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How to Measure Specific Deposit Washout and Backwash Efficiency of Granular Filters

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Abstract

Practical experience shows that water treatment filters develop problems over time due to the routine running of the filter, including backwashing. There are difficulties in maintaining filters in good condition, given the eutrophic state of many South African raw waters, high water temperatures and the development of difficult-to-remove biofilm as a result. Such difficulties are often related to deposits accumulated on the filter media and it is, therefore, expected that the backwash system should be good enough to ensure that the filter is kept clean in the long run. This paper deals with a fairly simple operational option to significantly improve backwash efficiency at treatment plants where air and water are used consecutively.

The paper describes methods used and typical results obtained in the testing of the quantitative benefits of multiple wash cycles. Multiple washing shows great promise for improving backwash efficiency, with an average of an additional 40% to 50% of the solids that would have been washed out with a single wash, removed by a second wash. Furthermore, third and even fourth washes continue to remove additional dirt from the filter. Multiple washing, therefore, may be a useful tool for the effective rehabilitation of a filter, as well as for routine operation procedures.

Keywords: Washout; backwash efficiency; multiple wash cycles

INTRODUCTION

Theory suggests that a filter starts out with new, perfectly clean media. The pores between media grains gradually clog up with particles that are trapped during filtration and a backwash cycle is initiated when this "clogging" affects head loss or filtrate quality at some predetermined "unacceptable" limits. As a result, the air-water combination quickly returns the media to its original perfectly clean state and so continues this process for the life cycle of the filter. However, it is common to find a filter, that has been commissioned a decade or more ago, with unacceptably dirty media and a backwash system that is incapable of returning the media to its original state of cleanliness. However, the reasons for these problems often remain elusive.

Backwash theory suggests that media cleaning requires more than just hydrodynamic shear. It also requires abrasion of the media surface by adjacent media grains rubbing onto each other. This is the express purpose of the air scour step, where the rising air bubbles cause continuous media movement. The primary purpose of the water washing is to remove the deposits from the bed. If air scour, however, is continued for more than a minute, the media compacts, air channels form and abrasion amongst grains ceases to a large degree. By interspersing shorter air-water cycles, as opposed to a single cycle, the media can be fluidized repeatedly, providing the opportunity for each new burst of air to effectively abrade the media grains.

This concept is not new and some South African treatment plants started to employ "double" or even "triple" washes about twenty years ago, with success. The Water Research Group at the University of Johannesburg (up to 2004, the Rand Afrikaans University) began systematically investigating this phenomenon in 2002 through regular visits and sampling of five full-scale treatment plants, as well as in a laboratory column, with the hope of providing answers to why and when multiple washing offers a practical operational strategy for keeping filters clean.

METHODS

In order to determine the effectiveness of multiple washes, it was necessary to quantify the specific deposit removed with each wash. Measuring the solids in the backwash water offers a practical way of doing so. However, backwash water testing faces the practical obstacle of time lags between media contact and sampling and difficulties in obtaining representative samples from a large flow of backwash water that is not necessarily homogenous in terms of its suspended solids concentration.

Samples of dirty backwash water were taken at least every 30 seconds for the duration of the backwash and were evenly spaced in time. Wherever possible, samples were taken from a collection channel rather than at the first overflow weir to prevent "streakiness" due to uneven cleaning of adjacent media patches. Samples of 200ml were transferred to bottles and their total suspended solids (TSS) determined in the laboratory. (Standard Method 209C, AWWA, 1992)

If the results obtained from different treatment plants have to be compared, there is a need to account for different bed depths and backwash rates of the filters tested. The concept of "empty bed volumes" was used by the authors as a means to standardise the volumes of backwash water at different plants, i.e. one bed volume of washwater = the total volume occupied by the media bed.

The backwash rate (BR) was measured in situ by closing the backwash discharge valve while the backwash pumps were running, noting the time taken for the water to rise at least 500mm within the filter box, and calculating directly (areas occupied by backwash troughs or other filter box intrusions were corrected for). Bed depth (BD) was measured by probing with a thin rod at a few positions. Using the equation below, specific deposit was then calculated.

$$TSS_{specific\ deposit}\left[kg/m^3\right] = \frac{BR\left[mm/s\right].\sum\left(TSS\left[mg/l\right].t\left[s\right]\right)}{1000\,.\,BD\left[mm\right]}$$

with t the backwash time represented by each sample.

RESULTS

Measuring solids washout in a uniform manner

Three different sets of backwash data are presented here. The first comprises the "first" backwashes, conducted after the filters were taken out of service at the time of the visit. The second comprises "second" backwashes immediately following the "first" backwashes described above. The third comprises backwashes conducted in the laboratory column. Media samples were transferred to the column from the filter after the "first" backwashes and given a "column" backwash (Figures 1, 2 and 3 respectively).

Figures 1, 2 and 3 show a remarkably consistent pattern, given all the experimental concerns. They indicate that there was little benefit in using more than four or five bed volumes of washwater per wash. In the case of the "first" wash as well as the "column" wash, the specific deposit removed per bed volume was less than 0.20 kg/m^3 if the wash is extended beyond five bed volumes. In the case of the "second" wash, this figure was 0.05 kg/m^3.

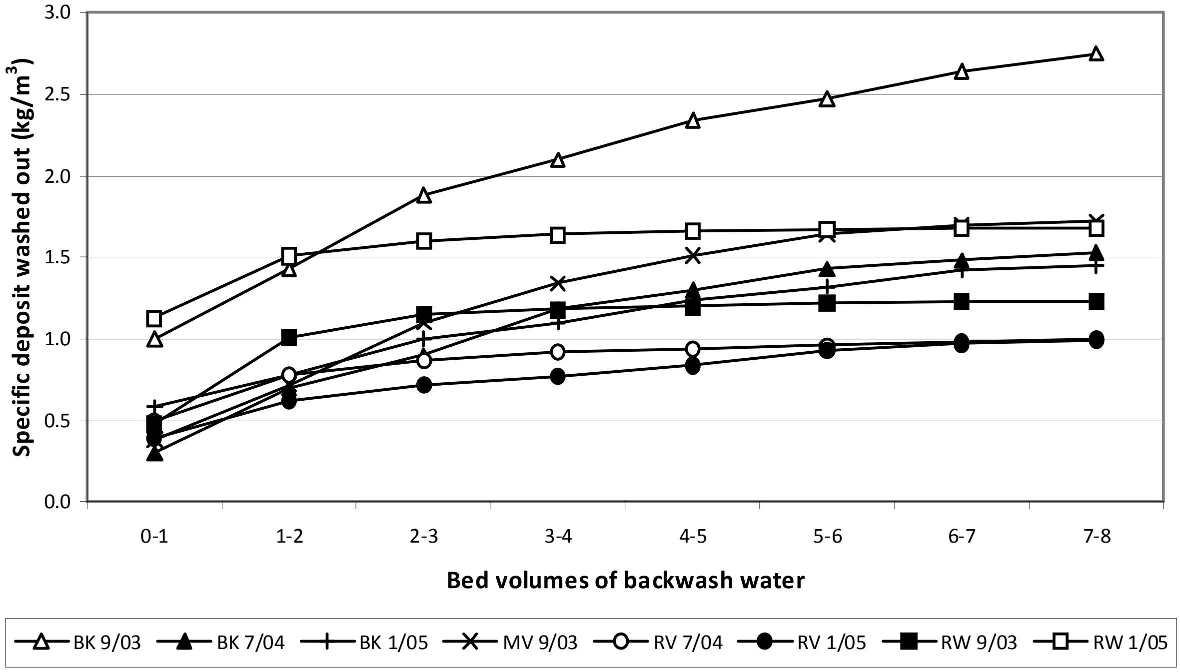

Figure 1 | Rate of specific deposit washout for “first” backwash data set.

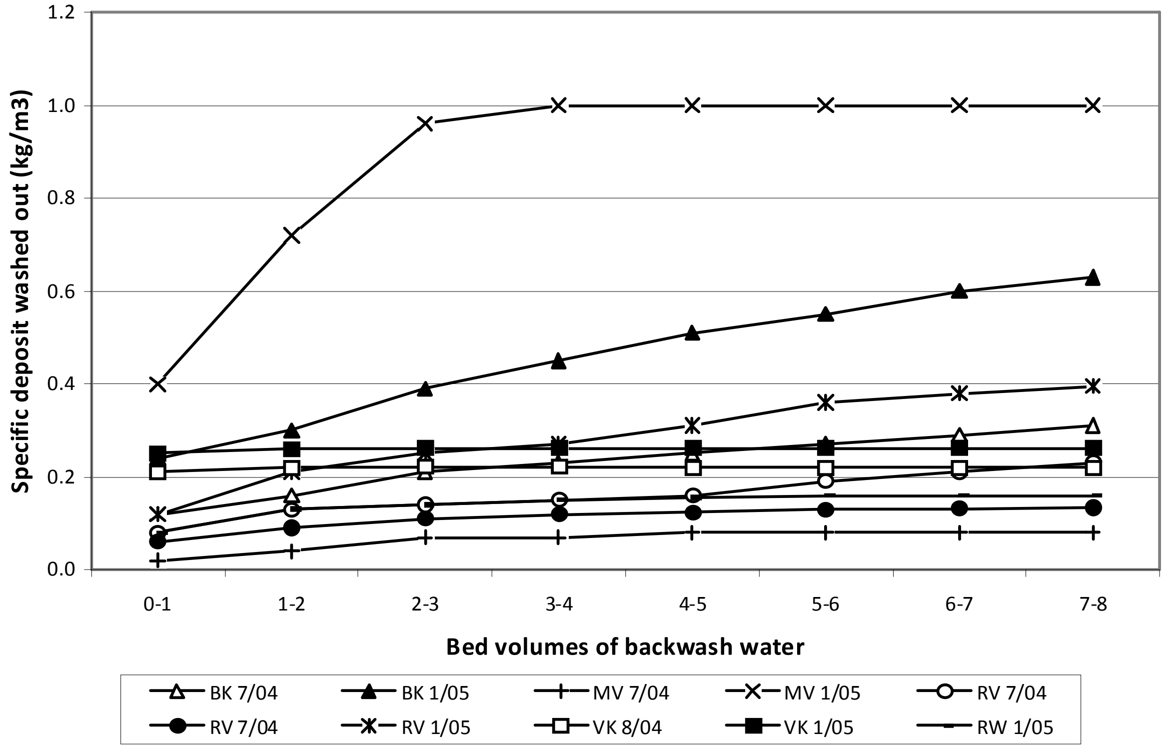

Figure 2 | Rate of specific deposit washout for “second” backwash data set.

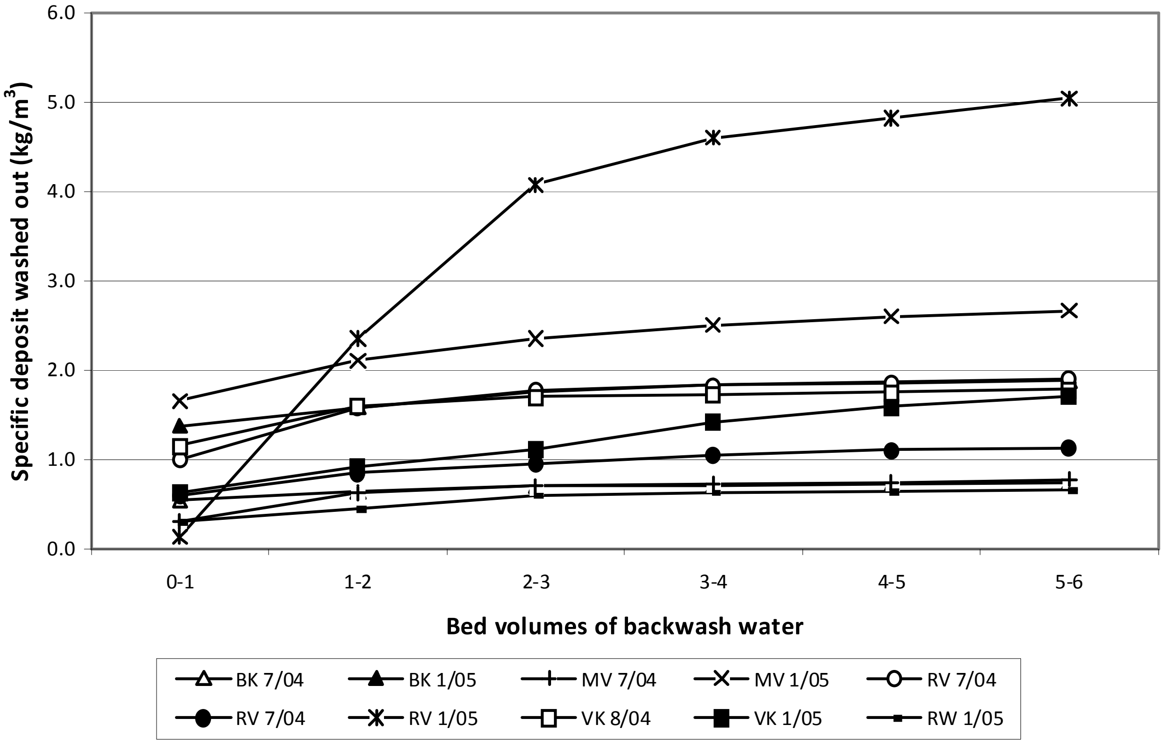

Figure 3 | Rate of specific deposit washout for "column" backwash data set.

The benefit of multiple backwash cycles

Whilst the above general pattern observed at all the treatment plants is of importance, it is useful to look at the analysis of individual plants to gain more specific insight.

Figure 4 is an example of a plant where multiple washes are of an obvious benefit. In this figure the "second" and "third" washes remove up to 60% of the total specific deposit removed in the "first" wash, whilst the "fourth" and "fifth" washes remove up to 30% of this total.

Figure 5 illustrates a plant where multiple washes have very little benefit. It shows that the "second", "third", "fourth" and "fifth" washes removed only 20 to 25% of the total solids removed during the "first" wash.

DISCUSSION AND CONCLUSIONS

The results above show that the concept of bed volumes of washwater is useful for comparing backwash data when backwash rates and media bed depths are different.

The vast bulk of the specific deposit is washed out during the first two bed volumes. There is little point in continuing the backwash cycle beyond five bed volumes per wash. If a wash is repeated (using both the consecutive air and water again), more specific deposit can be removed. For example, at the treatment plants surveyed a third wash removed between 50% and 100% of what was removed during a second wash. However, the use of multiple backwash cycles at plants should be investigated on an individual basis, since the advantage may be very significant at some plants whilst being marginal at others.

The results suggest that it may be more beneficial to use say three consecutive wash cycles – the first two using say 2 bed volumes, and the third with 4 bed volumes, as opposed to a typical single wash of 8 bed volumes (until the washwater appears perfectly clean). In this way, much more specific deposit can be removed whilst still using the same amount of water.

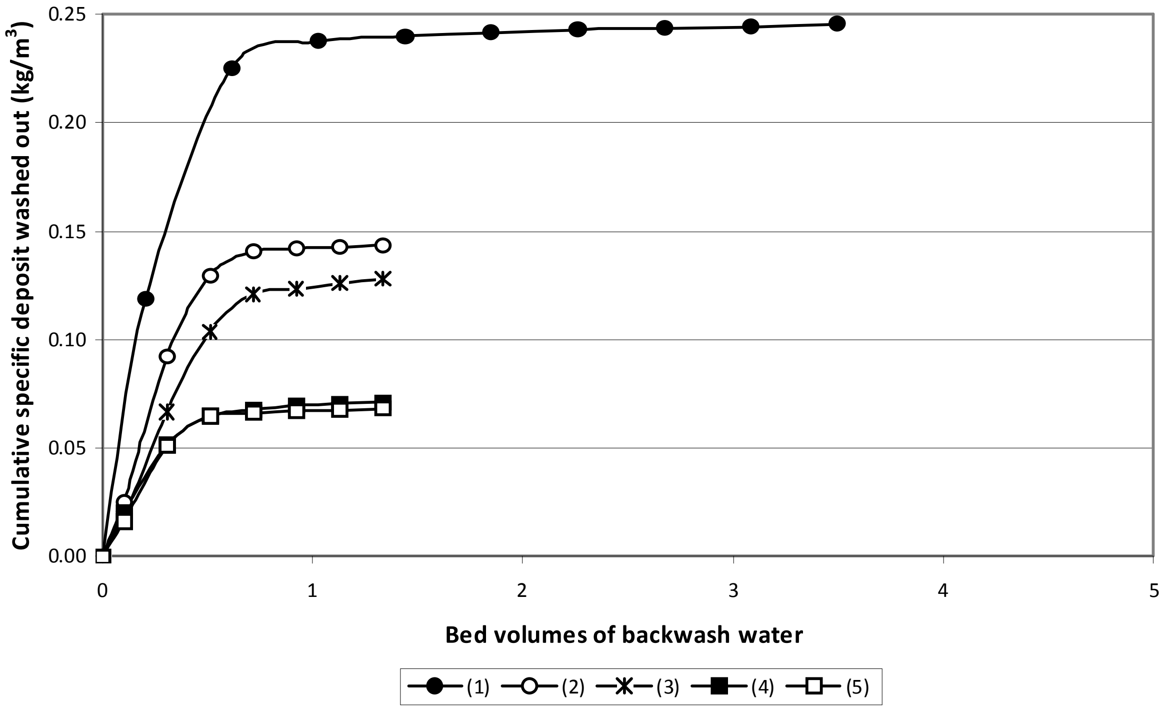

Figure 4 | Cumulative washout of solids at VK Plant for the 08/2003 visit.

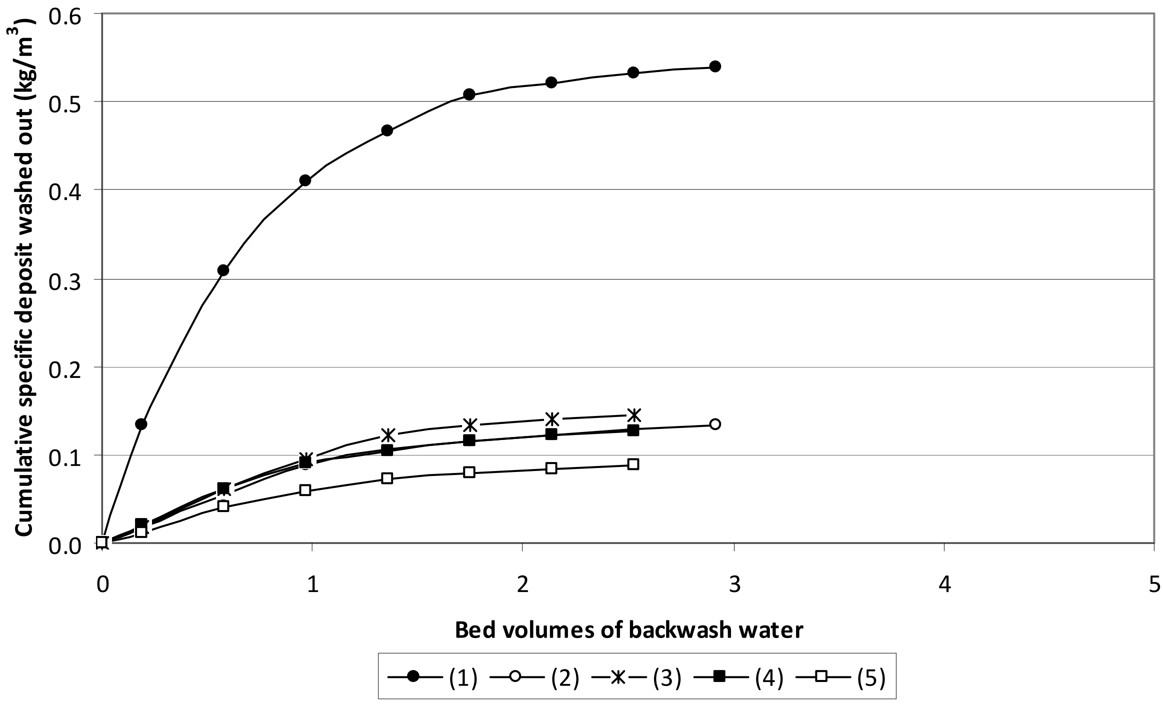

Figure 5 | Cumulative washout of solids at RV Plant for the 08/2003 visit.

REFERENCE

AWWA 1992 *Standard Methods for the Examination of Water and Wastewater*, 18th edition. American Public Health Association, Washington, District of Columbia, USA.