EGU2020-493, updated on 30 Jun 2021
https://doi.org/10.5194/egusphere-egu2020-493
EGU General Assembly 2020

Lignin microspheres as a nature-based material for effective nickel(II) and cadmium(II) ions removal

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Sustainable development and the circular economy are becoming the new imperative of industrial growth, as the world faces the depletion of natural resources and consequences of climate change. The utilization of waste streams through the concept of 'new added value' gives life to the production of materials and their environmental application. Therefore, the development of novel, eco-friendly, nature-based adsorbents that possess high degradable and recyclable potential is on the forefront of research. The modifications of wood derivates, such as cellulose and lignin, are widely applied as natural polymers due to their economic feasibility, ecological similarity and adsorption capabilities.

The subject of this study is the adsorption of nickel(II) and cadmium(II) ions from aqueous solutions using 5.0 mass % of alginate lignin microspheres (A-LMS). Due to their toxicity, persistence, high solubility and mobility, such heavy metals are widely dispersed throughout environmental media (chiefly, aquatic bodies), leading to ecological and public health problems. The raw lignin used as a source material in the study originates from the waste stream of the lumber industry. The porous microspheres are of a radius of 50 to 950 microns and a surface area of 36.9 m^2 g^{-1} were synthesized via inverse suspension copolymerization of the kraft lignin with a poly(ethylene imine) grafting-agent and an epichlorohydrin cross-linker. The structural and surface characteristics were confirmed via Fourier transform-infrared (FTIR) spectroscopy, x-ray diffraction (XRD) and scanning electron microscopy (SEM). The textural properties of the synthesized A-LMS were determined according to the Brunauer, Emmett and Teller (BET) method of analyzing nitrogen adsorption. The adsorption batch and column testing were carried out by varying the reaction time, temperature, adsorbent mass, at predefined pH values of the initial solutions. The maximum adsorption capacity of the A-LMS for nickel (II) ions was 89.286 mg g^{-1} at a temperature of 318 K, while for the adsorption of cadmium(II) ions it was 96.154 mg g^{-1} at a temperature of 308 K. The kinetic data followed the pseudo-second-order kinetic model, while the Weber-Morris model indicated intra-particle diffusion as a rate limiting step. The thermodynamic parameters for the A-LMS further confirm that the adsorption process was spontaneous and endothermic.

The study indicates the high potential of by-products or waste products from heavy industry to be repurposed for environmental engineering applications by which they may serve a benefit as

opposed to being a detrimental risk. Such is the case here with lignin-natural polymers taken from the lumber industry, which themselves may be reutilized for the removal of heavy metals from wastewater.

Acknowledgments

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (project no. 172007). The authors would like to acknowledge the financial support provided by COST-European Cooperation in Science and Technology, to the Cost Action CA17133: Circular City.