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Helminth eggs removal by microscreening for water reclamation and reuse

S. Quinzaños, C. Dahl, R. Strube and R. Mujeriego

ABSTRACT

Irrigation with reclaimed water is becoming a practical alternative to conventional irrigation in semi-arid areas of the Mediterranean like Spain, but it requires a reliable treatment process to provide a safe water supply. Helminth eggs are one of the main concerns for the safe use of reclaimed water, as they can survive adverse environmental conditions and they are highly infective. Spanish water quality criteria and International guidelines set a limit of 0.1 eggs/l for water uses with unrestricted human exposure. Two microscreening processes have been tested to determine their potential for helminth eggs removal, after a conventional physic-chemical reclamation process. Hydrotech Drum and Discfilters®, provided with 10 μm pore size filter cloth, were tested to determine their efficiency for helminth eggs straining. An experimental test was conducted using 20 μm spherical latex particles, as surrogates for helminth eggs, to test the removal efficiency of a small full-scale drumfilter. In a subsequent laboratory test, actual *Trichuris suis* eggs were strained using a 10 μm pore size filter cloth from a discfilter. Results from both tests indicate that drum and discfilters are able to achieve 99% removal efficiency for spherical latex particles and a complete removal for helminth eggs in reclaimed water.

Key words | helminth eggs, microscreening, water reclamation

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INTRODUCTION

Natural water sources are becoming increasingly scarce in Mediterranean semi-arid countries such as Spain. In this context, agricultural and landscape water irrigation with reclaimed water is an attractive alternative which diminishes the demands on conventional water sources, offering the possibility to use them for drinking purposes and promotes environmental protection and enhancement. However, reclaimed water must be adequately treated in order to become a safe water source with respect to human health protection (Fatta & Kythreotou 2005). Among the waterborne disease-causing pathogens present in treated wastewater, helminth eggs have been pointed out among those posing a major health risk for humans, due to their ability to survive in adverse environmental conditions, their minimum infective dose and the limited human capacity to develop self-immunity (Westcot 1997). Both Spanish proposed water quality criteria (MMA 2006) and the World Health Organization recommendations (WHO 2006) are becoming increasingly stringent concerning the helminth eggs limits in reclaimed water, proposing an upper limit of 0.1 egg/l for water uses with unrestricted human exposure. Therefore reclamation processes must be designed to achieve an efficient and reliable removal of helminth eggs, before reclaimed water is supplied for reuse.

The main objective of this paper is to determine the potential of microscreening technology for the removal of helminth eggs in treated water, taking into account two critical parameters, i.e. the differential pressure and the pore size of the filter cloth. Specifically, the paper focuses on evaluating the performance of Hydrotech Drum and Discfilters®, equipped with 10 μm pore size filter cloths, for removal of helminth eggs in reclaimed water. The main

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advantages of drum and discfilters are their small footprint and their fine filter openings (Persson *et al.* 2003), which act as a physical barrier for helminth eggs, by straining them during the surface filtration process. A two-phase experimental study was conducted to determine the efficiency of those microscreens to remove helminth eggs from water.

DRUM AND DISCFILTER TECHNOLOGY

Microscreens are low speed filtration devices that ideally operate under gravity flow conditions (Tchobanoglous *et al.* 2003). Hydrotech Drum and Discfilters® are microscreens in which a woven polyester filter media acts as physical barrier for particles larger than the cloth's actual pore size. In discfilters, influent water is distributed from the central drum into the filter segments, where it is filtered on the inner side of the filter panels; in drumfilters, influent water enters through the periphery of a slowly rotating drum (Hydrotech 2005). Drum and discfilters have the same operation principle: particles larger than the filter openings (nominal pore size) are strained on the surface of the filter cloth and, as a result, the filter cloth becomes steadily clogged and the differential pressure across the screen increases. When the influent water level reaches an upper limit set by a sensor inside the drum, automatic backwashing is triggered and the filter cloth is rinsed by spray bars using high pressure filtered water (Hydrotech 2005). Figure 1 shows the discfilter process flow diagram.

The maximum differential pressure (headloss) across the filter cloth and the nominal pore size of the filter are

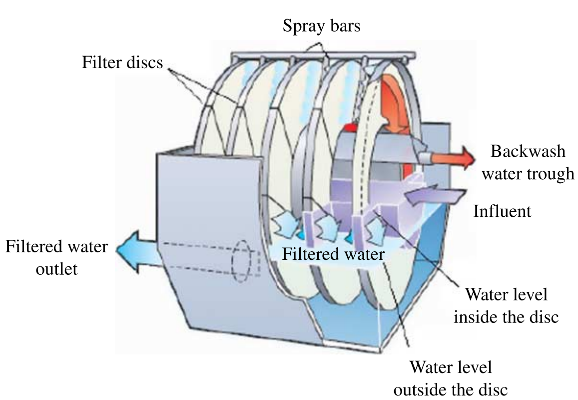

Figure 1 | The discfilter process flow diagram (Quinzaños 2006).

critical parameters for the helminth eggs removal efficiency of drum and discfilters. The maximum differential pressure can possibly affect the filter removal efficiency by distorting the shape of helminth eggs and consequently forcing them through the filter openings and into the filtered effluent. The choice of filter cloth pore size determines the minimum helminth eggs size that will be removed during the filtration process. The maximum differential pressure allowed in the microscreens used in this experimental study was 300 mm, similar to that adopted in full-scale applications. Microscreens with 10 μm pore size filter cloths were used in this study, because it was determined that 20 μm was the minimum size of helminth eggs detected in the Mediterranean region, based on literature review and consultations with experts (Quinzaños 2006).

MATERIALS AND METHODS

Bench test using 20 μm spherical latex particles

A small full-scale Hydrotech Drumfilter® (HDF 801) was used for testing helminth eggs removal efficiency from tap water. Bench scale tests were carried out in April 2006 at the Hydrotech facilities, in Vellinge (Skåne, Sweden). The dimensions of the drumfilter were 700 × 960 × 980 mm. It was built in stainless steel and equipped with a 10 μm pore size filter cloth. Test water entered the drumfilter through a rubber pipe connected to a steel inlet tank, with a holding capacity of 300 l. The microscreen was not provided with water recirculation.

The helminth eggs removal process was simulated by using spherical latex beads with a diameter of 20 μm (Beckman Coulter 2006), because their shape, size and density are very similar to those of helminth eggs. A vial containing 18 million of these particles was added to the inlet tank containing 180 l of tap water, as to achieve an estimated particle concentration of 100,000 particles/l. Tap water was used because of its availability and similar characteristics to those of reclaimed water (almost free of particles with size equal or larger than 10 μm, which prevents filter cloth clogging). Gentle mixing was applied to the tank to ensure a uniform distribution of particles.

Microscreen operation started immediately after addition of the 20 μm particles to the inlet tank. Influent water entered the drumfilter and it passed through the 10 μm pore size filter cloth. Water level inside the drum remained almost constant, since no large solids were present and backwashing was set to occur continuously. Operation of the drumfilter was maintained at a constant flow of 2 l/s (~7.2 m^3/h) equivalent to a 24 m/h filter cloth flux rate based on the entire filter area.

Water samples were collected manually at three different sampling points, simultaneously: inlet tank, inside the drum and outlet pipe. Three samples were taken at each sampling point. Reject water was also sampled once.

Sample analysis was performed on site, using a light-blockage particle counter HLAC ROYCO *9064*, Sampler *3000A*. The sensor, HRLD-*600*, was calibrated for the 2–500 μm size range. Particle counters sensors detect the percentage of light blocked by each particle and send a pulse proportional to particle size. Particles are therefore grouped into intervals according to their size (Gregory 2005). The particle size interval of most interest in this test was that covering the 19–21 μm range. Four particle size measurements were made on each 10 ml water sample analyzed; the first measurement was systematically discarded. The particle removal efficiency (% Rem.) for different size intervals was estimated based on inlet and outlet concentrations (N_{in} and N_{out}, respectively), using the following formula:

$$\% \text{ Rem.} = (1 - N_{out}/N_{in}) \times 100$$

Laboratory test using *Trichuris suis* eggs

Helminth eggs removal by a 10 μm pore size filter cloth was tested using a filter cloth disc in the laboratories of the Royal Veterinary and Agricultural University (KVL, acronym in Danish) in Copenhagen in May 2006.

Filter cloth discs were prepared from a larger piece of filter cloth, identical to that used in Hydrotech Drum and Discfilters®, with a 10 μm pore size (filter opening). The cloth filter disc had a diameter of 7.6 cm and was attached to the bottom of a plastic cylindrical test tube of 29 cm of height. The tube holding capacity was therefore one litre and the maximum differential pressure over the filter was 290 mm.

Tests were performed using suspensions of helminth eggs from the specie *Trichuris suis* (Figure 2). Those eggs are among of the smallest helminth eggs observed in the Mediterranean region, their width ranging from 21 to 31 μm (Thienpont *et al.* 1986). In addition, among the helminth species affecting humans, *Trichuris* species are the third most common helminth species in wastewater. The eggs were collected *via* the rectum of an infected pig kept at the KVL's farm.

Helminth eggs had to be separated from the faeces, before tests could be conducted. The separation process was performed by the method normally used at KVL. First, the faeces was filtered through two consecutive sieves (112 and 90 μm); the liquid sample obtained (5 l) was allowed to settle during two hours and then the supernatant was extracted with a vacuum pump until the volume was reduced to one litre. This volume was distributed into 16 tubes of 50 ml each that were subsequently centrifuged at 1,200 rpm during 7 min.; the pellets obtained by centrifugation were mixed in four tubes of 50 ml each. These four tubes were filled up with a glucose-salt solution and centrifuged again, to promote egg flotation. After this second centrifugation step, aliquots from the top layer of the tubes were analyzed under microscope to confirm the presence of eggs. The top layers of the four tubes were extracted and mixed together to produce a final 30 ml egg suspension sample (Figure 3).

A total of 10 aliquots of 30 μl each, prepared from the final 30 ml suspension sample, were counted under

Figure 2 | *Trichuris* eggs (CDC image).

microscope at a 10 × magnification; the average and standard deviation were estimated at 86.2 and 6.2 eggs, respectively. A water sample containing 1,000 eggs/l was prepared by adding 350 μl of the final suspension sample to one litre of tap water. The cylindrical test tube ($r = 6.7$ cm; $h = 29$ cm), with the 10 μm pore size filter disc attached to its bottom, was filled with a one litre sample. The sample was kept inside the tube for a few seconds, to simulate the differential pressure produced by inlet water in drum and discfilters full scale installations (max. 300 mm) and then filtered through the 10 μm pore size filter disc. This operation was repeated eight times with different 350 μl aliquots.

Finally, water collected from the filter disc filtration (effluent water) was analysed using the centrifugation method previously described, but without addition of the salt-glucose solution. Final samples (<5 ml) were observed under microscope in search of any *Trichuris* eggs that might be present.

RESULTS AND DISCUSSION

Bench tests indicate that the Hydrotech Drumfilter® equipped with the 10 μm pore size filter cloth achieved removal efficiency higher than 98% for particles within the size range of interest 19–21 μm, for the three samples analysed. The average removal efficiency was estimated at 99% with a standard deviation of 0.83 (Table 1, Figure 4).

Since the 20 μm latex particles used for the test belong to the 19–21 μm range, it can be concluded that a drumfilter microscreen with 10 μm pore size filter cloth should be an efficient process for removing spherical latex particles of 20 μm of diameter. Moreover, as most helminth eggs are round-shaped and 20 μm is the shortest dimension of the smallest helminth eggs known in the Mediterranean region (Thienpont *et al.* 1986), it can be concluded that a drumfilter microscreen with 10 μm pore size filter cloth should be an efficient process for removing helminth eggs from reclaimed water, with a 99% removal efficiency for 20 μm size particles.

Figure 4 indicates a slight decrease of removal efficiency for particles larger than 20 μm. This result can be explained either by the particles breakage during the filtration process or by a preferential orientation of the irregularly shaped particles naturally present in tap water, which interferes with the counting method. However, removal efficiency estimates become really significant as the difference between the number of particles in the inlet and the outlet of the process gets larger. Since concentration of particles larger than 20 μm in tap water is quite rare, estimates for the removal efficiency out of the range 19–21 μm are not significant and can therefore be ignored. The irregularly shaped particles naturally present in tap water could also influence the

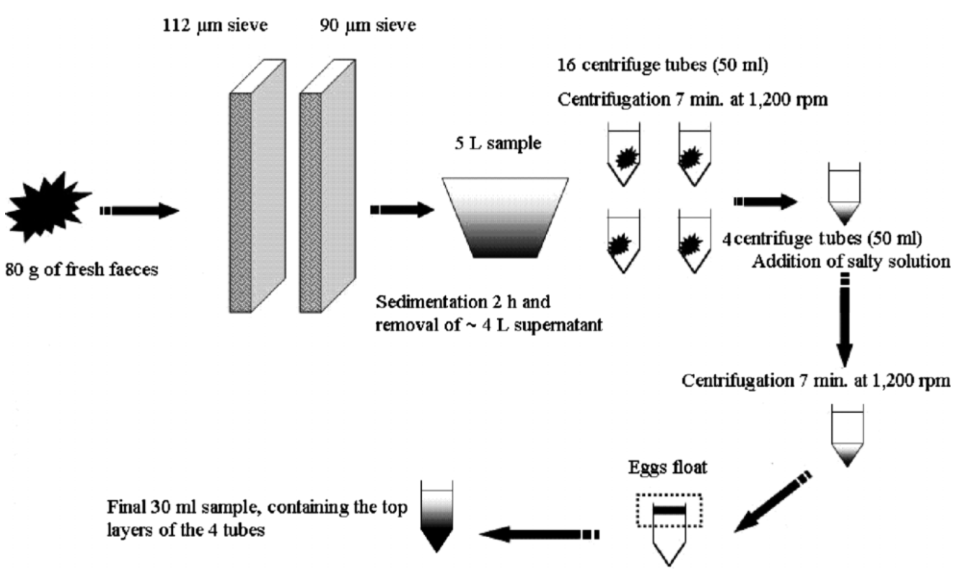

Figure 3 | Sketch of the separation of *Trichuris* eggs from faeces.

Table 1 | Concentration of particles within the size range 19–21 μm in the inlet and outlet flows of the drumfilter after addition of the 20 μm latex particles suspension, in the three samples analyzed. Removal efficiency observed with every sample, and average removal efficiency and standard deviation for the three samples

Sample n°	In (N/ml)	Out (N/ml)	Rem. (%)	Rem._av (%)	Std_dev
1	74.37	0.57	99.23		
2	75.83	0.30	99.60	98.95	0.83
3	77.13	1.53	98.02		

removal efficiency of the range 19–21 μm and show 19–21 μm particles in the filtered water due to passing through the filter cloth by orientation according to their shortest dimension during filtration. Therefore the 99% removal efficiency for the 20 μm beads could have been higher.

The results of the second experimental phase indicate that the 10 μm pore size filter cloths were able to remove 100% of the *Trichuris suis* eggs present in the samples that were filtered, since no eggs were found in any of the eight test's replications carried out. These results are statistically robust because the *Trichuris suis* eggs concentration in the inlet flow was very high (~1,000 eggs/l) and the test was repeated eight times to increase statistical significance.

Straining was the main separation mechanism responsible for removal of *Trichuris suis* eggs from water. Figure 5 shows *Trichuris suis* eggs retained by the close-woven net provided by the 10 μm pore size filter cloth. Furthermore, *Trichuris suis* eggs were measured under microscope and their shortest dimension–the width- was 20 μm, in agreement with the dimensions reported in the literature (Thienpont *et al.* 1986).

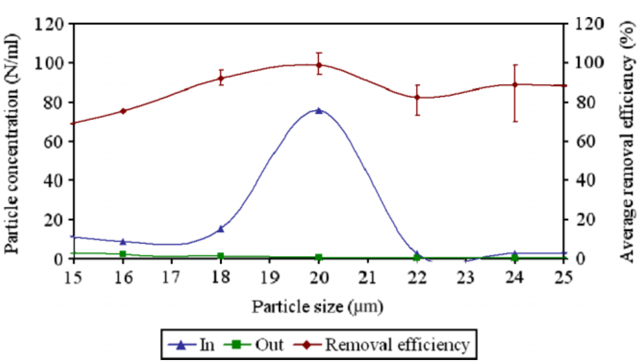

Figure 4 | Particle size distribution in the inlet of the drumfilter and outlet flows and removal efficiency for particle sizes within 15 and 25 μm, as a function of particle size. Each size interval in the figure is represented by its average size. Error bars indicate the maximum and minimum values of the removal efficiency.

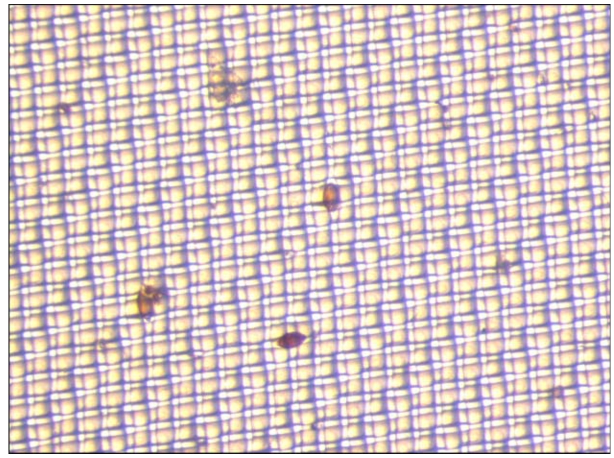

Figure 5 | Close view of *Trichuris suis* eggs blocked on a 10 μm pore size filter cloth. Note that the threads in the filter cloth have a thickness of approx. 35 μm and therefore are thicker than the 10 μm openings. This gives an approx. 5% open area in the filter cloth. The picture was taken by optical microscope and subsequently enlarged.

The helminth eggs removal efficiencies observed during the laboratory experiments can be extrapolated to full-scale drum and discfilter microscreens, for several reasons. First, the critical parameters for helminth eggs removal by filter cloth microscreens are pore size and maximum differential pressure: the values experimentally adopted for both parameters (10 μm and 290 mm, respectively) are those used in full-scale facilities. Second, since straining is the main separation mechanism and the helminth eggs species used (*Trichuris suis*) is among the smallest observed in the Mediterranean area, it is reasonable to expect a complete removal efficiency for helminth eggs of larger sizes. And third, the tests were carried out under unfavourable conditions for eggs removal, by using a water source (tap water) with a low concentration of particles larger than 20 μm and thus a low tendency for floc formation. As a result, helminth eggs removal in full-scale facilities can be expected to reach even larger values when influent waters have greater concentrations of larger particles and where the helminth eggs will be captured in larger flocs.

CONCLUSION

Filtration by drum and discfilter microscreens has been found to be an efficient treatment process for helminth eggs removal from water, based on the two phases experimental study carried out. During the first phase, a small full-scale drumfilter equipped with a 10 μm pore size filter cloth achieved a 99% removal efficiency of 20 μm spherical latex particles, used as surrogates for helminth eggs. During the second phase, a 7.6 cm filter disc of a 10 μm pore size filter cloth, like those used in drum and discfilter microscreens, achieved a 100% helminth eggs removal efficiency, using a 1,000 eggs/l suspension of the *Trichuris suis* species. The similarity of pore size (10 μm) and differential pressure (290 mm) between the filters adopted in this study and those used in full-scale drum and discfilters allows an extrapolation of the removal efficiencies observed in the laboratory tests to those achievable by actual full-scale microscreens.

Drum and discfilters have the potential to become essential elements of water reclamation processes, by ensuring a highly effective removal of helminth eggs and thus providing a safe water source, i.e. reclaimed water containing practically no helminth eggs.

Considering the relevance of helminth eggs as a quality parameter for water reclamation and reuse, further investigations should be conducted to confirm the removal efficiency of microscreening filter cloth processes, such as those considered in this study, with special emphasis on determining the ability and reliability of full-scale facilities in achieving the helminth eggs removal efficiencies observed in this study.

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