

## Filter backwash water treatment options

S. Arendze and M. Sibiya

### ABSTRACT

Filtration acts as the final step in the removal of suspended matter and protozoa. The accumulated residue is removed during the backwash process and any subsequent recycling of filter backwash water could potentially re-introduce these contaminants into the main treatment process. By separating the filter backwash water from the main treatment process, factors that could interfere with the integrity of the primary treatment barriers, will be eliminated. Treatment and recovery of the filter backwash water would be beneficial in terms of water reuse, by replacing a proportion of the freshwater demand. The aim of this study was to investigate possible treatment options for the filter backwash water at Rand Water. Treatment options for filter backwash water treatment plants usually consist of a solids removal process and a disinfection process. Three solid removal processes for filter backwash water from Rand Water's filtration systems were selected for testing on an experimental basis: (1) sedimentation without flocculation, (2) sedimentation with flocculation, and (3) dissolved air flotation with flocculation. Flocculation with sedimentation produced the best results when compared to the other two treatment options evaluated. It is a simple and effective option for the treatment of filter backwash water.

**Key words** | dissolved air flotation, filter backwash water, flocculation, recycling, sedimentation, water reuse

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### INTRODUCTION

The concept of multiple-barriers is the cornerstone of safe drinking water (LeChavallier & Au 2004). The presence of multiple barriers means that failure of one barrier is compensated by effective operation of the remaining barriers, thus minimising the likelihood of contaminants passing through the treatment system (LeChavallier & Au 2004). The barriers include factors such as source protection, optimisation of the water treatment plant processes, such as coagulation, flocculation, sedimentation, filtration and disinfection, and a properly maintained distribution system (Betancourt & Rose 2004).

The design of the water purification process should provide for a multi-barrier system during which chemical treatment in the form of coagulation and flocculation precedes physical processes such as sedimentation and filtration. The incorporation of the successive treatment steps, if well designed and operated, would ensure the

effective removal of contaminants, including protozoa. Filtration acts as the last physical unit process for suspended solid removal in conventional treatment systems.

During the filtration process, most of the residual suspended matter and micro-organisms that may have passed through the sedimentation process are trapped by the filter media (LeChavallier & Au 2004). The accumulated residue is then removed during the backwash process. Filters are typically backwashed by flushing them with water in the reverse direction to normal flow. Compressed air may also be used to aid this process. The resulting water is termed waste or filter backwash water (United States Environmental Protection Agency (USEPA) 2002a). Filter backwash water is therefore characterised as having a high concentration of suspended solid residues of coagulants and flocculants, metals, inorganic matter, algae (which could cause taste and odour compounds), bacteria, viruses, invertebrates, and protozoan

parasites, such as *Cryptosporidium* and *Giardia* (Linde 2004). Of all the processes that produce residual streams in water treatment, filter backwash typically produces the largest volume of water at the highest rate (USEPA 2002b).

### The necessity for the treatment of filter backwash water

Recycling of filter backwash water reintroduces all the deleterious matter that was removed by filtration, usually to the head of works, and thus back into the main treatment scheme (Linde 2004). This could have an effect on the water treatment chemistry, and consequently the final water quality, as conventional water treatment technology does not provide consistent removal of pathogens if present in high numbers (Wilf & Pearce 2003). Filter backwash water may also reintroduce these contaminants in more concentrated form into the main treatment process. Studies by Arora *et al.* (2001) have shown that levels of protozoa in filter backwash water are higher than those in raw water; *Cryptosporidium* concentrations were found to be 61 times higher, and *Giardia* concentrations were 16 times higher. The presence of protozoan cysts in high numbers could be detrimental, as this challenges the effectiveness of the multi-barrier treatment capability, and this could thereby affect public health (Arora *et al.* 2001).

The separate treatment of filter backwash water in dedicated plants would reduce the potential risk of reintroducing contaminants into the main treatment process. This would avoid having to upgrade the primary treatment technology and thus save on the capital and operational costs that would be required to treat the entire volume of water with advanced processes.

A further benefit is that the current volume of filter backwash water at Rand Water, estimated at 2% of the volume of raw water treated, if treated separately, would increase the capacity of the plant by this margin (Linde 2004). Treatment and recovery of the filter backwash water would be beneficial in terms of water reuse. South Africa is currently characterised as a country with high water stress, due to low rainfall volumes (Adewumi *et al.* 2010). Population growth, the expanding economy, and high evaporation rates due to climate change are all putting pressure on limited water resources in the country, thus in the near future the country

could go from a water stressed country to a water scarce country (United Nations Environment Programme (UNEP) 2012). Due to these challenges, there has been a need to improve the efficiency of water consumption and the need to supplement existing sources of water in a more sustainable manner, thus water reuse serves to protect freshwater resources, as the direct use of wastewater streams can replace a proportion of the freshwater demand (UNEP 2005; Department of Water Affairs South Africa (DWA) 2011).

### USEPA filter backwash recycling rule (FBRR)

Although there is a lack of formal regulation of filter backwash water in South Africa, the importance of its management and control is recognised and legislated internationally. The most prominent example of such regulation is the FBRR of the United States Environmental Protection Agency (USEPA 2002b). The FBRR is intended to reduce the opportunity for recycle practices to adversely affect the performance of drinking water plants (USEPA 2002b).

The FBRR affects all water purification plants in the USA that:

- use surface water or ground water under the direct influence of surface water;
- treat water using conventional filtration processes; and
- recycle one or more of the following: spent filter backwash water, thickener supernatant, or liquids from dewatering processes.

The FBRR requires that recycle streams pass through all the unit treatment processes of a treatment system before recycling, in order to minimise the risk of contaminants not being contained by the system on recycling (USEPA 2001).

## METHODS

Treatment options for filter backwash water are similar to those for raw water treatment in water purification, and usually consist of a solid removal process and a disinfection process. Table 1 shows a study done by Cornwell *et al.* (2001) on different solid removal treatment options that were compared at different treatment plants for the treatment of filter backwash water. The turbidity and particle removal

**Table 1** | Log reduction in turbidity and particles from spent filter backwash water for different treatment options and their relative cost ranking (USEPA 2002a)

Treatment process	Turbidity log reduction	Particle log reduction	Relative cost ranking
Sedimentation without flocculant	0.1 to 0.8	0.2 to 0.9	1
Sedimentation with flocculant	1.4 to 2.3	1.9 to 3.3	2
DAF with flocculant	1.7 to 2.7	1.9 to 3.5	3
Granular media filtration with pre-treatment	2.2 to 3.0	2.4 to 4.4	4
Membrane micro-filtration	2.6 to 3.9	1.6 to 3.5	5

efficiency, as well as the relative costs of each are also shown. Relative cost ranking is rated as 1 for the lowest treatment cost to 5 for the highest treatment cost.

From those listed in Table 1, the following treatment processes were selected and evaluated on filter backwash water from Rand Water's Vereeniging treatment plant: (1) sedimentation without flocculation, (2) sedimentation with flocculation, and (3) dissolved air flotation (DAF) with flocculation. The processes were chosen based on economic viability, least complex methodology, potential to implement and acceptable turbidity removal. Investigations into disinfection practices were not done in this study.

## Sampling

Filter backwash water samples (100 litres) were sampled from Rand Water's Vereeniging treatment plant, while filters were being washed. All the samples were then added to a large 200 litre tank, and mixed well using a submersible pump.

## Sedimentation without flocculation

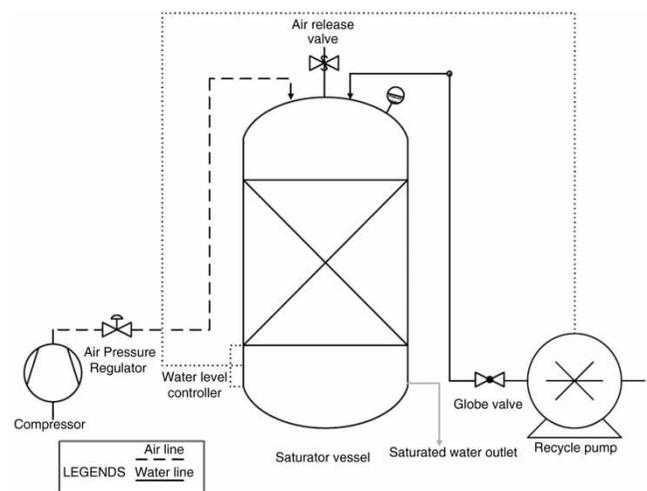
This method was tested to see if existing sedimentation tanks could be used to settle the filter backwash water. One litre samples were put into settling cones and left to settle for 4 h, i.e. the approximate retention time in a normal sedimentation tank, and longer, up to 12 h. Turbidity readings were then measured. Different retention times were tested on filter backwash water samples from different days, due to the manual analysis involved.

## Sedimentation with flocculation

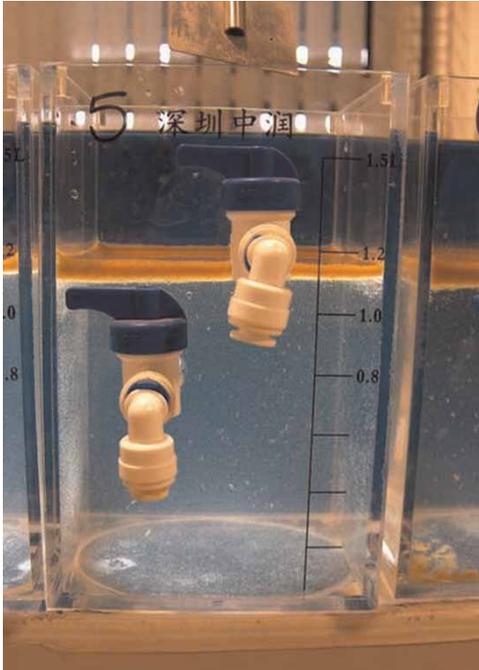
Jar stirring tests were performed on 1 litre samples of this well mixed filter backwash water. A high energy jar test method was used, which included a settling time of 15 minutes. This high energy jar test method, in conjunction with settling, is a laboratory scale simulation of the flocculation and sedimentation processes (g-values, mixing velocity and settling rates) on the full scale plant. This procedure was developed around the conditions at Rand Water's full scale plants and was developed based on comparative data. A cationic polyelectrolyte, a diallyldimethyl ammonium chloride and polyamine and polyaluminium chloride blended product, was dosed, and turbidity readings were taken by drawing supernatant from each beaker with syringes after settling.

## DAF with flocculation

Jar tests were again performed on 1 litre samples using a high energy jar test method, including 15 minutes of floating after the DAF was applied. The same cationic polyelectrolyte was used as described above. As soon as stirring was complete, water saturated with dissolved air ('white water') was added. The 'white water' was added at 10% of the 1 litre sample volume. The saturated water was produced using a saturator. Figure 1 shows a schematic of the experimental set-up of the saturator. Figure 2 shows the scum-float that was formed with the flocculated



**Figure 1** | The experimental set-up of the DAF saturator.



**Figure 2** | The scum float that was formed with the flocculated particles once DAF was applied.

matter once DAF was applied. Samples for turbidity measurements were drawn from taps on the side of the jars (the bottom tap on Figure 2), at 2 cm below the surface of the water, so as not to disturb the float. Jar test runs for sedimentation with flocculation, and DAF with flocculation, were done on the same filter backwash water, on the same day.

## RESULTS

### Sedimentation without flocculation

Table 2 shows the results from settling the filter backwash water for periods of 4–12 h. It shows the average final turbidity and percentage decrease in turbidity for the settling periods listed. As mentioned before, different backwash waters were used. The turbidity values before indicate the variation of the different filter backwash water samples. The average percentage decrease in turbidity for 4 h, i.e. the approximate retention time in a normal sedimentation tank was 96.9%. For periods greater than 5 h, the average decrease in turbidity was greater than 99.0%.

**Table 2** | Results for the sedimentation of filter backwash water without flocculation

Settling period (h)	Average turbidity before (NTU)	Average turbidity after (NTU)	Average percentage decrease in turbidity (%)
4	335	7.97	96.9
5	274	1.40	99.5
6	433	4.40	99.0
7	496	2.30	99.6
9	206	0.90	99.6
12	745	3.80	99.5

### Sedimentation with flocculation

Table 3 shows the average turbidity results after settling; using progressively increasing dosages of polyelectrolyte on filter backwash water. The table also shows the average percentage decrease in turbidity. The average initial turbidity was 385 NTU. The settled turbidity decreases with an increase in polyelectrolyte concentration. A turbidity of less than 5 NTU is an acceptable operational specification for settled water before filtration, thus a concentration of 3 mg/L is considered the optimum amount of polyelectrolyte to be dosed to settle the filter backwash water. The average percentage decrease in turbidity is greater than 99% at dosages higher than 4 mg/L polyelectrolyte.

### DAF with flocculation

The turbidity results for the treatment of filter backwash water with increasing concentrations of polyelectrolyte in

**Table 3** | Results for the sedimentation of filter backwash water with flocculation using a polyelectrolyte

Concentration of polyelectrolyte (mg/l)	Average turbidity after settling (NTU)	Average percentage decrease in turbidity (%)
1	11.10	97.1
2	6.54	98.3
3	4.35	98.9
4	3.74	99.0
5	3.06	99.2
6	2.81	99.3

conjunction with DAF are shown in Table 4. The average percentage decrease in turbidity is also shown. The average initial raw water turbidity was also 385 NTU. The final turbidity varied with polyelectrolyte dose. The optimum dosage point was found to also be at 3 mg/L, which gave a minimum turbidity of 11.5 NTU, and turbidity removal of 97.0%. In Figure 2, it can be seen that the scum-float that is formed is fairly thick which suggested that DAF could be a viable option in the treatment of filter backwash water.

## DISCUSSION

Based on the results obtained, sedimentation without a flocculant showed good turbidity removal. The average percentage decrease in turbidity was 96.9% for 4 h of settling, the average settling time in a normal sedimentation tank, and greater than 99% for more than 5 h of settling. These values are indicative that the filter backwash water consists of a high concentration of suspended solid residues of coagulants which have already been destabilised and settle very readily. Sedimentation without a flocculant could be considered for the removal of solids, given adequate settling infrastructure and sufficient time.

Sedimentation with flocculation using a polyelectrolyte showed decreased turbidity with increasing polyelectrolyte dosage. Low turbidity values in the supernatant were observed, with values less than 5 NTU at dosages of 3 mg/L and greater. A turbidity of less than 5 NTU was achieved at a concentration of 3 mg/L, which related to a

turbidity removal of 98.9%. The average percentage decrease in turbidity was greater than 99% at dosages greater than 4 mg/L polyelectrolyte. The use of a chemical coagulant produced better final turbidity values when compared with settling alone.

DAF in conjunction with a flocculant produced a minimum turbidity of 11.5 NTU at a dosage of 3 mg/L polyelectrolyte. This turbidity is higher than that of sedimentation with a flocculant. This related to a turbidity removal of 97.0%. The turbidity removal from DAF did not go below 5 NTU.

The average percentage decrease in turbidity from DAF treatment at a flocculant dosage of 3 mg/L was 97.0%, which is lower than that of sedimentation with a flocculant which was 98.9% at the same dosage. This could be due to factors inherent to small scale experiments, such as disturbance of the scum float while taking turbidity samples. However it could be that the particle settling rate was higher than the rise rate, thus some of the flocculated material did not float.

In terms of turbidity removal, the methods tested rank, from best, as follows:

1. flocculation with sedimentation;
2. sedimentation without flocculation; and
3. DAF with flocculation.

Flocculation with sedimentation produced the best results compared to the other two treatment options evaluated. It is a simple option, yet could be just as effective as the more complicated and expensive treatment options that are available. After dosing with polyelectrolyte and settling, water with a turbidity of 4.35 NTU was obtained, this adheres to a turbidity of 5 NTU after sedimentation.

Based on these preliminary results, the recommended separate treatment for filter backwash water is as follows. Cationic polyelectrolyte can be used as a coagulant, to flocculate particles. The concentration however will have to be optimised through regular jar tests, as the filter backwash water quality will change depending on season and changes in raw water quality. After settling, water with a turbidity of less than 5 NTU will be obtained. This water could possibly be disinfected with ultraviolet light (UV) and fed back into the main stream to enter the system just prior to filtration.

**Table 4** | Results for the flocculation of filter backwash water using a polyelectrolyte in conjunction with DAF

Concentration of polyelectrolyte (mg/l)	Average turbidity after settling (NTU)	Average percentage decrease in turbidity (%)
1	16.65	95.7
2	16.00	95.8
3	11.50	97.0
4	12.30	96.8
5	13.60	96.5
6	13.00	96.6

A separate dedicated filtration plant will therefore not be necessary.

The incorporation of the filter backwash water will increase the filtration rate in each filter by 2%, if all filters are in commission; however it could be more if filters are being backwashed or if a filter is out of commission. This should have little effect on filtration in the main stream (Letlape 2010).

The treated filter backwash water will then undergo primary disinfection with chlorine along with the rest of the outgoing, treated water. This will decrease the raw water intake by about 2%, with minimal capital expenditure apart from a dedicated UV process.

Recycling of filter backwash water could challenge the effectiveness of the multi-barrier treatment capability, by reintroducing these contaminants in more concentrated form, which could affect public health. The separate treatment of filter backwash water in a dedicated plant would reduce the potential risk of reintroducing contaminants into the main treatment process. This would also be a financially sound option in the long run, as this would avoid having to upgrade the entire primary treatment technology, due to concentrated contaminants found in a waste stream; this would save on the capital and operational costs that would be required to treat the entire volume of water with advanced processes. Water treatment plants should thus look at incorporating filter backwash water treatment plants into the budget. Lastly treatment of filter backwash water will also add value in terms of the environment through water reuse, as it would serve to augment the supply and thus the freshwater demand will be reduced.

## CONCLUSIONS

- Recycling of filter backwash water could challenge the effectiveness of the multi-barrier treatment capability, which could eventually affect public health. The separate treatment of filter backwash water is important as it would reduce the potential risk of reintroducing contaminants into the main treatment process.
- In terms of turbidity removal, the methods tested rank, from best, as follows: 1. flocculation with sedimentation,

2. sedimentation without flocculation, and 3. DAF with flocculation. Flocculation with sedimentation produced the best results compared to the other two treatment options evaluated. It is a simple option, yet could be just as effective as the more complicated and expensive treatment options that are available. This water could then possibly be disinfected with UV, and then fed back into the main stream to enter the system just before filtration, which may have little effect on filtration in the main stream.

- Dedicated filter backwash water treatment plants are also a financially sound option, as the need to upgrade the entire primary treatment technology would be avoided; the concentration of contaminants in the filter backwash water could affect the raw water quality through recycling, thus costs to treat the entire volume of water with advanced processes would be evaded. Water treatment plants should incorporate filter backwash water treatment plants into their budgets.
- Treatment of filter backwash water is also a benefit to the environment through the concept of water reuse, as a proportion of the freshwater demand will be replaced.

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