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Hellenic Foundation for Research & Innovation

Description of the funded research project

2nd Call for H.F.R.I. Research Projects to Support Post-Doctoral Researchers

Title of the research project: Advanced nanocomposite adsorbents for the removal of high-valent pollutants from water

Principal Investigator: Konstantinos Simeonidis

Reader-friendly title: MagnoSorb

Scientific Area: Engineering Sciences & Technology

Institution and Country: Aristotle University of Thessaloniki, Greece

Host Institution: Department of Chemical Engineering

Collaborating Institution(s): Universitat Pompeu Fabra, Barcelona

Project webpage: www.magnosorb.eu

Budget: 197000 €

Duration: 36 months

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Research Project Synopsis

The project aims in the development of a novel class of drinking water adsorbents oriented to the removal of high-valent inorganic pollutants such as Cr, Mo and Se, and based on cost-affordable magnetic core-shell nanoparticles. On this purpose, a combination of parallel tasks shall focus on the synthesis and evaluation of engineered nanoparticles consisting of magnetic iron oxide seeds covered by a thin layer of tin oxy-hydroxide, while the implementation of nanoparticles in a continuous-flow pilot unit operating under real conditions of water treatment is another priority. The required core-shell architecture will be realized by a three-step chemical process which includes sequentially the precipitation of magnetic seed, the formation of the tin oxy-hydroxide coating and its surface activation by ion-exchange with electrolytes. Replacement of the tin phase by iron oxide is expected to result in a significant cost reduction compared to the best known tin-based adsorbents. Validation of the morphology, the physico-chemical and surface properties will be performed by advanced characterization techniques in order to understand the critical parameters for synthesis optimization. In parallel, the evaluation of uptake efficiency for high-valent pollutants, emphasizing in the case of hexavalent chromium, will signify the application potential of the product. The qualified nanoparticles will be used to design and operate a pilot unit for the treatment of polluted water in a contact reactor and the recovery of nanoparticles by a magnetic separator. The study considers also the health and environmental effects of the introduced technology while a plan for the regeneration of nanoparticles combined with the recovery of the heavy metal as a useful compound will be attempted as a way to contribute in a zero-waste methodology.

Project originality

MagnoSorb attempts to deliver a competitive solution for the serious problem of drinking water pollution with high-valent heavy metals such as chromium, selenium and molybdenum, by introducing a methodology that combines modern knowledge on nanotechnology, magnetism and water treatment adapted to the principles of circular economy and sustainability. Particularly, the objective of MagnoSorb is the development of a novel class of adsorbents engineered in the nanoscale but realized in kilogram-scale production rates. The building units will comprise of spherical core-shell nanoparticles with a magnetically-responding phase in the inner part covered by a thin layer of the adsorption-active phase, a surface-modified tin oxy-hydroxide. Such nanocomposite will be prepared by the translation of nanoscale synthesis methods for nanoparticles into sequential continuous-flow reaction processes. An integrated frame of advanced characterization techniques will be employed to validate the properties of the nanocomposite, reveal the occurring mechanisms during water treatment and resolve critical points of efficiency by providing feedback to the preparation setup. Importantly, research will also focus on the complete recovery, the recycling, the safe handling, the toxicity and the expected fate of engineered nanoparticles in the environment. As proof of concept for the competitiveness of the developed technology, the obtained knowledge will be integrated into the construction of a continuous-flow laboratory unit that will treat polluted water sources.

Expected results & Research Project Impact

MagnoSorb is expected to bring a major breakthrough in water treatment technology and the engineering of nanomaterials. It is clear that Cr(VI) problem in drinking water is already a major concern for customers and authorities around the world while interest about high-valent pollutants is going to become more intense in the near future when more measurements and epidemiological data will be announced. Under public pressure, the continuous discussions in the frame of international organizations are expected to end in the determination of much lower regulation limits. However, the limited number of simple, cost-effective and efficient technology solutions for Cr(VI) removal is the major inhibiting point for setting more strict legislation. Accordingly, there is a favorable opportunity for the introduction of novel methodologies specified in high-valent heavy metals which not only succeed improvement in the efficiency of existing adsorbents but also open new directions for affordable costs and novel applications practices.

The potential interest for MagnoSorb overcomes the scientific field covering the sustainable growth of modern societies. Water treatment oriented to drinking purposes aims to the safe distribution of the most essential nutrient for human health. However, any step added in the commonly applied procedure of filtration and disinfection has severe impact in the consumer's price, reflecting the cost for required consumables and energy. The adoption of strategies similar to those introduced by MagnoSorb supports lower operational cost and the infinite re-use of an adsorbent for drinking water treatment, thus, eliminating expenses for consumables. Other important benefits emerge from the minimization of potentially toxic wastes and the effort needed for their inertization, the confinement in the consumption of natural resources and the use of green chemistry practices. The development of such an applied research program with cost optimization features that will reach a TRL 4 level, will actuate the commercial exploitation of the findings and the pilot unit.

The importance of this funding

The funding provided by HFRI will offer significant benefits to the PI, the members of the research group and the host organization. Since the study deals with a novel scheme for the removal of Cr(VI) and high-valent pollutants from water, a prevalent and challenging problem for scientists and engineers, the PI and the members of the group are expected to expand their knowledge in the field and contribute in the fabrication of a novel nanoadsorbent for competitive drinking water treatment. However, independently to the fulfilment of the scientific objectives, the long-term goal of this work will be the establishment of a highly experienced working group able to develop and handle research projects with an improved level of scientific impact but also a high degree of novelty for commercial exploitation.

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