Functional nanostructured materials for stormwater runoff treatment

Numerous heavy metal removal practices for stormwater runoff have been studied and applied; however, there is still room for improvement. Among these practices, adsorption has proven to be the most efficient way of removing heavy metals. Commonly used adsorbents have an innate sorption capacity in relation to high concentrations of heavy metal ions, but if they are to be used for stormwater runoff, high affinity with rapid sorption kinetics for low concentrations of heavy metals is necessary. Therefore, in this study, new types of functional nanostructured polymer sorbents for effective heavy metal removal from stormwater are suggested.

First, comparison studies of several existing polymer sorbents were conducted, to find decisive functional groups for removing heavy metals from the solution. To enhance the sorption kinetics and affinity of polymer sorbents in the presence of competing ions, sulphur functional groups and polar functional groups in the polymer networks were found to be imperative. Based on this result, new types of covalently connected polymer sorbents were devised and characterised. One of the novel polymer sorbents, disulphide-linked polymer (COP-63), was selected for perusing heavy metal sorption behaviour. Although COP-63 has a moderate surface area, it demonstrated cadmium removal efficiency equivalent to highly porous activated carbon (AC), while it also exhibited 16 times faster sorption kinetics compared to AC, owing to high affinity towards disulphide and thiol functionality. The chemisorption mechanism of sorbents was confirmed by sorption kinetics, the effects of pH and metal complexation. The metal ions copper, cadmium and zinc showed high binding affinity towards the polymer sorbent, even in the presence of competing cations in the form of calcium.

To retrofit polymer sorbents for a real stormwater filter, controlling the size of sorbents by formulating composites was applied. The first composites were obtained by grafting polymer onto granular-AC through acyl chlorination (DiS-AC), and the formulation of composites was confirmed by various characterisation techniques. DiS-AC demonstrated 89 L/g sorption affinity for cadmium, which is notably higher than conventional sorbents’ sorption affinity. Furthermore, within an hour, half of the trace amounts of cadmium ions were removed by the DiS-AC, even in a batch test. Other composites were obtained by embedding the polymer particles on the surface of an alginate bead (DiS-algi). Moreover, the sorption capacity of DiS-algi was 22.3 mg/g, and within 6 minutes, half of the cadmium had been removed with 31 L/mg of Langmuir sorption affinity, outperforming an AC filter. Moreover, DiS-algi was used to build the reactive filtration column for simulating a real stormwater treatment filter. A breakthrough test of the reactive column showed the complete uptake of cadmium from a contaminated flow, lasting two hours until reaching the breakthrough point. The maximum sorption capacity of the reactive column was 877 µg/g. Furthermore, regeneration tests of the column verified its reusability.

Based on the results of this PhD, novel polymer and composites sorbents are proposed for distinct uses. The devised functional nanostructured polymers confirmed their potential for efficient heavy metal removal, and the simulation of a real-life stormwater filter was successful. Therefore, the novel polymer sorbents herein proved to be viable materials for stormwater runoff filtration systems.

General information
State: Published
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Number of pages: 48
Publication date: 2017

Publication information
Place of publication: Kgs. Lyngby
Publisher: Department of Environmental Engineering, Technical University of Denmark (DTU)
Original language: English
Electronic versions:
WWW-version. Embargo ended: 02/03/2018
Research output: Research › Ph.D. thesis – Annual report year: 2018