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Removal of TiO_2 nanoparticles by porous media: Effect of filtration media and water chemistry

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HIGHLIGHTS

- Nano-TiO_2 retention in saturated granular beds depends strongly on the filtration media.
- Sand and activated carbon provided little retention for TiO_2 nanoparticles.
- Diatomaceous earth provided superior nanoparticle capture capacity.
- Solution contaminants greatly influenced nanoparticle retention in all media.

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ABSTRACT

The use of nanoparticles in manufacturing as well as in commercial products continues to rise despite concerns over the environmental release and potentially negative ecological and health effects. Some aqueous waste streams carry a large fraction of released nanoparticles and thus should be targeted for treatment. Conventional porous media filtration has focused on sand as the bed material with discouraging results. This study investigated the effectiveness of three different bed materials, namely, sand, activated carbon, and diatomaceous earth, on the removal of nano-TiO_2 from aqueous streams. Additionally, the impact of solution chemistry (a commercial dispersant and the two organic compounds lysozyme and glycine) on nanoparticle retention by the various bed materials was evaluated. Diatomaceous earth displayed great promise in nanoparticle capture, providing full retention of a 50 mg TiO_2 L^{-1} stream for the 30 bed volumes tested as compared to zero and only 20% TiO_2 capture for sand and activated carbon, respectively. Batch isotherms showed that diatomaceous earth, with specific loading capacities exceeding 25 mg TiO_2 g_{medium}^{-1}, has a high affinity for nano-TiO_2. This loading capacity is 20- and 1000-fold higher compared to activated carbon and sand, respectively. The solution contaminants investigated had varying effects on nano-TiO_2 retention depending on the bed material, indicating the need for investigation of co-contaminants and their role on nanoparticle filtration. This study demonstrates the superiority of diatomaceous earth as a filtration material compared to conventional sand and indicates its suitability as a new material for the removal of nanoparticles in porous media filtration.

1. Introduction

Nanoparticles (NPs) form the basis for development of new nano-enabled technology, which is expected to be worth approximately $1 trillion annually by 2015 [1]. Metal oxide NPs, such as nano-titanium dioxide (n-TiO_2), are of particular interest due to their use in varied commercial products, from sunscreens and cosmetics to abrasives in slurries used for semiconductor manufacturing [2]. A recent study puts the upper bounds of yearly n-TiO_2 production at approximately 2.5 million metric tons by 2025 [3]. Evaluating the health and environmental risks of these emerging contaminants is an active area of research [4]. Effects on human health are of great concern with n-TiO_2 being shown to display neuro-toxicity toward dorsal root ganglion cells, even with commonly applied inorganic coatings [5] and to bring about apoptosis and necrotic death in human umbilical vein endothelial cells [6]. Ecotoxicity is also concerning as n-TiO_2 has been found to be damaging toward both *Bacillus subtilis* and *Escherichia coli*, possibly due to production of reactive oxygen species [7]. The numerous exposure pathways and potential toxicity leads to concerns about the release of these nanomaterials into the environment [8,9].

Wastewater streams have been specifically found to be potential point sources of NP release [10]. A recent modeling of environmental concentrations of n-TiO_2 produced an estimate of over 1500 Tons of n-TiO_2 per year entering sewage treatment plants in the United States, with the majority of release being divided between the soil (~48%) and surface water (~24%) [11]. While no

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