❖ ENVIRONMENTAL SUSTAINABILITY AND CIRCULARITY FOR INDUSTRIAL BIO-BASED SYSTEMS

Impact of substrate adsorption behaviour for emerging pollutants in constructed wetlands

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Abstract
Emerging pollutants (EPs) have become a considerable concern for human health and all biota, thereby endangering the health and lives of the whole environmental system. For example, pharmaceutically active compounds, including over-the-counter medications, have more frequently been found throughout water bodies around the world. Moreover, a pandemic caused by the SARS-CoV-2 virus has entailed increasing the use of various chemicals and compounds, including Pharmaceuticals and Personal Care Products. Therefore, the risk of environmental damage has received extensive attention in recent years. This research aims to investigate, evaluate, and compare the role of two different substrates, sand and perlite, within the waste products removal process regarding the adsorption capability of EPs, including ibuprofen (IBU) and diclofenac (DCF) in constructed wetlands (CWs). The comparative results showed that perlite provides a superior condition for plant growth versus sand and indicates that the size difference of the plant shoots and roots length is 20% and 16%, respectively, in favor of perlite. In addition, the removal efficiencies of TOC, PO43-, and NH4+ have shown the best sorption results using perlite increased treatment process by 5%, 25%, and 42%, respectively, compared to sand. Furthermore, the influence of perlite also contributed to higher IBU and DCF removal efficiency. It was 88.57% and 63.48% for perlite, which is higher than the adsorption ability of sand by 23 and 27%, respectively. Besides, the perlite significantly boosts the contents of IBU in the rhizosphere soil and raises the presence of DCF in plant roots. Moreover, the contents of IBU and DCF metabolites (2-OH IBU and 4вЂІ-OH DCF) in the plant roots were also higher. It can be concluded that perlite may be contributing to the high removal efficiency of emerging pollutants, including pharmaceuticals. Thus, the characteristics of this substrate are promising due to its effectiveness in emerging pollutants removal. This paper considers the components, pathways, and impact of pollutants on the ecosystem. The presumed mutual influence and co-dependency of the elements of nature can shed new light on the existing problem and may contribute to solving it. Introduction Emerging pollutants have attracted increasing concern due to dramatic growth in population and rapid industrialization in the 20th century worldwide. Large-scale production and use of EPs as goods, services, personal care products, pharmaceuticals, and further discharge of their processed products into the environment are some of the crucial causes of ecosystem disturbance in the 21century. Moreover, water and air pollutions create a high load on the human immune system. Consequently, they have an extremely negative effect on all body such as increased morbidity and mortality and different kinds of allergies (Manisalidis et al., 2020). Sources of EPs are agricultural, urban, and rural areas. The emerging contaminants, including personal care products, are known as (PPCPs), Non-steroidal anti-inflammatory drugs (NSAIDs), hormones, pesticides, plasticizers, industrial and household products, metals, food additives, solvents, flame retardants, and other organic compounds in the water generated mainly by human activities (WWW.UNESCO.ORG, 2019). For instance, PPCPs such as detergent for the washing machine may anticipate ensuring daily human life in terms of comfort: time saver and alleviate manual labor. While on the other hand, their usage has environmental harming by polluting and dwindling supply of resources and destructively altering the climate condition. Another significant negative contribution is that washing machines require high energy consumption from fossil fuels. Fossil fuels are burning for energy production, at the same time producing carbon dioxide and greenhouse gases. After the penetration into the air, they aggravate the global warming crisis. Furthermore, beyond the existing issues, the onset of the COVID-19 pandemic enhanced PPCPs production and medical consumables and caused an extremely high discharge of waste in the ecosystem. Hence, the consequences for the environment by releasing the debris, including non-biodegradable plastic syringes, pose additional challenges for ecologists. Wastewater treatment plants (WWTPs) focus on removing contaminants from wastewater and, by effluent,

discharge it into the water cycle. However, Corada-FernГЎndez et al. (2017) have noted that most WWTPs were not designed to eliminate PPCPs, including NSAIDs. Therefore, in the world, especially in big cities, the overflow of the sewage system causes a significant content of EPs in the groundwater and surface water. So, the occurrence of EPs in the environment their detection in different combinations is constantly reported and accounted for worldwide. Once released into the environment, the degradation process begins. Unfortunately, the behaviour of many EPs is still insufficiently understood. Therefore, it can be out of control and cause or aggravate undesirable consequences (Llamas et al., 2020). Therefore, CWs have been identified as a sustainable wastewater management solution worldwide. The components of CWs included: substrates, emergent/submerged vegetation, and water. The substrate plays a pivotal role in the adsorption within the pollutantвЂ™s removal process. But even here, there are still many unexplored gaps because of a lack of familiarity and experience with this methodology and availability (Nelson et al., 2007). Large-scale production and consumption create a heavy load on conventional WWTPs, which are not designed for many pollutants, including medicals that appear in large amounts in the water. Additionally, the COVID-19 pandemic raised the release of a considerable amount of medicine in the sewage system. Thus, an urgent need arose to use CWs in terms of efficiency, economy, and ecologically friendly application. As noted above, NSAIDs' removal method in CWs, including IBU and DCF and sorption efficiency of given absorbent, are still not thoroughly studied. Their further fate is still not well understood. Therefore, the primary purpose of this research was: -To investigate and compare the adsorption behaviour of the chosen substrate: sand, and perlite for selected EPs in VSSF CWs. -To analyze and estimate their role and purification ability in CWs for removing EPs, including pharmaceuticals IBU and DCF. The research may provide data and knowledge about the purification process. In addition, the obtained data can be helpful in improving methods of elimination of EPs in CWs and mitigating their impact on aquatic and human life. Conclusively, the study can shed light on issues related to the impact of EPs on the ecosystem to contribute to future research. Initially had planned to study both the adsorption and desorption capacity of sand and perlite. Unfortunately, due to the unpredictable situation of the COVID-19 epidemic in the Czech Republic, the desorption capacity of given substrates couldnвЂ™t be achieved. Conclusion The five months of study have demonstrated by our results that the type of substrates may play a significant role and have a considerable influence on the biomass of plants. The analysis, which used small-scale experimental VFCWs, illustrates different results for each compound. The experiment has shown that perlite as an adsorptive substrate plays a critical function in CWs. Due to its porous structure, perlite contributed to the faster growth of wetland plants. It promoted the development of all plant tissue, thereby enhancing the surface area for the absorption of metabolites, which was beneficial by the plant nutrient uptake process. The given outcome has agreement with Stottmeister et al. (2003) that soil has a crucial aspect of the interaction taking place in the rhizosphere, such as interconnection and synergistic effect between rhizomes and the soil matrix. However, the overall picture is not yet clear enough since there are still multiple gaps in the study of the toxicology of pharmaceuticals, their transformation products, and their interaction with other inorganic contaminants in the environment. Furthermore, the shortcoming of our experiment was that it was carried out in a given climatic region limited by the climatic conditions of the current season, in particular temperature, lighting, and humidity. Moreover, the measurement error should be taken into account since perlite is only one of the chain elements in the removal process. Additionally, microbial interaction was not evaluated, and the synergistic/antagonistic effect of all participants involved in a given remediation process was also not considered. Thus, the study conducted above assists in getting an expanded practical knowledge concerning the aspect involved in the adsorption mechanism. It can be summarized that substrate plays a crucial role in the removal process. Our study has demonstrated that perlite coped better with issues and obstacles than the sandy filter. Therefore, it has the potential to expand its usage in the adsorption process. Unfortunately, perlite is a non-renewable resource since it naturally occurs. Nevertheless, due to its low cost and reuse ability, perlite is the most promising filter material for removing given emerging pollutants, including pharmaceuticals.

Keywords: Emerging pollutants, Pharmaceutical and personal care products, Constructed wetlands, Adsorption, Substrates.