors identified that maintaining microbial water quality and the required free chlorine level (>0.2 mg/L) are challenging issues for regional water distribution networks. Another interesting observation from this study was the fact that water taps installed in public places are rarely used by the regional population and most of them failed to meet drinking water quality guidelines. The authors recommended basic modifications in design and operational procedures to solve regional drinking water systems.

In the same magnitude of environmental and health effects as that of persisting/emerging contaminants, pesticide and insecticide usage has become a necessary evil in developing countries. It has increased several-fold where agriculture is anticipated to be the backbone of the economy. During the past few decades, agrochemicals have been widely used in most agricultural sectors for enhancing crop yield and improving the quality of the product. Consequently, the extensive application of pesticides poses potential risks to the biodiversity of freshwater aquatic environments because of their bioaccumulation and intrinsic toxicity. The insecticide

imidacloprid is a chloronicotinyl nitroguanidine and due to its systemic nature, it is ranked as the second most widely used pesticide globally. Muazzam *et al.* (2019) evaluated the toxicity of combined exposures of endosulfan and imidacloprid on zebrafish in terms of oxidative stress and deoxyribonucleic acid (DNA) damage in liver and histological alterations in gills and muscles. Zebrafish were exposed to three different sublethal concentrations of endosulfan and imidacloprid along with control selected for each treatment for 21 days. The authors reported a substantial increase in DNA damage after 21 days' exposure to pesticides and significant morphological changes were observed in the gills of the fish.

The presence of high nitrate concentrations in drinking water results in health issues such as blue baby syndrome (methemoglobinemia), stomach cancer, high blood pressure, thyroiditis, cytogenetic malfunction, and several other defects in newborn babies. Conventional treatment processes include reverse osmosis, adsorption, ion exchange, chemical denitrification, photocatalytic reduction and electro-dialysis for the remediation of water containing excessive levels of nitrate. As a low-cost and eco-technology, phytoremediation can be considered as a versatile treatment technology for removing nutrients and trace contaminants from wastewater and surface water sources. As a proof-of-concept, Shyamala *et al.* (2019) demonstrated the application of ornamental plants for the treatment of nitrate containing water by performing laboratory-scale experiments using two ornamental plants: money plant and arrowhead plant. The authors reported that the individual (main) effect of the process variables, i.e. the initial nitrate concentration, growth period, plant density, was found to play a major role in affecting the nitrate removal process. Furthermore, it was reported that an increase in the growth period, i.e. the time, increased the rate of nitrate removal with k values of 0.22 d^{-1} for money plant and 0.35 d^{-1} for arrowhead plant, respectively.

In natural systems, the removal of ammonia nitrogen (NH_3-N) is mainly through adsorption or ion exchange in the soil and filler. Zhang *et al.* (2019) proposed a practical long-term treatment method for treating high nitrate river water in the Taihu basin (China): the traditional emergency method (e.g. water diversion) or short-term method (e.g. sediment dredging). The authors designed six enhanced submerged media, operating at four hydraulic retention times (HRTs) for the bioretention cells to treat the highly nitrogenous river water. According to the authors, the bioretention with activated carbon showed the highest removal of nitrate (93–96%) compared to surfactant-modified activated carbon (SMAC), surfactant-modified zeolite (SMZ), zeolite, fly ash and ceramsite. For long-term performance, the activated carbon, non-modified zeolite and SMZ showed high nitrate removal efficiency due to the formation and stabilization of the denitrification system. The authors recommended the most cost-efficient design as follows: 150 mm activated carbon +150 mm gravel operating under hydraulic loading of 4 L/h. In another bioretention study, Yang *et al.* (2019) determined the proper composition of filter media using locally available materials, which are suitable for the specific/local climate and environmental conditions in the Yangtze River delta region (China). The results of that study showed that the sand with discontinuous gradation contained a certain amount of clay, leading to unsatisfying hydraulic performance (hydraulic conductivity ranged from 423 to 1,054 mm/h, and 1,500 to 29 mm/h). On the contrary, the mixture of locally available sand, which consisted of continuous gradation of coarse sand (40–70%, by mass), fine sand (0–40%, by mass), very fine sand (10–60%, by mass) and nutrient soil (0–3%, by mass), had a hydraulic conductivity ranging from 200 to 400 mm/h and relatively stable structure. Furthermore, during the 70-day flooding test, the hydraulic conductivity changed within the first 20 days due to the migration of particles (mainly <0.6 mm) and thereafter the bioretention cell became stable. Thus, the authors recommended that easy availability and a simple production process make these materials more economic and easier to promote their utilization in the construction of sponge cities in China. In another novel bioretention study, Wang *et al.* (2019) operated a bioretention cell (BRC) and an enhanced system combined bioretention cell with microbial fuel cell (BRC-MFC) to treat domestic wastewater. The authors investigated the nitrogen removal characteristics and permeation characteristics of these two systems by adjusting the influent carbon/nitrogen ratio (C/N = 2.0–20.0). Based on the results, it was delineated that the nitrification and denitrification performances were mainly influenced by organic matter present in the wastewater and the system combination influenced/promoted better nitrogen removal.

The discharge of excess nutrients into the water bodies affects the self-purification ability of aquatic ecosystems, resulting in algal blooms. Eutrophication leads to the sharp

decline of dissolved oxygen in water and the deterioration of water quality which destroy freshwater ecosystems. Therefore, in order to solve the problem of poor P removal efficiency of traditional floating beds under low P concentration, Liu *et al.* (2019) proposed an efficient P removal composite (EPRC) as the growth substrate of the ecological floating island. The main components of the EPRC were fly ash and steel slag. According to the authors, the composite floating bed was able to significantly enhance the P removal efficiency of *Ipomoea aquatica* and promote its growth.

The overload of organic matter pollution in surface water leads to operational challenges during treatment in conventional drinking water treatment plants. These challenges include higher consumption of coagulants and higher disinfection by-product formation potential. There has been limited research on membrane bioreactors (MBR) in treating polluted surface water. Li *et al.* (2019) analyzed and compared the endogenous respiration process in an aerobic membrane bioreactor (aMBR) and UV/O_3-aMBR systems in treating polluted surface water by the respirometry method. The authors compared the microbial activities, including heterotrophic and autotrophic entry time of endogenous respiration, and ability under anti-decay conditions. The UV/O_3-aMBR system was able to make full use of the advanced oxidation process (AOP) and biological process, leading to a higher treatment performance, and has the potential to mitigate total energy demand. According to the authors, the study provided useful information for the understanding and practical application of aMBR and UV/O_3-aMBR processes in treating polluted surface water for drinking purposes in a more environmentally friendly way.

With the worldwide construction of reservoirs and inter-basin water transfer projects, an optimal joint operation of multi-reservoir systems has recently become a research hotspot. In this context, double-reservoir-and-double-pumping-station systems are commonly used for irrigation water supply in hilly regions. Gong *et al.* (2019) proposed an optimization model for a water supply system in order to minimize water shortage. The optimization models include two types of decision variables (water supplies and spills) that increase with the number of reservoirs; increased variables lead to the 'curse of dimensionality' in the solving process. The authors developed an optimization method based on the decomposition-aggregation theory for the joint operation of a double-reservoir-and-double-pumping station system that can provide optimal results following normal operation regulations. The authors integrated a joint operation rule of the system into the optimization model to obtain an appropriate operation scheme of both reservoirs and pumping stations.

Landfill leachate can be defined as an aqueous liquid generated as a consequence of the percolation of precipitation (rain, snow melt) and infiltration of groundwater through wastes, biochemical processes in waste's cells and the inherent water content of wastes themselves. Leachate is a complex wastewater comprising of a large number of different substances or compounds of mainly organic matter, ammoniacal nitrogen, heavy metals and other dissolved solids. In this special issue, two case studies focused on practical issues related to landfill sites.

In the first case study, Narayan *et al.* (2019) proposed a sequencing batch reactor (SBR) for the treatment of landfill leachate in the Lany municipality of Czech Republic. The authors also performed an economic assessment on the proposed design of SBR using cost benefit analysis (CBA) and evaluated the economic performance of the project by estimating cash flow, net present value and internal return rate. According to the authors, the net present value of the project was 19,526 €, with an internal return rate of 21.6%. Furthermore, an assessment of environmental, economic, and community impact on the existing practice (total score 55.1%) and on-site treatment (total score 59.6%) was comparable in that study. In the second case study, Anvarov *et al.* (2019) assessed different strategies for the remediation of groundwater contaminated with the leachate from an old, non-functional landfill located next to Hořkovec open cast mine, in the Czech Republic. The leachate consisted of mainly chlorinated aliphatic compounds and aromatic volatile compounds. The authors presented an analysis of the advantages, disadvantages and limitations of different remediation technologies. From a practical perspective and in view of their suitability for the treatment of the landfill leachate, a combination of different technologies was proposed by the authors. Additionally, the authors proposed financial assessment and an environmental impact assessment of the proposed treatment. Some recommendations from this study include: (i) consideration of the geology and geochemistry of the area while evaluating the suitability of different technologies, and (ii) to perform pilot tests before designing

the remediation treatment in order to characterise the pollutants present and the characteristics of the treated area.

Based on the topics covered in this special issue, it is evident that ecotechnologies are becoming more and more important and playing critical role in removing a wide variety of organic and inorganic pollutants from water. This special issue required substantial commitment 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. We thank and appreciate the continuous support and invaluable guidance received from Ms Emma Gulseven and her team at IWA Publishing in making this special issue possible.

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