



Non-equilibrium zinc uptake onto compost particles from synthetic stormwater

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HIGHLIGHTS

- ▶ Zinc uptake from synthetic stormwater on various compost particle sizes was studied.
- ▶ Uptake on smaller particles conformed to equilibrium assumptions.
- ▶ Intra-particle diffusion caused rate limited metal uptake on larger particles.
- ▶ Non-equilibrium modelling adequately modelled larger particles.
- ▶ Design of bioretention systems should consider filtration media particle size.

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ABSTRACT

Zinc uptake onto different particle size compost was evaluated in batch and column studies using a synthetic stormwater to quantify sorption capacity and kinetics. The results showed that the pseudo equilibrium time for uptake increased from 2 h to greater than 120 h as the particle size of compost increased from 75 μm to 6.75 mm. This was due to intra-particle diffusion becoming a rate limiting process as the particle size increased. Column effluent data with 1.18 mm particles could be fitted by Freundlich isotherm while that from the 4.75 mm particles and a mixed particle size columns showed rate limited sorption with tailing and could not be adequately fitted using an equilibrium based isotherm. The results have established rate-limited sorption in amended filtration media due to larger particles under these flow conditions. This needs to be accounted for in the design of these filtration media and during performance modelling.

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1. Introduction

Traditionally, stormwater infiltration systems have been designed around being hydraulically effective and have used relatively inert media such as coarse sand/fine aggregate as a filtration media. Stormwater treatment within subsurface filtration media has occurred primarily through a physical process of filtering out contaminants. Whilst these inert media have proven to be effective in removing particulate-bound stormwater contaminants they have not been as effective removing dissolved metal constituents. Enhanced performance for dissolved metal removal can be achieved by incorporating reactive materials (amendments) such as agriculture waste (Sciban et al., 2007; Sud et al., 2008) which can provide removal through physical filtration as well as sorption and precipitation.

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Sorption is a general term to describe overall processes resulting in the transfer of dissolved solutes to solids. The prediction of dissolved metal sorption in filtration systems often relies on the assumption of local equilibrium between stormwater solutes and filtration media. Linear and non-linear isotherms are then used to quantify metal uptake. Factors such as flow, particle size and sorbent composition can affect the interaction between the solute and sorbent and may shift sorption from equilibrium to a non-equilibrium state. When non-equilibrium occurs, the breakthrough curve shows a diffuse front and tailing phenomena which results in rate-limited sorption. The mechanistic basis of these non-equilibrium phenomena may be physical and/or chemical. Physical non-equilibrium may occur due to two widely documented processes; film diffusion and intra-particle diffusion. Chemical non-equilibrium at the sorbent–solute interface may also control uptake kinetics through sorption onto or desorption from sites with relatively large activation energies, and the slow formation of surface precipitates (Sparks, 2003). Treatment effectiveness of filtration media under non-equilibrium conditions may differ significantly from that under equilibrium conditions due to rate-limited sorption.