

Predicting the efficiency of deposit removal during filter backwash

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Abstract

The long-term performance of granular media filters used in drinking water treatment is ultimately limited by the efficiency of the backwash process. This paper demonstrates that it is possible to develop quantitative predictions of backwash efficiency based on filter operating conditions. An experimental investigation into the effect of backwash rate, type of coagulant, degree of clogging and accumulation of residual deposits (not removed by backwash) on the efficiency of fluidised bed filter backwash in laboratory scale filters is described. A natural raw water was used and small variations in the raw water characteristics (manifested as variations in raw water turbidity, temperature, pH, rate of head loss development and turbidity removal efficiency) within each set of experiments appeared to affect the efficiency of backwash in addition to the parameters varied deliberately. Stepwise linear regression and statistical analysis of model significance were used to determine which of several possible filtration and backwash parameters were the best predictors of backwash performance. Backwash rate, filter run time, rate of head loss development and mass of residual deposits accumulated during previous runs were found to be the best predictors of backwash efficiency for any given filter cycle. Floc deposits appeared to become more difficult to remove the longer they remained in the filter, while rate of head loss development appeared to provide some indication of the strength of cohesive deposits for filter runs of similar length. The efficiency of detachment of freshly deposited floc appeared to increase as the mass of residual deposits and mud balls in the filter increased. The numerical correlations developed in this study are site specific but the methodology can be adapted to any filter operation and backwash regime.

Keywords: water treatment, sand filters, fluidised backwash, backwash efficiency, backwash modelling, floc ageing

Introduction

Failure to adequately clean filters during backwashing results in the deterioration of the state of the filter bed, which can eventually impair the performance of the filter. Filters with inefficient backwash tend to accumulate aggregates of dirt, media and coagulant known as mudballs (Logsdon et al., 2002). These can grow into inactive sub-surface masses of clogged material which increase local velocities in the filter with a potentially negative impact on filtrate turbidity and filter run time (Cleasby, 1990). Larger mud balls can sink into the fluidised media and accumulate adjacent to the underdrain and gravel layers, causing non-uniform distribution of the backwash water. Clogged regions of the filter also tend to contract as the head loss increases, leading to the development of cracks in the bed, which result in short circuiting of the filter influent and a subsequent decline in filtered water quality (Kawamura, 1975; Cleasby, 1990).

Over the past few decades, there has been a substantial amount of research on modelling the filtration phase of the filter operating cycle. However, there has been little fundamental research into the backwash process and few of the models developed can easily be adapted for use in full scale water treatment plants. A critical review of previous approaches to backwash modelling is presented in Brouckaert (2004). While a number of

backwash studies have yielded important insights into the mechanisms involved in filter cleaning (Amirtharajah, 1978; Amirtharajah and Giourgas, 1981; Fitzpatrick, 1993; Mahmood et al., 1998) and have made it possible to predict the conditions for optimum backwash (Amirtharajah, 1978; Amirtharajah, 1984), none has led to the development of a model which can predict what the actual backwash efficiency will be under a given set of conditions and how this will affect the filter in the long term.

In order for any model of filter backwash efficiency to be useful for the design and optimisation of filters outside of a closely controlled laboratory environment, it is important that it includes all relevant processes and effects, and that the input data required are readily available at most treatment plants. A better understanding of backwashing would assist in the optimisation of existing filters as well as improving filter design for more robust operation, particularly in applications where optimum backwash cannot be guaranteed. These applications include many water treatment plants in developing countries which operate without auxiliary wash (air scour or surface wash).

This paper presents experimental results and analysis of the impact of various factors on backwash effectiveness and their implications for the operation of real filters. The experimental work was restricted to fluidised bed backwash but the approach taken in modelling and analysing the data should be equally applicable to auxiliary backwash systems.

Theoretical considerations

At the scale of a single floc coated filter grain, the probability that some or all of the floc deposit will detach during back-

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