

SEPARATION OF ULTRAFINE PARTICLES FROM TAILINGS THICKENER OVERFLOW

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Separation of ultrafine particles at mineral processing plants is a painful challenge. In some cases, a notable part of the concentrate, i.e. the product, is lost because of needs to grind finer to liberate and thus generating very fine particles down to micrometers. These valuable particles escape conventional processing. Fines may also cause issues in tailings thickening, from where water can either be discharged or purified and recycled back into mineral processing. Advanced filtration offers a potential solution for these challenges. However, conventionally filtration is challenging for ultrafine particles due to blinding of the filter medium, increased filter cake resistance and the subsequent loss of capacity in filtration.

The objective of this work was to investigate the separation of ultrafine particles from the overflow water of a tailings thickener at Oulu Mining School (OMS) using advanced fine particle filtration. The Sofi Filter® is a high velocity filtration unit which can be operated either in cross-flow or dead-end modes using most commonly stainless-steel filter elements with nominal pore sizes down to 0.3µm. The Sofi Filter® uses unique ultrasonic self-cleaning technology and is designed for separation of ultrafine mineral particles.

Ores from two mines, a polymetal mine and a silver mine, were used in concentration tests at OMS. Different pH adjusting chemicals were used in froth flotation leading to four different tailings thickener overflow waters for each ore. Each water was filtered with three filter elements having micron ratings between 0.3 and 20µm. The overflow waters were characterised by TSS and PSD measurements and filtration performance was evaluated by measured flux and calculated solid reductions.

The self-cleaning technology worked well for the particles in these overflow waters. The composition of the waters varied for TSS and PSD, which in some cases clearly had impact on the filtration capacity and solid reduction rate. TSS values in the overflow waters were 18–82mg/L. Median particle sizes were below 10µm for the water from polymetal ore processing and 9–97µm for the waters from silver ore processing. Fluxes from below measurement accuracy to over 40m³/(m²h) were measured with solid reductions varying all the way from 0 to 100%, generally filter elements with larger pore size giving higher fluxes than elements with smaller pore sizes.

KEYWORDS

Ultrafine particles, mining, filtration, self-cleaning filter, ultrasound

1 Introduction

Ore concentration crushes the ore, separates and concentrates the valuable mineral(s) from less valuable ones leading to a concentrate product and tailings that contain low quantities of valuable minerals and high quantities of gangue. Solids can be separated from the process water by settling in a thickener, where most and the largest of the particles settle and are removed from the bottom of the thickener, whereas the overflow water contains smaller particles that are unable to settle in the thickener. Whether this overflow water is intended to be recycled to the concentration process or discharged, it would be beneficial to separate the fine particles at this stage.

Filtration of (ultra)fine particles (typically smaller than 20 μm) at low concentrations is a painful separation challenge. To make techno-economic sense, both retention of particles as well as filtration capacity should be as high as possible. In the treatment of (ultra)fine particles, the filter medium is easily blinded leading to the need of replacing the medium and/or performing extensive maintenance. Self-cleaning filters (also sometimes called automatic filters or screen filters) clean the filter medium thus reducing overall operational expenditure.

The objective of this study was to evaluate the performance of the self-cleaning Sofi Filter® in filtration of varying tailings thickener overflow waters.

2 Materials and methods

2.1 *The Sofi Filter®*

The Sofi Filter® SF200 filtration system consists of an SF200 filter, a control unit, a feed pump, and a feed tank (Fig. 1). Pressure, temperature and flow data are recorded by a computer. The filter is equipped with an ultrasonic rod and employs either patented cross-flow technology or, alternatively, dead-end filtration mode. All the functions i.e. pump speed, valve openings and back washing parameters can be managed from the control unit. The surface area of a SF200 filter element is 0.2 m².

The self-cleaning can be adjusted to take place either at certain time interval or at certain pressure difference. During the self-cleaning, first ultrasound is used to dislodge the solid particles inside and on the surface of the filter element, then pressurized air pulse is used to push a small amount of filtrate through the filter media from the filtrate side to the feed side, i.e. backwash the filter element. The self-cleaning takes only a few seconds (typically less than 10s).

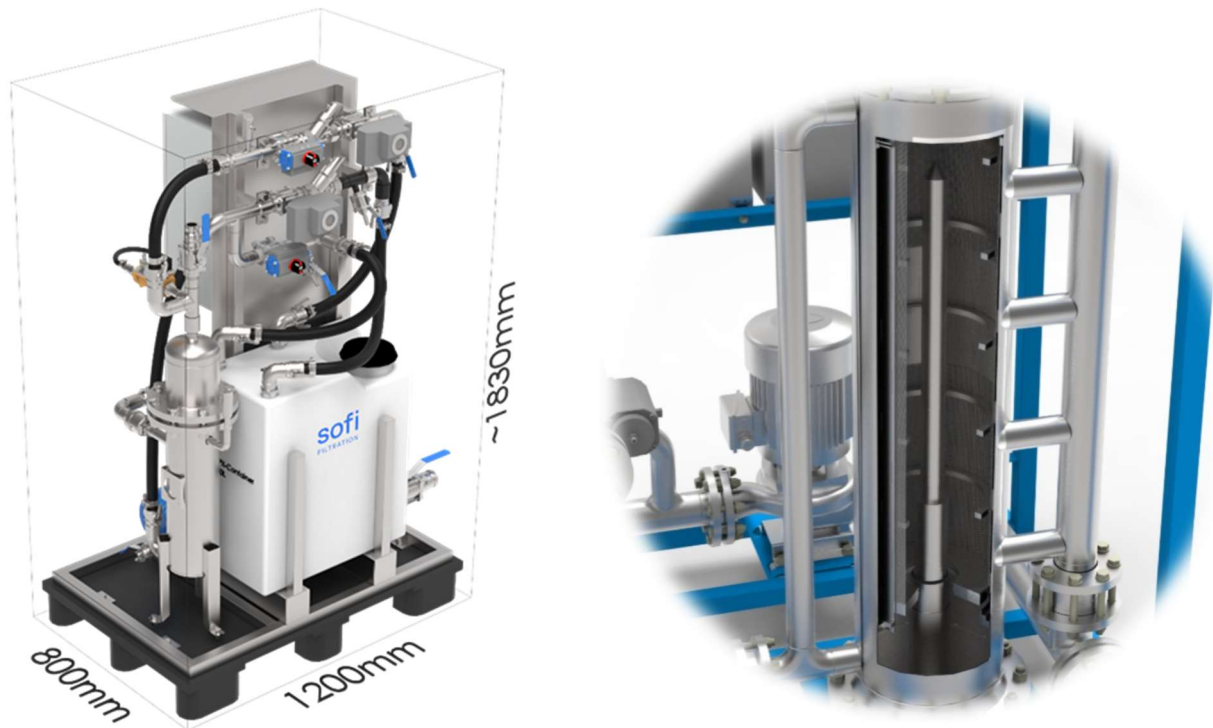


Figure 1. The Sofi Filter® SF200 filtration system and the ultrasonic rod inside the pressure chamber.

2.2 Filtration procedure

The tests were run in dead-end mode using a closed-loop and thus circulating the filtrate and reject back to the feed tank throughout the experiment. This way a small sample, 80–100L in these experiments, can be used to run extended laboratory trials. Filtrate flow rate, and, feed and filtrate line pressures were measured during the filtration. Samples were collected from feed, filtrate and reject fractions. Filtration cycle was set to be 60–300s, depending on the feed characteristics and filter element, after which self-cleaning initiated automatically.

All the fractions were collected and mixed after each filtration and the same feed was used for the next two filtration experiments covering three different filter elements for each feed sample. Stainless-steel wire mesh elements were used in this study for their proven applicability for mineral particles. Pore sizes 0.3, 1, 5, 10 and 20 μ m nominal were used according to the feed TSS which varied between the tailings thickener overflow waters.

2.3 Tailings thickener overflow waters

Overflow waters were provided by Oulu Mining School (OMS), where two different ores, a polymetal ore and a silver ore, were used in flotation experiments at their concentrator mini-pilot plant. OMS studied the effect of four different pH adjustment chemicals on the flotation process as part of the EU funded project Green Lime.

Flotation experiments with the polymetal ore resulted in waters 1–4 and the silver ore in waters 5–8 (Fig. 2). These eight collected overflow waters were filtered at OMS by SF200 filter unit. Each water was filtered with 3 filter elements of different micron ratings.

EXPERIMENTAL PLAN

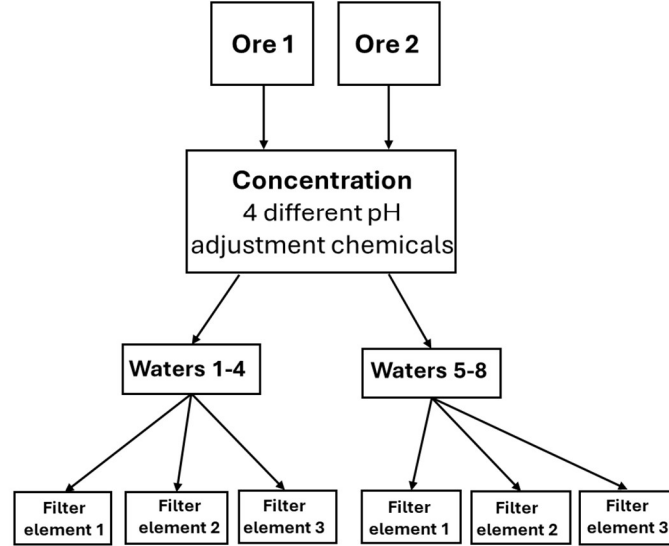


Figure 2. Description of the experimental plan from ores, through concentration process to tailings thickener overflow waters which were filtered by SF200 filter.

2.4 Analysis

Particle size distributions (PSD) for the feeds were measured by laser diffraction. Total suspended solids (TSS) were analyzed from the feed, the filtrate and the reject samples according to SFS-EN 872:2005. TSS retentions were calculated (Eq. 1) to evaluate the separation efficiency.

$$R = \frac{(c_{Feed} - c_{Filtrate})}{c_{Feed}} \times 100\% \quad (1)$$

where,

R retention, %

c_x concentration in given fraction, mg/l

The filtrate fluxes were calculated according to Eq. 2.

$$J = \frac{V}{A \times t} \quad (2)$$

where,

J	<i>flux, $m^3/(m^2h)$</i>
V	<i>volume of the filtrate, m^3</i>
A	<i>filtration area, m^2</i>
t	<i>time, h</i>

3 Results and discussion

The tailings thickener overflows were characterised by their solid contents and particle size distributions. The filtration performance of the Sofi Filter® was evaluated by filtration capacity and separation efficiency.

3.1 Composition of the tailings thickener overflow waters

The solid content was low in the waters 1–8 (Table 1) and had only minor variation between the different waters, except in water 8, where the TSS was higher than in the other waters. The particle size varied more, especially in waters 5–8. This might be due to the different ore as raw material, different pH adjustment chemicals in flotation process, or changes in the point of time when the overflow was collected. The cause for the variation was not the main focus here but its effect on filtration performance.

Table 1 Total suspended solids and volumetric mean particle sizes in different tailings thickener overflow waters.

	TSS (mg/L)	D₅₀ (µm)	Ore
Water 1	49.4	2.06	Polymetal
Water 2	39.7	8.37	Polymetal
Water 3	21.4	3.37	Polymetal
Water 4	21.1	3.56	Polymetal
Water 5	30.3	16.3	Silver
Water 6	19.3	33.1	Silver
Water 7	17.5	96.7	Silver
Water 8	81.4	8.72	Silver

The concentration of particles in some of the feed samples was too low to obtain optimal particle loading for laser diffraction, but the results are indicative and show that particles in waters 1–4 were much smaller than the particles in waters 5–7 (Fig. 3).

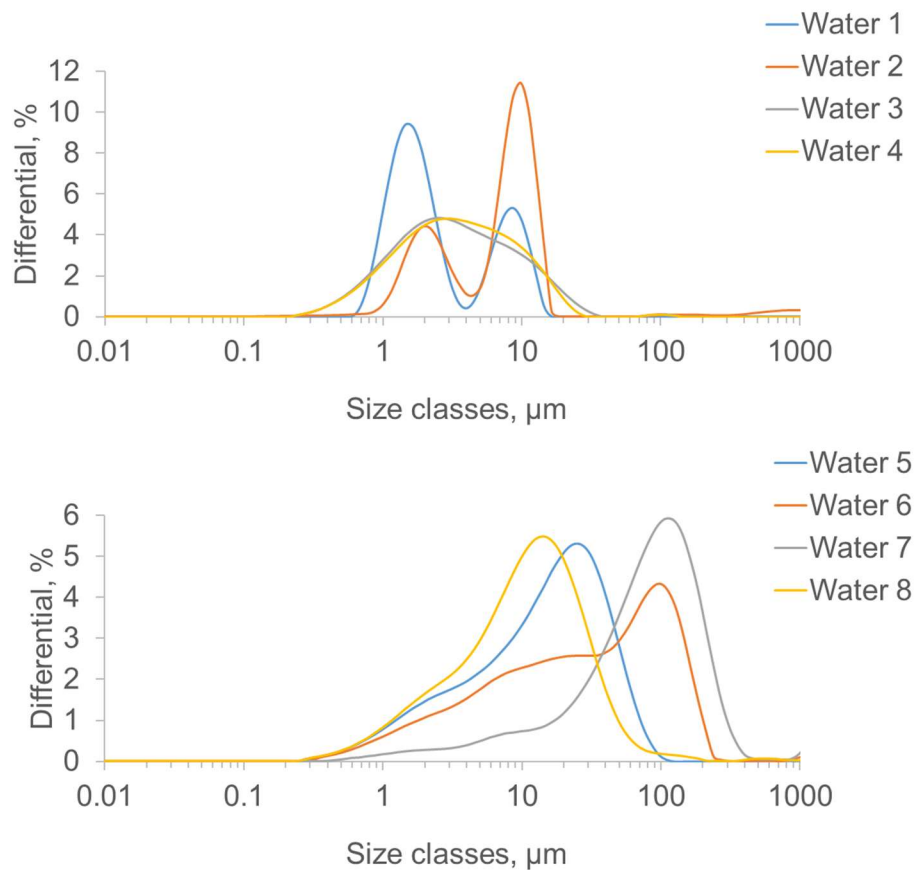


Figure 3. Particle size distributions for tailings thickener overflow waters analysed by laser diffraction.

3.2 Filtration capacity

Filtration capacities for the filter elements in filtering waters 1–4 are presented in Fig. 4a and waters 5–8 in Fig. 4b.

Filtration capacities of the 1µm filter element decreased during the filtration cycle with waters 1–4, but self-cleaning restored the flux efficiently after each cycle. Filtration capacities of the 5 and 10µm filter elements in filtration of waters 1–4 remained stable, and longer filtration cycle could have been applied. Flux behaviour for each filter element was similar for waters 1–4.

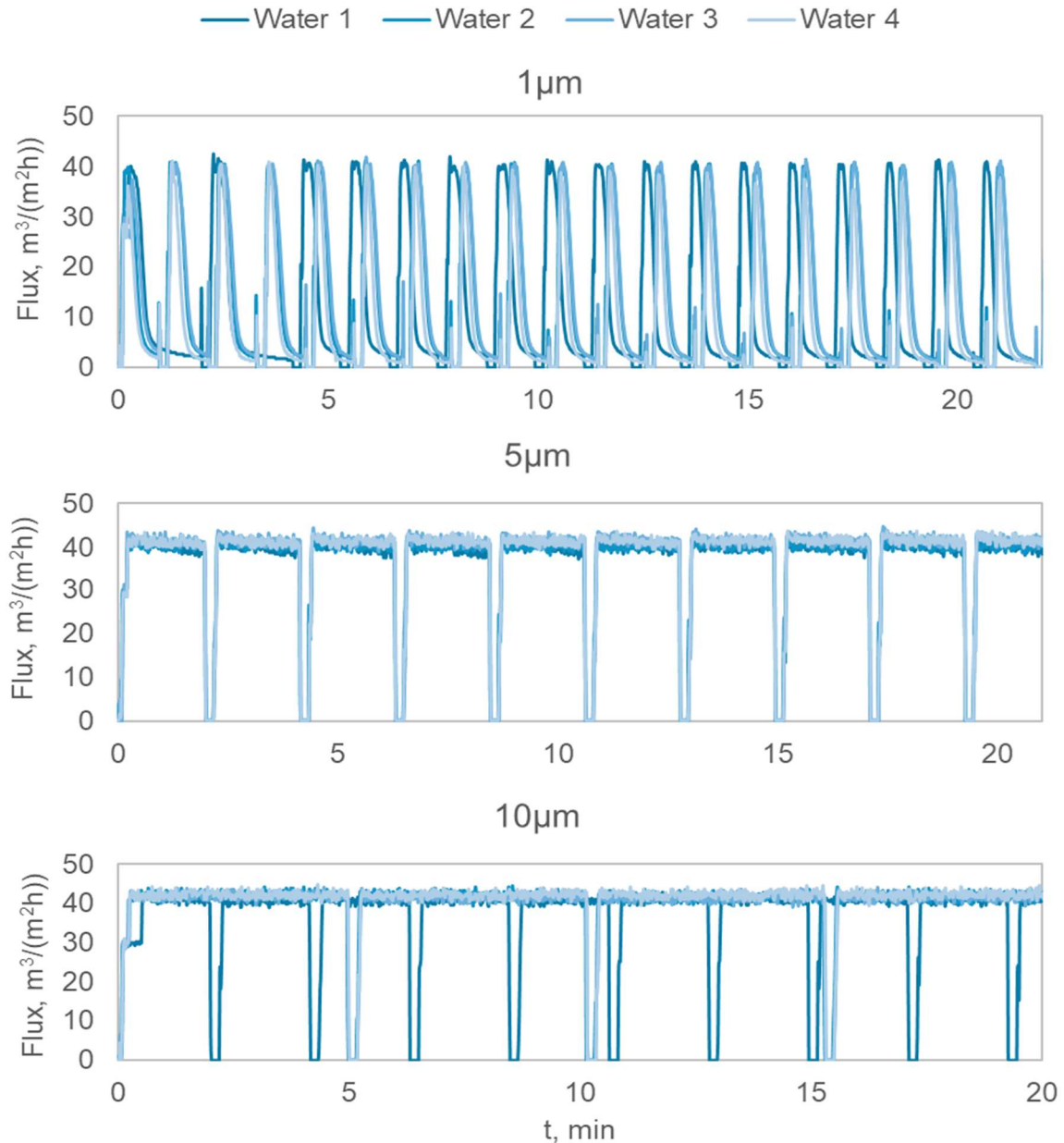


Figure 4a. Filtration capacities of 1, 5 and 10µm filter elements in filtration of tailings thickener overflows (waters 1–4).

With waters 5–8, the filter elements behaved somewhat differently (Fig. 4b). Water 8 was not filtered successfully with the 5µm filter element probably due to higher TSS, and therefore the 20µm filter element was tested in addition to 10µm filter element. The 0.3µm filter element was not even tested because the filtration with the 5 µm filter element was unsuccessful.

With waters 5–7 the 0.3µm filter element was clearly clogged more easily than the other filter elements, and even the self-cleaning did not completely restore the flux, at least with the parameters (duration of ultrasound, air pulse and reject opening) used in this study.

The flux of the 5µm filter element was roughly at the same level for waters 5–7, and the self-cleaning restored the flux efficiently. When the filtration capacity of the 5µm filter element is viewed for the waters 1–4 and 5–7 as two groups, it can be noticed that the flux for the waters 1–4 remains at high level for the whole filtration cycle, whereas for the waters 5–7 the flux declines fast during the filtration cycle. The TSS values (Table 1) cannot explain this difference, but the particle size distribution might be the explanation (Fig. 3). For the waters 1–4, the particle size distributions are much narrower than for the waters 5–7. Because the smallest particles are roughly the same size in all the tested waters, narrower particle size distribution means that all the particles are smaller than in case of wider distribution, whereupon there are also larger particles present. It can be speculated, that the larger particles, roughly >30µm are the ones that clog the 5µm filter element, and <30µm particles pass the filter element more freely.

In case of the 10µm filter element, water 8 clearly stands out, because the flux was smaller than in filtration of waters 5–7 and it also decreased during the filtration cycle. However, the self-cleaning worked efficiently also in that case. The filtration of water 8 with the 20µm filter element started with a stable flux, but soon the flux started to decline during the filtration cycles, meaning that the filtration was too short to reveal the filtration capacity in a longer or continuous filtration.

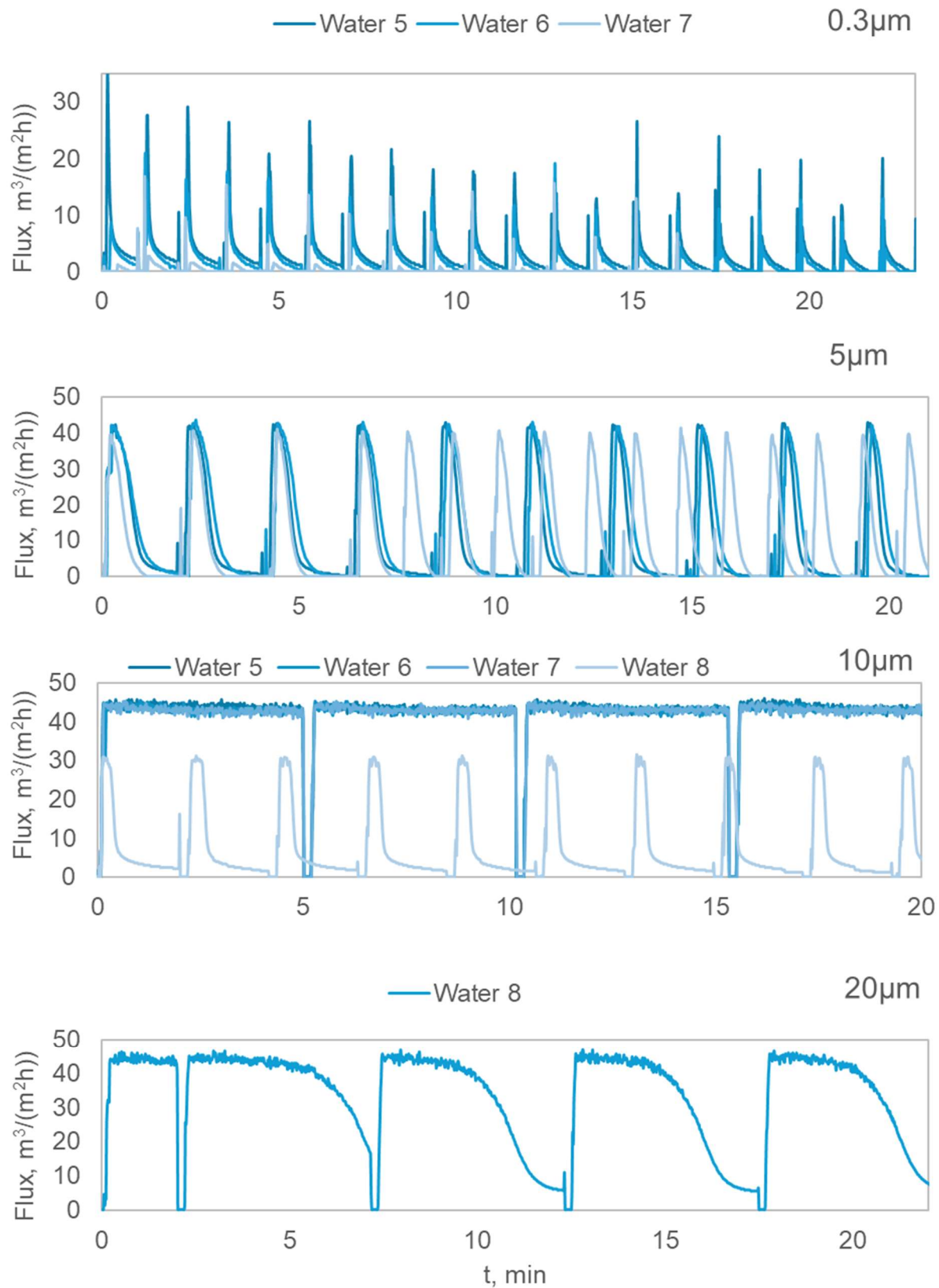


Figure 4b. Filtration capacities of 0.3, 5, 10 and 20µm filter elements in filtration of tailings thickener overflows (waters 5–8).

Filtration capacity seems to be more dependent on the filter pore size than the slight variation of solid content (in waters 1–7). However, clearly higher solid content in water 8 impacts the filtration capacity significantly.

3.3 Purification of the tailings thickener overflows

TSS retentions in filtrations of waters 1–4 were moderate, i.e. 0–56%. Although, or because, the TSS levels were rather low in the feeds, the observed filtrate quality was to be expected (Fig. 5). Even with the 1 μ m filter element the separation efficiency was low, although the flux decreased during the filtration (Fig. 4a) and the filter resistance clearly increased due to the solid particles in the feed.

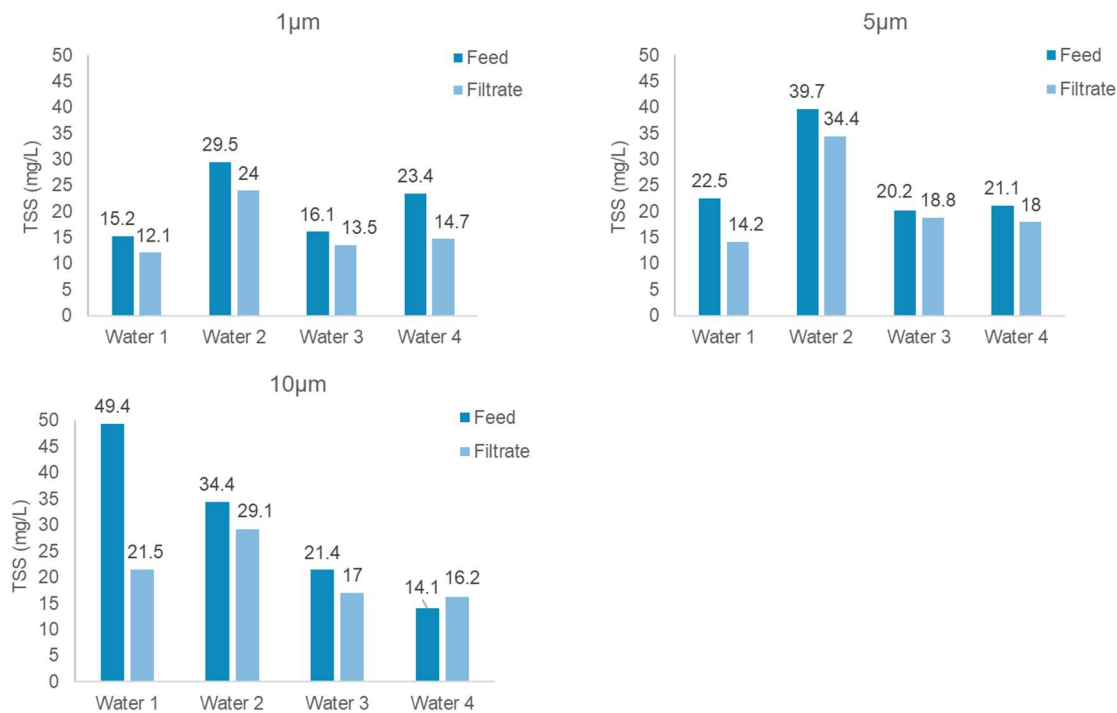


Figure 5. TSS values in feed and filtrate samples of 1, 5 and 10 μ m filter elements in filtration of tailings thickener overflows (waters 1–4).

TSS retentions in filtrations of waters 5–8 were higher, 60–100%, which led to clearer filtrates (Fig. 6) even when the feed TSS was low. Most probable reason for this is the wider particle size distribution and therefore the presence of larger particles in the waters 5–8 than in waters 1–4 (Fig. 3). As discussed before, the smallest particles can easily pass the filter elements at low solid concentrations because a cake does not form on the filter surface. When larger particles are present, at least they are rejected by the filter element, which can be seen in higher retentions, but also may increase the retention of the smaller particles compared to the situation where only small particles are present.

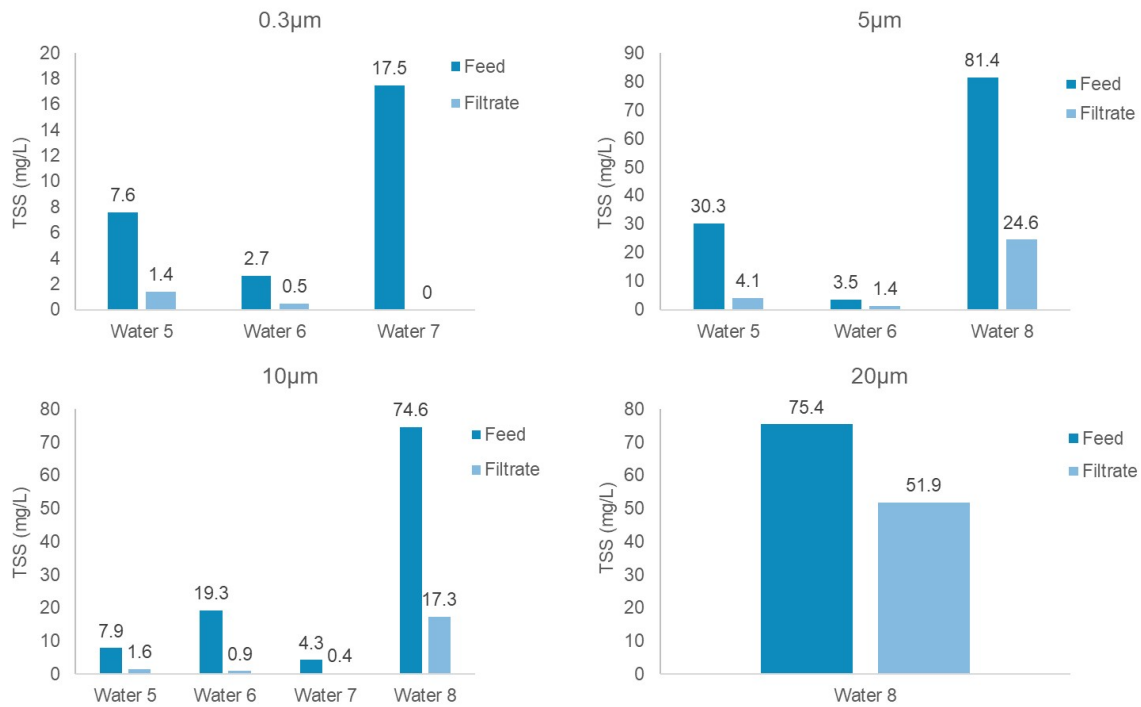


Figure 6. TSS values in feed and filtrate samples of 0.3, 5, 10 and 20µm filter elements in filtration of tailings thickener overflows (waters 5–8).

4 Conclusions

The tailings thickener overflows had somewhat different particle size distributions depending e.g. on the ore used in concentration process. The solid content variation in the overflow waters was more likely due to changes in the sampling of the overflow than the ore or changes in the flotation chemicals and did not affect the filtration performance, except with the clearly higher TSS value in water 8, which caused lower filtration capacity than with the other waters.

The amount of solids mainly affected the filtration capacity, whereas the particle size distribution affected both filtration capacity and solid retention; larger particles were retained by the filter element and increased filtration resistance leading to decreasing filtration capacity.

Removal of solids from tailings thickener overflow is possible by the Sofi Filter®. One of the best results, 95% solid removal and 41m³/(m²h) flux, was obtained with 10µm filter element and water 6. Selection of suitable filter element micron rating is essential to obtain optimal filtration capacity. Overflow waters having wider particle size distribution and larger particle size could be purified more efficiently than the overflow waters with narrower particle size distribution.

The self-cleaning of the Sofi Filter® worked very well in most of the filtrations.

Acknowledgements

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