Assessment of Screen Filters for Algae Removal from Treated Wastewater

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Abstract

Fine screen filters have the potential to provide economic and environmental benefits over the currently used methods for algae removal in rural wastewater treatment plants. These benefits would include providing savings in both capital and operational costs, and a reduced environmental footprint. To assess the effectiveness of these fine screens at removing algae, trials of the screen filters were conducted with varying screen mesh apertures, water qualities and differential pressures. The water samples collected from these trials were then tested for several water quality indicators. The results have demonstrated an inconsistent effluent quality, that is not of the standard required to consider replacing media filters for screen filters.

1 Introduction

The change in rainfall patterns along with rising populations in Western Australia has meant that continual focus is being placed on recycling wastewater. Due to public concern regarding drinking recycled wastewater (Kemp, et al., 2012), non-potable reuse is currently the only widely accepted method of reusing wastewater. For this reason non-potable wastewater reuse has been a major focus of the Water Corporation.

For rural communities in Western Australia, water reuse for irrigating ovals, golf courses and other public grassed areas has occurred for decades. Almost 40% of Western Australian rural towns reuse some portion of their treated wastewater (Water Corporation, 2013). In rural areas, waste stabilisation ponds (WSPs) are the most commonly used wastewater treatment technology. These ponds utilize natural physical, biological and chemical processes, such as algal photosynthesis, to treat wastewater (Spellman & Drinnan, 2014).

After treatment, this water is then often held in storage dams which may have conditions that allow algae to further thrive. A high algal population in reuse water can create odours, increase the rate of chlorine decay, hinder disinfection and block or foul pipes, tanks and sprinklers (Tchobanoglous, et al., 2014; Water Quality Branch, 2015). Additionally, some algal species (i.e., blue-green algae/cyanobacteria) may produce cyanotoxins, which have the potential to cause illness when coming in contact with humans or livestock (Paerl & Otten, 2013). Therefore, after treatment has occurred in the WSPs it is important to remove this algae presence prior to reuse applications.

Currently, the most common methods used by the Water Corporation for algae removal is through the use of either media filtration or ultrafiltration. These methods both require expensive initial investment and when compared to screen filtration, the operational costs are significantly greater. The effluent produced by the filtration is then dosed with chlorine for disinfection of remaining pathogens. Although expensive, these media and ultrafiltration methods have been proven effective in the filtration of algae and other solids. As media filtration is cheaper and less effective then ultrafiltration, it is more likely to be substituted by a screen filtration system.

1.1 Screen Filtration

Screen filters are currently employed at many of the Water Corporation's treatment plants to provide an initial filtration of the stored effluent prior to a secondary stage of finer filtration. These screen filters typically contain mesh screens of 300μm apertures, such as the one at the Beverley Reuse Compound, and are placed prior to the media filter. The purpose of these screens is to: 1) prevent larger solids from clogging the secondary fine filters, 2) reduce the potential for damage, and 3) reduce the frequency of backwashing in secondary filters.

Recent breakthroughs in screen filter technology have included self-cleaning mechanisms and the fine Dutch weave wire mesh configurations. Self-cleaning mechanisms eliminated the requirement to stop the water flow through the filter when cleaning the screen, and reduced the level of maintenance required. The Dutch weave wire configuration (Figure 1) provides high particle retention whilst not significantly compromising the open area and the pressure drop experienced through the filter (Allhands, 2005; Sutherland & Chase, 2011).

The choice of appropriate screen depends on three water quality factors as specified in a paper by screen filter manufacturer Amiad (Allhands, 2003). These are:

- The concentration of suspended solids.
- The particle size distribution.
- The clogging factor of the materials present in the water, which is dependent on the nature of the materials.

Automated self-cleaning screen filters are available with screen mesh apertures down to the size of 10µm. As algae sizes can be as small as 1µm (Rogers, 2011), the outcome of this project will be influenced by the types and sizes of algae present in the stored water.

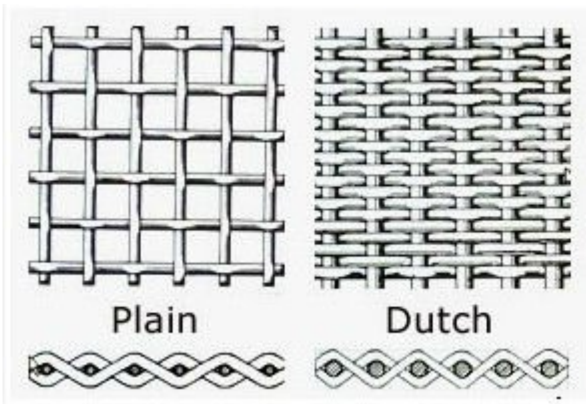

Figure 1 A plain weave compared to a dutch weave wire mesh configuration (Heibei Hangjin Wire Mesh Co., 2016)

Additional factors that could impact the the performance of screen filters include caking and the feed pressure. Caking occurs as trapped suspended solids build up on the screen, reducing the flow through area and increasing the surface area on which suspended solids can be trapped. It is influenced by the nature of the suspended solids and the backwashing rate. The occurrence of caking can be inferred by a rising differential pressures across the filter and if desired this sediment can be removed by performing a backwash (Hamilton, 1998; Allhands, 2003). Feed pressure has been found to be inversely proportional to the suspended solid removal efficiency of coarse media filters (von Sperling, et al., 2007). Although this study was performed on media filters, there could potentially be similar effects with screen filters and therefore the feed pressure will be kept constant.

A trial study undertaken by Amiad (Hamilton, 1998) summarises four different case studies where 10µm screen filters are used in the Amiad SAF models (the same model which will be used in this project). This paper demonstrated that the filter was highly effective at removing low levels of suspended solids in a well, reservoir and canal where suspended solids were primarily inorganic. In these cases the removal rate of total suspended solids ranged from 76-97%. However, in a natural river where suspended solids were primarily organic solids, the removal rate of the suspended solids was found to be just 19% (Hamilton, 1998).

This study compares the algae removal rates of screen filtration and media filtration to determine whether screen filters could be a viable substitute. The influence of the size of mesh aperture, feed water quality and the differential pressure across the filter on removal rates will be investigated. If deemed viable, the use of screen filters rather then media filters could significantly reduce the capital costs required to construct wastewater reuse plants.

2 Method

The Beverley wastewater reuse compound the site for the experimental trials. All water at this compound was already treated at a separate location by WSPs. This site was chosen because it had an Amiad SAF-3000 self-cleaning screen filter in operation and the storage dam showed a visibly high algal presence. Under normal operation, the screen filter is fitted with a 300µm Dutch weave wire mesh which provides the first step of filtration.

The primary inlet tank at this site receives water directly from the treatment pond, and overflows into the storage dam. Both the storage dam and the inlet tank water can be pumped through the screen filter, which allowed for trials to be run using two different water qualities. On standard operation the plant pumps inlet tank water through the screen filter. This is then dosed with alum and is pumped through one of four activated filter media (AFM) filters arranged in parallel. It is then dosed with chlorine on its way to the shire's storage tank.

Initial water samples were collected from the storage dam and inlet tank. These samples were tested for total suspended solids (TSS) and algae concentrations. Based on these results and using a particle size distribution (PSD) determined from a similar storage dam, mesh apertures of 10µm and 25µm were chosen to be tested and these were procured from Amiad. Samples both before and after the SAF filter were collected from the site using the 10µm, 25µm and the previously installed 300µm screens. These were collected using both water supplies, whilst attempting to maintain a constant feed pressure which fluctuated between 215kPa and 245kPa. In each trial when using the inlet tank water source, a sample was taken at a lower (0-20kPa) and higher (30-50kPa) differential pressure. Additional samples were also collected after the media filter.

Each sample collected was tested for TSS, PSD, chlorine demand, and algae type and concentration. TSS and the PSD were determined by an external laboratory (Microanalysis Australia). Chlorine demand was determined using a pocket colorimeter. Three readings were taken in the first hour and then approximately 24 hours and 48 hours later. A logarithmic curve was fitted to the data to find the demand at 30 minutes, 24 hours and 48 hours. Algae concentrations were determined using a Fluoroprobe (Beutler, et al., 2002). The removal rates or reduction values were calculated as the percentage reduction of the parameter. Outliers (removal rates that showed increases greater then 100%) were discarded.

3 Results and Discussion

3.1 Water Source Characteristics

The inlet tank and storage dam water sources had a number of key differences that may influence the screen filter's effectiveness. The dam sample generally had lower TSS values, that primarily consisted of blue-green algae species. The inlet tank had a greater TSS value on average and these solids were largely made up by green algae species. The PSDs of suspended solids in each water source varied significantly. Table 1 shows a summary of the PSD results obtained from these water sources. The D-values referred to are calculated as the particle size at which a certain percentage of suspended solids mass falls below (ie D(0.1) represents the particle size of which 10% of suspended solids are less then).

Averaged Size Distributions		
	Storage Dam (μm)	Inlet Tank (μm)
D(0.1)	10.32	9.44
D(0.5)	62.74	27.12
D(0.9)	177.41	77.75

Table 1 D-values of the Storage Dam and Inlet Tank. These values show a greater proportion of larger particles in the storage dam when compared to the inlet tank.

3.2

3.3 Results

Figures 2 and 3 show the determined removal rates of total suspended solids and algae for each filtration method. Positive values correlate to a reduction of the parameter. The TSS results indicate that the 10μm filter is the most efficient of the screen filters, whilst the higher differential pressure appears to slightly improve the efficiency of each screen's performance.

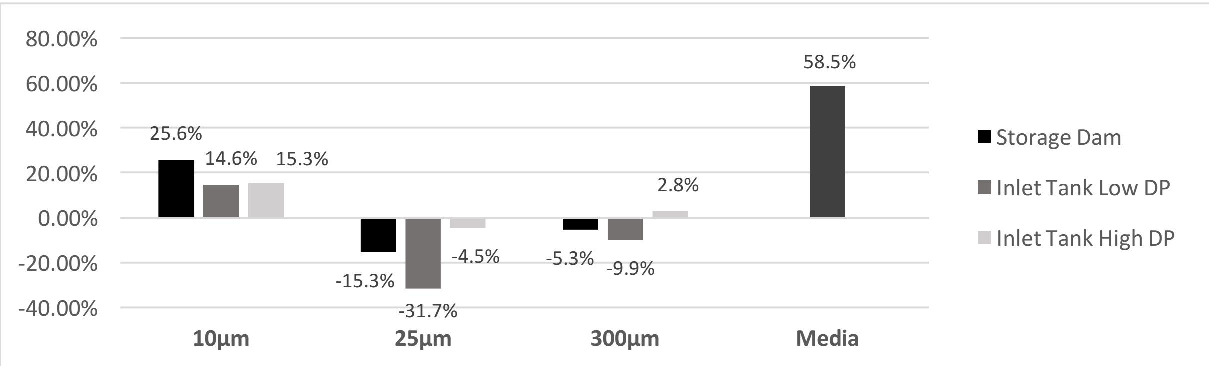

Figure 2 TSS removal rate at various mesh apertures, water source and differential pressure (DP) with media filtration presented for comparison.

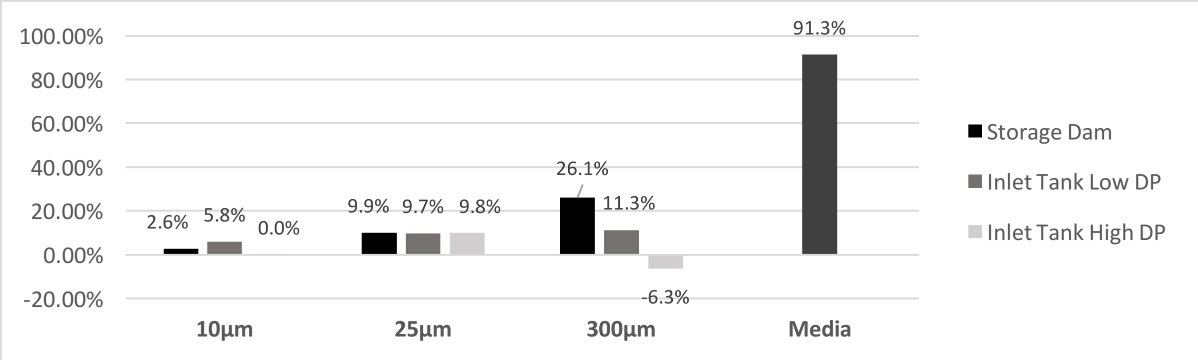

Figure 3 Algae removal rates at varying mesh apertures, water sources and differential pressure (DP) with media filtration presented for comparison.

The algae removal rates of the screen filters do not correlate with the TSS results, with the 25µm and 300µm screens achieving better removal rates then the 10µm. The media filters exhinited effectiveness and consistency, reducing the concentration of algae 91.3% on average and never falling below 82% removal efficiency. The reduction in chlorine demand is shown in table 4. Whilst all filters except the 300µm generally reduced the quantity of chlorine demanded, the effectiveness of the screen filters was inconsistent.

Reduction in Chlorine Demand					
			Inlet Tank		
		Storage Dam	Low DP	High DP	Media Filtration
10µm	30mins	4%	6%	0%	54%
	24hrs	7%	9%	19%	49%
	48hrs	7%	10%	21%	48%
25µm	30mins	25%	28%	-6%	21%
	24hrs	28%	21%	7%	22%
	48hrs	28%	21%	8%	22%
300µm	30mins	13%	-7%	1%	27%
	24hrs	8%	-8%	-10%	21%
	48hrs	7%	-8%	-11%	20%

Table 2 % Reduction of Chlorine Demand

3.4 Discussion

Given that the majority of the particles in the storage dam sample were greater then 30µm, it was expected that the screen filters could be able to filter a significant quantity of these solids. Although achieving removal rate of 25.6% of TSS when using a 10µm screen, the algae removal rate was only 2.6%. This suggests that whilst retaining the inorganic matter, the majority of algae is either breaking apart or changing shape to fit through the aperture when experiencing pressure against the mesh screen. The 25µm and 300µm screens retained less TSS then the 10µm screen, however with the storage dam water source the 300µm screen was able to remove 26% of algae species and the 25µm consistently reduced the algae concentration by between 9 and 10%. The lower differential pressure experienced by these larger aperture screens could be contributing to this increased removal of algae as there would be less pressure forcing the algae to breakdown or alter shape against the mesh screen. However, all of these removal rates are still less then half of the efficiency of the media filter. The most noticable difference is in the algae removal rates, where the slower gravity filtration of the media is able to retain 91% of algae on average. These high rates of TSS and algae removal then correlate to the consistency seen in the reduction of chlorine demand.

4 Conclusions and Future Work

The results indicate inconsistency in the algae filtering performance by screen filtration. Continuing analysis that will be undertaken over the next two months includes flow cytometry and microscopy analysis. This has the potential to identify which algae species are predominately avoiding filtration, as well as providing a view of the change in size and shape of the algae that is passing through the screen. It does not appear that screen filtration will be an appropriate substitution for media filtration for the purpose of algae removal. The best algae removal through screen filtration was obtained when using the 300µm aperture screen, which experienced the lowest starting algae concentration and the lowest differential pressure. Any future study in this area should focus on reducing the initial load experienced by the screen filter, potentially by running a number of screen filters in series.

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