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Analysis and Modelling of Granular Media Filtration Processes

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INTRODUCTION

Granular media filtration is widely used as a treatment technology for drinking water. Modelling of such filtration processes has been the subject of numerous studies over many years. Such models help to understand and manage the processes that are responsible for blocking the filter media and creating headloss during the filtration process. To date, such models invariably are one-dimensional (variation with media depth) and assume media uniformity (porosity and media size). Such models cannot account for observed 'worm hole' effects and are inherently unrealistic.

In this study a new model has been developed in which filter media heterogeneity has been incorporated by representing the filter as a collection of individual cells differing in grain size and porosity. Classical filtration theory has been applied to represent the particle removal and headloss behaviour, and the overall model is based on finite difference calculations. Simulation results have shown that porosity and media size play a crucial role in the filtration performance, and the inclusion of media heterogeneity is important. As well as providing a more comprehensive representation of the overall filtration process, the model can give a detailed description of pore blocking and local flow velocities within the filter media, offering a unique insight into the fundamental nature of the treatment process.

PROJECT OBJECTIVES

- Develop a mathematic model to help analyze the changes inside the filter.
- Understand the key variables which could affect the filtration process.
- Investigate the relationship between particle size and filter performance.
- Visualize the temporal and spatial variation of porosity during the filtration process.

FILTRATION PROCESSES AND MODEL DEVELOPMENT

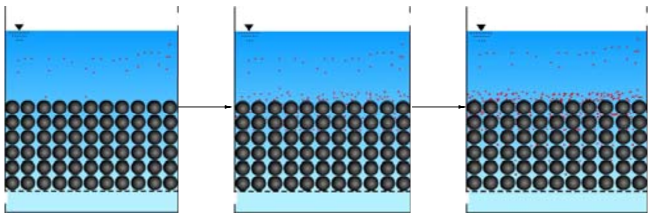
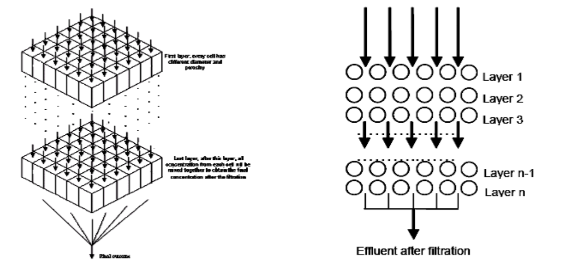


Figure 1: Filtration Processes

During the filtration process, suspended particles are removed by filter grains due to filtration mechanisms and thus attach on grains and reduce the pore volume of the filter media.



General view of the unit cell model   Vertical view of the unit cell model

Figure 2: Theoretical calculation concept of the unit cell model

A new mathematical representation, 'unit cell model', has been developed in this research. The model also incorporates the particle size distribution of the influent suspension during filtration. The filter media is considered to be constructed of a vertical series of filter layers consisting of an array of individual cells. In each cell, three filtration transport mechanisms – interception, sedimentation and diffusion - are assumed to account for the removal of suspended particles.

EXPERIMENTAL

Figure 3: Filtration apparatus

Figure 4: Coulter counter

Two sets of filtration experiments have been carried out with influent concentrations of 1g/L and 0.5g/L of kaolin clay to analyze the filtration process and provide physical data for the modelling. Influent flow is pumped into a filter column consisting of ballotini beads. Headloss through the filter is monitored by water manometers, and influent and effluent particle concentrations were determined by Coulter Counter and turbidity meter.

MODEL CALIBRATION AND SIMULATION WORK

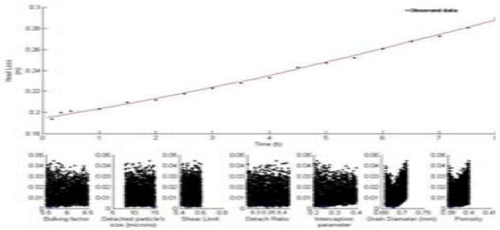


Figure 5: Monte Carlo calibration for headloss

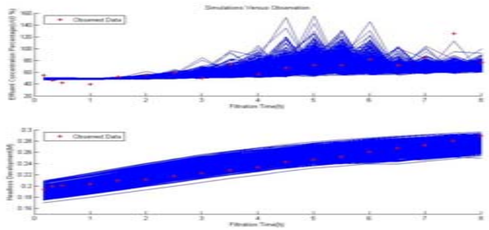


Figure 6: Simulation example with variation of porosity and grain size

Porosity and grain size are the two most sensitive parameters in model simulations. A Monte Carlo method was used in the model calibration. By use of random variation of calibrated average porosity and grain size, the model could produce a range of reasonable curves which cover the observed data.

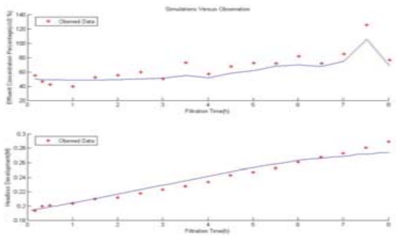


Figure 7: Best fit from figure 6

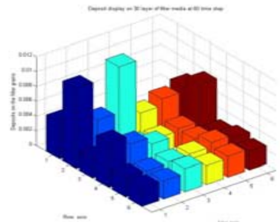


Figure 8: Visualization example of specific deposit

The unit cell model was able to simulate adequately observed data and quantitatively define the changes of some filter parameters during the filtration, e.g. the specific deposit for each calculation cell.

FURTHER WORK

- Incorporation of particle size distribution in modeling would help model to simulate filtration process more accurately.
- Visualization of model simulation is useful for understanding what has happened inside the filter during the filtration.