Numerical investigation of magnetic nanoparticles clearance from drinking water using a rotating magneto-mechanical device

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The migration process of magnetic nanoparticles and colloids in solution under the influence of magnetic field gradients, which is also known as magnetophoresis, is an essential step in the separation technology used in various biomedical and engineering applications. In addition, several environmental applications of magnetic nanoparticles (MNPs) have already been translated from bench to bedside like wastewater treatments and pollutant removal [1]. In some of these applications, magnetic nanoparticles are added in water circulation in order to purify it from toxic substances such as hexavalent chromium [2]. Although they are destined to be cleared from water with flow processes, some nanoparticles may remain in water, until they are removed by extracorporeal magnetic fields. The present work aims at studying computationally the clearance of magnetic nanoparticles from water circulation under the influence of an external magnetic field by further development of a rotating turntable able to host rectangular NdFeB permanent magnets that are positioned in a Halbach array configuration. This versatile device produces tunable modes of rotating magnetic fields with respect to their amplitude, frequency and spatial gradients. The resulting magnetic fields are numerically quantified with COMSOL Multiphysics along with the estimation of magnetic field gradients and produced mechanical forces that act on aqueous dispersion of iron oxide nanoparticles. The partial differential equations that describe nanoparticles motion under the magnetophoretic forces are formed for the above magnetic field design. Then, they are numerically solved using finite elements method through the platform of COMSOL Multiphysics to predict the trajectories in water that is represented by a sample computational space. Moreover, the simulation estimates the percentage of captured nanoparticles, i.e., those reaching the surface of the NdFeB permanent magnets. This strategy provides a holistic view of the magnetic separator design and simulation leading to the optimization of nanoparticles transport and capture mechanisms in drinking water, which could be particularly useful in the design of larger scale magnetic separators for engineering applications.

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[1] M. Tzirini et al. Environ. Adv. 2, (2020) 100013.
[2] K. Simeonidis, Sci. Tot. Environ. 535, (2015) 61.