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Editorial

Wastewater Treatment by Adsorption and/or Ion-Exchange Processes for Resource Recovery

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Nowadays, resource recovery is a trending topic following the circular economy schemes proposed by the European Union. The main idea is to recover as much as resources from wastewater or other residues, realizing the "waste to product" concept. In this sense, adsorption and ion-exchange processes are environmental, eco-friendly and non-expensive technologies that can achieve this aim. For that reason, this Special Issue is centered on wastewater treatment by adsorption and/or ion-exchange processes for resource recovery.

Six full research articles are published in this Special Issue. Although the authors are mostly Spanish and mainly from the Chemical Engineering Department of Universitat Politècnica de Catalunya, the published articles covered the removal and recovery of several compounds/minerals from water and wastewater, with worldwide interest. Specifically, the removal/recovery of organic dyes, phosphates, heavy metals, biosurfactants, Pb(II) or lactic acid has been studied using different sorbents or resins, including commercials and natural ones.

For instance, an international research group formed by researchers from different Chemical Departments of Pakistan, Malaysia, Saudi Arabia, Poland and Greece studied a hybrid biosorbent process for heavy-metal-polluted water, followed by a nanofiltration step. Indeed, the main objective of the work was the removal of Pb(II) from wastewater. In this case, a maximum biosorption capacity of 365.9 mg/g was achieved, following the Langmuir isotherm model. Moreover, different desorption agents were studied, acetic acid being the optimal one for hybrid biosorbent regeneration. Finally, a nanofiltration step was used to increase the remediation effectiveness, even when treating wastewater with high Pb(II) concentrations. All in all, authors concluded that the integration of the hybrid biosorbent and nanofiltration techniques resulted in a low-cost and attractive process for the removal of Pb(II) from wastewater [1].

This Special Issue also contains another work related to bioconcepts. In this case, two research groups from two Chemical Departments from Spanish universities collaborate with CETaqua, a Spanish Water Technology Center, to recover biosurfactants from an agro-food stream through a novel and sustainable method. Thus, calcium-alginate-based polymers were evaluated for use in the recovery of biosurfactant in corn steep water. The results showed that, although biosurfactants from corn steep water have other competing compounds (such as inorganic solutes and biomolecules), calcium-alginate-based biopolymers had an adsorption capacity around 50 mg/g, recovering around 50% of the biosurfactants. Then, the authors concluded that it would be possible to formulate green membranes based on calcium-alginate-based polymers for a sustainable recovery of biosurfactants from aqueous streams [2].

Regarding organic compounds, some of the previous Spanish authors published another article of this Special Issue, reporting the recovery of lactic acid by commercial ion-exchange resins. This topic could be of interest in the bio-refinery field and different industrial sectors, such as the cosmetic, food or pharmaceutical industries. The study was focused on the determination of the optimal operational parameters for the adsorption (e.g., pH, solid/liquid ratio, contact time) and desorption (e.g., regenerant agent, contact time, solid/liquid ratio) steps. For that, a Box–Behnken factorial design and the response surface methodology were used, as well as isotherm and kinetic models. The authors concluded that the best option was to use the A100 resin for the adsorption/desorption process, using the feed water at pH 4, with a solid/liquid ratio of 0.15 g/mL for 1 h (adsorption step) and using NaOH 0.1 M for 30 min, with a solid/liquid ratio of 0.15 mg/mL (desorption step). All in all, the Langmuir isotherm and pseudo-second-order kinetic model fit the results, which were able to recover 85% of the lactic acid, achieving a desorption capacity of around 4.5 mg/g [3].

Moreover, Spanish researchers from the Universitat Politècnica de Catalunya and the Technological Center Eurecat published two articles in this Special Issue [4,5]. The first manuscript [4] was focused on the reduction of granular ferric hydroxide (GFH) to improve phosphate adsorption kinetics. In that case, two methods were used: ball milling and ultra-sonication. With the first one, it was possible to reduce the GFH from 0.5–2 mm to 0.1–2 µm and achieve a total disaggregation of its structure, whereas the ultra-sonication system allowed only a partial disaggregation and a final size of 2–50 µm. Experimental isotherm data were fitted properly to the Langmuir model, while kinetic tests were correlated with the pseudo-second-order model. Finally, it was concluded that the application of both methods for GFH reduction increased the kinetic constant in contrast with the virgin GFH, thus enhancing the phosphate adsorption rate. On the other hand, the aim of the second manuscript [5] was the removal of heavy metals (mainly Zn and Cu) from contaminated wastewater by hydroxyapatite (HAP)-based particles. In that case, HAP was synthetized by a cost-efficient route: the combination of natural solid calcite and a phosphate solution. Kinetic and isotherm experiments were carried out by the synthetized HAP, and the sonication effect was compared. The results showed that the synthetized HAP with calcite particles has a high Zn and Cu removal capacity (34.97 mg/g for Zn and 60.24 mg/g for Cu). In addition, sonication tests demonstrated that Zn removal was enhanced but Cu removal was not.

Finally, one more article was published by researchers from Pakistan, Slovakia and Iran focused on wastewater treatment by the adsorption of malachite green dye onto mesoporous natural inorganic clays (NICs) [6]. Several operational parameters of the batch adsorption process were studied, such as dye concentration, contact time, the amount of NICs or the solution pH. Equilibrium isotherms and kinetic studies fit properly to the Langmuir and pseudo-first-order kinetic models, respectively. Moreover, the authors concluded that NICs with high surface areas and high aqueous solution pH were favorable for the adsorption process, indicating that NICs can be effective adsorbents for the removal of dye from aqueous solutions.

As a summary of this Special Issue, it can be concluded that sustainable, green, low-cost, attractive and efficient adsorption and ion-exchange processes can be used for resource recovery from wastewater.

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References

1. Hanif, A.; Ali, S.; Hanif, M.A.; Rashid, U.; Bhatti, H.N.; Asghar, M.; Alsalme, A.; Giannakoudakis, D.A. A Novel Combined Treatment Process of Hybrid Biosorbent–Nanofiltration for Effective Pb(Ii) Removal from Wastewater. *Water* **2021**, *13*, 3316. [CrossRef]
2. Martínez-Arcos, A.; Reig, M.; Cruz, J.M.; Cortina, J.L.; Moldes, A.B.; Vecino, X. Evaluation of Calcium Alginate-Based Biopolymers as Potential Component of Membranes for Recovering Biosurfactants from Corn Steep Water. *Water* **2021**, *13*, 2396. [CrossRef]

3. Vecino, X.; Reig, M.; Valderrama, C.; Cortina, J.L. Ion-Exchange Technology for Lactic Acid Recovery in Downstream Processing: Equilibrium and Kinetic Parameters. *Water* **2021**, *13*, 1572. [CrossRef]
4. Martí, V.; Jubany, I.; Ribas, D.; Benito, J.A.; Ferrer, B. Improvement of Phosphate Adsorption Kinetics onto Ferric Hydroxide by Size Reduction. *Water* **2021**, *13*, 1558. [CrossRef]
5. Gibert, O.; Valderrama, C.; Martínez, M.M.; Darbra, R.M.; Moncunill, J.O.; Martí, V. Hydroxyapatite Coatings on Calcite Powder for the Removal of Heavy Metals from Contaminated Water. *Water* **2021**, *13*, 1493. [CrossRef]
6. Ullah, S.; Rahman, A.U.; Ullah, F.; Rashid, A.; Arshad, T.; Viglašová, E.; Galamboš, M.; Mahmoodi, N.M.; Ullah, H. Adsorption of Malachite Green Dye onto Mesoporous Natural Inorganic Clays: Their Equilibrium Isotherm and Kinetics Studies. *Water* **2021**, *13*, 965. [CrossRef]