Helminth Eggs Removal in Water Reclamation: Disc Filtration as an Effective Barrier

Authors: J. Sanz, R. Strube, S. Quinzaños, C.P. Dahl, I. Montoliu, M. Gracenea, R. Mujeriego

Presenter: Joan Sanz
Technical manager-Veolia Water Solutions & Technologies-Spain

Abstract

Increasing reuse of reclaimed water for unrestricted agricultural and landscape irrigation is raising considerable concern for human health protection due to the potential spread and contact with human parasites and pathogens. Parasites pose a significant public health concern and the removal of helminth eggs is becoming a crucial treatment step when providing safe reclaimed water. Although laboratory tests conducted so far indicate that microscreens can efficiently remove helminth eggs, convincing evidence was missing on the ability of full-scale processes to achieve such objective. This paper presents the results of a demonstration project conducted to validate the efficiency and the reliability of a gravity microscreening filtration process using the Hydrotech Discfilter, with a 10-µm pore size cloth, as a physical barrier for removing parasitic helminth eggs in full scale water reclamation plants. Tests were conducted at the Baix Llobregat Water Reclamation Plant in Barcelona (Spain) in May-June 2007. About 2 million helminth eggs of the Trichuris suis species were added to reclaimed water (7.6 m³ close recirculation system) and subsequently filtered through a Hydrotech Discfilter with 10-µm pore size cloth. A total of 68 samples of reclaimed water (34 influent samples of 20L, and 34 effluent samples of 100L) were analyzed using an adaptation of the Bailenger modified method, as recommended by WHO in “Wastewater analysis for agricultural use” by Ayres & Mara. Several changes to the modified method were applied at the Faculty of Pharmacy of the University of Barcelona, to improve the method recovery efficiency. Those adaptations resulted in an absolute recovery efficiency of up to 80-90%, considerably larger than the 30-74% recovery achieved by the recommended Bailenger modified method. Those recovery improvements were achieved by using a sample volume higher than that recommended, by omitting the grease extraction step, by analyzing total water sample volumes, and by counting all the helminth eggs present in a McMaster chamber. Results clearly showed that the Hydrotech Discfilter effluent had no helminth eggs, regardless of the helminth egg concentrations entering the filter (10–3200 eggs/20L), with the exception of one sample in which a 1egg/100L concentration was detected. Those results also confirm the high efficiency (up to 4.2 ulog for 100L samples) and reliability (3.5 ulog for 100L samples in 90% of the cases) of the parasitic helminth eggs retention process that takes places on the filter cloth. Those results illustrate the safety of the reclaimed water obtained, with parasitic helminth egg concentrations 10 times lower than the limit recommended by WHO guidelines (2006) and that established by the Spanish RD 1620/2007 (1 egg/10L). In summary, the Hydrotech Discfilter functions as an effective and reliable barrier against helminth eggs. Its small footprint, its low energy consumption and its simple operation and maintenance requirements make it a competitive and attractive technology for water reclamation and reuse. The full study report has been published by Veolia and is available at [www.veoliawaterst.es](http://www.veoliawaterst.es).
I. INTRODUCTION

The concentration of parasitic helminth eggs, as indicator of the sanitary risk associated to reuse of reclaimed water for unrestricted irrigation, is one of the water quality parameters included in the third edition of the Guidelines published by the World Health Organization (WHO) in 2006 and untitled “Guidelines for the safe use of wastewater, excreta and greywater”. WHO recommends a water quality limit equal or lower than 1 parasitic helminth egg per litre for the safe reuse of reclaimed water for unrestricted irrigation, and a more restrictive limit equal or below 0.1 parasitic helminth egg per litre when children younger than 15 years of age can be exposed to contact with reclaimed water.

The Decree RD 1620/2007 provides the regulatory framework for reuse of reclaimed water in Spain. Following WHO recommendations, those regulations establish a maximum limit of 1 intestinal nematode egg per 10 litres for diverse water reuse options in urban, agriculture, industrial, and environmental uses. Those limits are associated to a detailed monitoring procedure that includes, in most cases, a fortnightly sampling frequency for the parasitological control of reclaimed water.

The significant practical consequences of that parasitological monitoring requirement, such as the collection of a large water sample volume, the need for onsite water sample concentration, the services of a specialized laboratory, the considerable unit cost of the analyses, and the interpretation of the experimental results have stimulated the development of water reclamation processes able to remove effectively and reliably the parasitic helminth eggs that may be present in reclaimed water. The ultimate objective is to minimize the technical and economic efforts derived from a monitoring program based exclusively on an analytical follow-up of reclaimed water quality.

The characteristic size of parasitic helminth eggs (between 20 µm and 80 µm) highlights the potential that physical methods used for particle separation have for retaining this parasitic forms during the reclamation process. Specifically, cloth filters offer the possibility of retaining parasitic helminth eggs by means of the physical barrier they offer, and thus providing a practical way to comply with the limits established by Spanish regulations applicable to different uses of reclaimed water.

The Hydrotech Discfilter process was developed by Veolia Water Solutions and Technologies (patented in 2001) as a gravity filtration process based on a series of rotating cloth filters (Persson et al., 2006). In 2003, the Hydrotech Discfilter was officially granted recognition of his ability to produce reclaimed water in conformity with the requirements of Title 22 of California Reclaimed Water Quality Regulations (California Department of Health Services, 2003), with respect to turbidity and suspended solids concentration of reclaimed water.

The use of a Hydrotech Discfilter process, provided with a filter cloth of 10 µm pore size, offers the possibility to completely retain the parasitic helminth eggs that may be present in a water stream during its reclamation process. Studies conducted in the laboratory and with prototypes of the Hydrotech Discfilter process had already confirmed that hypothesis (Quinzaños, 2006; Quinzaños et al., 2008). In this context, it was of great practical interest to confirm this treatment efficiency, but under field operating conditions similar to those normally observed at a large scale water reclamation plant.
II. OBJECTIVES

The main objective of this demonstration project was to evaluate the efficiency and the reliability of a Hydrotech Discfilter process, provided with a filter cloth of 10 µm pore size, for retaining the parasitic helminth eggs present in a water stream during its reclamation process. The ultimate objective was to prove that the Hydrotech Discfilter process can effectively and reliably produce reclaimed water that is totally free from parasitic helminth eggs. The field evaluation of the Hydrotech Discfilter process was conducted during a 2-day large scale experiment, in May and June of 2007, at the Water Reclamation Plant of El Prat de Llobregat (Mujeriego et al., 2008) in Barcelona, Spain (Figure 1).

![Figure 1. Hydrotech Discfilter process at the Water Reclamation Plant of El Prat de Llobregat, Barcelona, Spain.](image)

III. METHODOLOGY

Parasitic helminth eggs were added to reclaimed water used in this demonstration project, because their concentration in secondary effluents from Spanish WWTPs is not high enough (Gracenea and Montoliu, 2007) to detect a statistically significant removal rate of helminth eggs during a reclamation process. A large number (approximately 2 million) of *Trichuris suis* eggs were added to the influent water tank of a demonstration water filtration system provided with two water tanks (influent and effluent) with a volume of 7.6 m$^3$ each. Arrangements were made to simulate parasitic helminth egg concentrations in the reclaimed water stream similar to the maximum values registered in the raw water influent to wastewater treatment plants in Spain (Gracenea and Montoliu, 2007).

The resulting seeded water was passed through the cloth filtration process and subsequently returned to the influent storage tank of the demonstration plant, together with the filter wash water flow, as to maintain a close water circuit and prevent the lost of any parasitic helminth egg from the demonstration system. The filtration process was kept in operation during 8 consecutive hours during each of the 2 days of the study, while 30-min composite samples were taken at the intake and outlet of the filtration process, during each of the 2 experimental days. The concentration of parasitic helminth eggs in every water sample collected was subsequently determined at the Laboratory of Parasitology of the Faculty of Pharmacy of the University of Barcelona.
IV. PARASITIC HELMINTH EGGS

The parasitic helminth eggs used in this demonstration project were provided (10 April 2007) by the Department of Veterinarian Pathobiology of the Natural Sciences School of the University of Copenhagen. The concentration of *Trichuris suis* eggs was verified by the Faculty of Pharmacy of the University of Barcelona, as well as their good condition, by means of microscopic observations of their morphology. The original sample of *Trichuris suis* eggs was kept in aqueous solution and refrigerated at 5°C until their transport to the Water Reclamation Plant of El Prat de Llobregat for the beginning of the experiments.

The parasitic helminth eggs used in this demonstration project were from the nematode species *Trichuris suis* (a pig’s parasite), for the following reasons:

1. The *Trichuris* species are among those most commonly detected in Spanish wastewater flows (Gracenea and Montoliu, 2007).
2. The eggs of the parasite responsible for human trichuriosis, *Trichuris trichiura*, are morphologically almost identical to those of *Trichuris suis* and they are considered by WHO as one of the three preferred bio-indicators for evaluating reclaimed water quality.
3. The eggs of *Trichuris* are among the smallest (according to their width) found in European raw wastewater [(50-68) µm of length and (20-31) µm width].

The tests conducted at the Faculty of Pharmacy of the University of Barcelona did confirm the satisfactory condition of the *Trichuris suis* eggs: the eggs were isolated, they did not show breaks, and were not attached (floc forming) to each other or to suspended particles. The eggs did not show any internal biological development, in the form of larvae or even in that of morula, and consequently there was no risk involved in the manipulation by humans, as they had no infection nature. Figure 2 shows a view of the eggs, as obtained by optical microscopy (480x magnification), while Figure 3 shows a micrograph of those same eggs, obtained by scanning electron microscopy (SEM).

![Figure 2. Optical microscopy views of *Trichuris suis* eggs in the sample seed used in the demonstration project, 65x32.5 µm (left), 65x27.5 µm (centre) y 60x32.5 µm (right).](image)
V. DEMONSTRATION PROJECT

5.1 Discfilter technology

Microscreens are low speed filtration devices that ideally operate under gravity flow conditions (Tchobanoglous et al, 2003). Discfilters are microscreens consisting of 1-20 filter discs with filter media on each side of the disc. A twill woven monofilament polyester filter cloth is the standard filter media for the Hydrotech Discfilter. Water flows by gravity into a central drum that supports vertically mounted discs covered with filter cloth on each side (Figure 4). During filtration, particles are retained on the inner side of the filter panels. The filtration principle is mechanical straining: 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 starts to rotate. Spray bars using filtered water at 7-8 bars rinse off the solids attached to the filter cloth. The rotation stops when the backwashing is finished. Backwashing typically requires 1-2% of the total water flow. About 55–60% of the filtration area is normally submerged. Filtration is continuous, i.e. filtration does not stop during backwashing. A low foot-print and a low energy consumption, as well as an easy operation, are the main advantages of this type of filter.

The two critical parameters determining helminth eggs removal by disc filters are: the maximum differential pressure (head-loss) across the filter cloth and the nominal pore size of the filter panels. The maximum differential pressure may distort the shape of helminth eggs and force them through the filter openings and into the filtered effluent. The maximum differential pressure adopted in this study was 200 mm, the level normally used for Discfilter operation. The choice of filter cloth pore size determines the minimum helminth eggs size that will be removed during the filtration process. Filter cloths with 10 µm pore openings were used in this study, because 20 µm is the minimum size of parasitic helminth eggs found in wastewater (Jimenez, 2007).
5.2 Demonstration Plant

The demonstration project was conducted using a Hydrotech Discfilter model HSF2204/1. The demonstration plant consisted of an inlet and an outlet tanks (7.6 m³ each), a pipe system, several recirculation pumps and a Discfilter unit (HSF 2204/1-1FN), provided with 28 filtration panels, made of polyester filter cloth with 10 µm pore size, and with a total filtration surface of 5.6 m² (Figure 5 and 6). The demonstration plant was covered with a temporary mobile tent (Figure 7), as to protect water samples from environmental conditions (rain and sunlight).
The water used as influent to the Hydrotech Discfilter demonstration project was the effluent from an Actiflo® process installed at the nearby Water Reclamation Plant of El Prat de Llobregat (Mujeriego et al., 2008) were it provides the first step of the water reclamation process. The El Prat de Llobregat water reclamation plant has a 300,000 m3/day (3.5 m3/s) capacity and includes: 1) ballasted coagulation-flocculation and lamella settling, using two lines of Actiflo process, with addition of coagulant, 130-150 µm sand particles, and polyelectrolyte, 2) filtration through 10 µm pore size microscreening using two lines of 5 Hydrotech filters each, operated at 10-14 m/h filtration rate, and 3) UV light disinfection, using four parallel channels, each with two banks of 200 lamps, making a total of 1,600 UV lamps. The water produced by the Actiflo® process was characterized by an average turbidity of 1.5 NTU, with a standard deviation of 0.4 NTU (34 samples), and an average suspended solids concentration of 2.8 mg/L, with an standard deviation of 0.5 mg/L (34 samples).

By using an Actiflo® effluent, as the influent water to the demonstration plant, it was possible to prevent the blockage of the Hydrotech Discfilter cloth, due to accumulation of suspended matter, and thus assure that parasitic helminth eggs retention was due exclusively to filtration trough the filter cloth and not to the combined effect of filter cloth and the filtration mat that could have formed over the filter cloth due to accumulation of suspended solids.

Experimental tests were performed during two days, by operating the Discfilter unit during 8 hours per day. Hydraulic loading rate during the test was 12.5 m/h, based on total filtration area. The Discfilter unit was operated in automatic mode (~ 50% backwash frequency, 200 mm head-loss) during the first 4 hours and in manual mode (100% backwash frequency, ~ 50 mm head-loss) during the last 4 hours of each day. This strategy allowed an evaluation of these two critical parameters of operation. The influence of head-loss was evaluated during operation in automatic mode, and the influence of the filter cloth alone was evaluated during operation in manual mode. Automatic mode implies that backwash is triggered when water level reaches the level sensor. Manual mode implies a continuous backwashing, i.e. the level sensor is turned off, and both rotation and backwashing are forced by a manual switch in the control panel. Backwash frequency is the ratio between backwashing time and total cycle time, i.e. backwashing time plus time between backwashes.
Both filtered water and rejection water were recirculated in order to avoid helminth eggs losses. Also, 2 m$^3$ of fresh reclaimed water were added to the system after the first testing day, in order to compensate the water volume taken out of the system during sampling.

![Demonstration plant setup](image)

**Figure 7. Demonstration plant setup, next to the Water Reclamation Plant of El Prat de Llobregat.**

VI. SAMPLING SCHEDULE AND PARASITOLOGICAL ANALYSES

Table 1 summarizes the sampling schedule of the demonstration project conducted at the water reclamation plant of El Prat de Llobregat between during May and June of 2007.

<table>
<thead>
<tr>
<th>Sampling point</th>
<th>Samples, day 1</th>
<th>Samples, day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent water</td>
<td>16 + 1</td>
<td>16 + 1</td>
</tr>
<tr>
<td>Effluent water</td>
<td>16 + 1</td>
<td>16 + 1</td>
</tr>
<tr>
<td>Total</td>
<td>32 + 2</td>
<td>32 + 2</td>
</tr>
</tbody>
</table>

Table 1. Sampling schedule of the demonstration project conducted at the Water Reclamation Plant of El Prat de Llobregat. May and June 2007.

Influent water samples (20 litres) and effluent water samples (100 litres) were 30-min composite water samples. Sampling water flow was adjusted as to collect a total of 20 and 100 litres of water, respectively, during each consecutive 30 minutes period. The composite sampling strategy ensured a systematic and continuous sampling of both influent and effluent waters, including periods with and without counter washing as well as periods with unexpected sudden changes in filtered water flow and quality.

All initial water samples, both from the influent and the effluent were concentrated by settling, at the demonstration project site, and subsequently reduced in volume by hydraulically forced extraction of
their supernatant, until water samples were brought down to a final volume of 5 litres (Figure 8). All plastic containers with the 5-litre samples were transferred to the Laboratory of Parasitology, at the Faculty of Pharmacy of the University of Barcelona, where they were analyzed according to the protocol previously established by Gracenea and Montoliu (2007).

![Figure 8. Extraction pumps and specially fitted pipe used for extracting water sample supernatant from influent water samples (left) and effluent water samples (right).](image)

The parasitological analysis of concentrated water samples was conducted at the laboratory, following the modified Bailenger method, as recommended by WHO in “Analysis of wastewater for agricultural use” (Ayres & Mara, WHO, 1996). The steps of this analytical method can be summarized as follows:

1. Concentration by sedimentation of final 5 litres sample.
2. Purification of the obtained sediment by a diphasic technique (ethyl ether plus an aceto-acetic buffer, pH=4).
3. Egg concentration by flotation (using zinc sulfate d=1.3).
4. Egg counting using a McMaster chamber and an optical microscope.

The Laboratory of Parasitology applied several adaptations to the modified Bailenger analytical method as to improve the efficiency of the helminth eggs recovery process. The main objective of those adaptations was to increase the absolute eggs recovery rate, up to 80-90%, as compared to the normal eggs recovery rate of 30-74% that can be achieved by the modified Bailenger method. The improved efficiency of the eggs recovery method was achieved by adopting the following four strategies:

1. Collecting water sample volumes larger than the 10 litre volume recommended by WHO: the water sample volumes collected were 20 litres for influent water, and 100 litres for effluent water.
2. Ignoring some steps of the parasitological method, such as the ether purification and the buffering solution (diphasic technique), because of the low concentration of oils and grease present in the water samples collected. This method simplification prevents the potential losses of parasitic helminth eggs during the mixing and extraction steps.
3. Observing the whole concentrated and homogenized (with zinc sulfate) water sample, as to obtain the total count of parasitic helminth eggs present and to obviate the need to estimate those counts by volumetric extrapolations from partial microscopic counts.
4. Observing the total water sample volume contained in the McMaster chamber, as to perform the analytical counting of the eggs present in the upper section of McMaster chamber frame and also those that have not floated and thus had remained at the bottom.

VII. RESULTS FROM DEMONSTRATION PLANT

Table 2 shows that the concentration of *Trichuris suis* eggs detected in influent water samples varied from 11 to 3,198 eggs/20L, with a 90-percentil of influent concentrations of 696 eggs/20L (equivalent to 35 eggs/L). On the other side, the parasitic helminth egg concentration in effluent water samples was nil in all cases, regardless of the influent concentration, except in one case, that of sample 9B, in which 1 egg was detected in a 100 L water sample.

Table 2 indicates that the Hydrotech Discfilter process is capable of retaining all the *Trichuris suis* eggs present in influent water, when they reach concentrations up to 3,198 eggs/20L. Considering that effluent water sample volume was 100 litres, those results can be interpreted as representing a minimum retention capacity of 4.2 ulog (log 15,990 eggs/100L). It is reasonable to consider that the actual retention capacity of the filtration process could have exceeded that limit, if the egg concentration in influent water had been higher. Considering that the concentration of parasitic helminth eggs observed in Spanish wastewater treatment facilities can reach up to 1,200 eggs/20L in raw wastewater and up to 7 eggs/20L in treated effluents (Gracenea and Montoliu, 2007), it can be postulated that the Hydrotech Discfilter process is capable of retaining all the helminth eggs present in Spanish treated wastewaters and producing an effluent actually free of parasitic helminth eggs.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Influent eggs/20L</th>
<th>Effluent eggs/100L</th>
<th>Sample</th>
<th>Influent eggs/20L</th>
<th>Effluent eggs/100L</th>
</tr>
</thead>
<tbody>
<tr>
<td>0A</td>
<td>3198</td>
<td>0</td>
<td>0B</td>
<td>301</td>
<td>0</td>
</tr>
<tr>
<td>1A</td>
<td>982</td>
<td>0</td>
<td>1B</td>
<td>42</td>
<td>0</td>
</tr>
<tr>
<td>2A</td>
<td>1108</td>
<td>0</td>
<td>2B</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>3A</td>
<td>813</td>
<td>0</td>
<td>3B</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>4A</td>
<td>543</td>
<td>0</td>
<td>4B</td>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td>5A</td>
<td>669</td>
<td>0</td>
<td>5B</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>6A</td>
<td>292</td>
<td>0</td>
<td>6B</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>7A</td>
<td>383</td>
<td>0</td>
<td>7B</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>8A</td>
<td>279</td>
<td>0</td>
<td>8B</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>9A</td>
<td>238</td>
<td>0</td>
<td>9B</td>
<td>66</td>
<td>1</td>
</tr>
<tr>
<td>10A</td>
<td>247</td>
<td>0</td>
<td>10B</td>
<td>62</td>
<td>0</td>
</tr>
<tr>
<td>11A</td>
<td>169</td>
<td>0</td>
<td>11B</td>
<td>56</td>
<td>0</td>
</tr>
<tr>
<td>12A</td>
<td>125</td>
<td>0</td>
<td>12B</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td>13A</td>
<td>183</td>
<td>0</td>
<td>13B</td>
<td>72</td>
<td>0</td>
</tr>
<tr>
<td>14A</td>
<td>96</td>
<td>0</td>
<td>14B</td>
<td>73</td>
<td>0</td>
</tr>
<tr>
<td>15A</td>
<td>59</td>
<td>0</td>
<td>15B</td>
<td>46</td>
<td>0</td>
</tr>
<tr>
<td>16A</td>
<td>61</td>
<td>0</td>
<td>16B</td>
<td>36</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2: Concentration of *Trichuris suis* eggs in influent water samples (20 L) and effluent water samples (100 L). Samples obtained during the first and the second experimental days are designated as A and B, respectively.
Aside from the actual reasons for detecting one egg of *Trichuris suis* in one of the 100 litres effluent samples (9B), it has to be noticed that such a concentration is 10 times lower than the maximum allowable limit recommended by WHO guidelines (WHO, 2006) for protecting children below 15 years of age that could be present in fields irrigated with water of such quality, and also the maximum allowable limit (1 egg/10L) established by Spanish regulations (RD 1620/2007) for the most restrictive uses of reclaimed water.

The experimental results obtained during the parasitic helminth eggs filtration process have been interpreted by means of a lognormal probability distribution (Mujeriego, 2005, Benjamin and Cornell, 1970). Figure 9 shows the lognormal probability distributions of the *Trichuris suis* egg concentrations in influent water samples (converted to 100L sample volumes) and in effluent water samples (directly obtained from 100L water samples) of the Hydrotech Discfilter process, as they are summarized in Table 2.

The lognormal probability distributions shown in Figure 9 lead to the conclusion that a parasitic helminth egg concentration in influent water equal or lower than 3,480 eggs/100L, as observed in 90% of the samples, results in a parasitic helminth egg concentration in the effluent lower than 1 egg/100L, resulting in a retention efficiency of 3.5 ulog for a 90-percentil. The effluent concentration observed in all cases is 10 times lower that the limit of 1 egg/10L required by Spanish regulations for the most restrictive uses of reclaimed water. Figure 10 shows a similar statistical evaluation, but using logarithmic values of parasitic helmint eggs per 100L volume (ulog/100L). The 90-percentil of the retention efficiency reaches 3.5 ulog, as referred to influent and effluent water samples of 100L volume.

Figure 9. Lognormal probability distributions of the *Trichuris suis* egg concentrations in the influent and the effluent of the demonstration plant.

Those experimental results indicate that the Hydrotech Discfilter, provided with a filter cloth of 10 µm pore size, is an effective and efficient physical barrier for preventing passage of the parasitic helminth eggs present in a water flow. Although the available experimental data only ensures an absolute retention of an influent parasitic helminth egg concentration of 3,198/20L (4.2 ulog referred to 100L effluent water samples), as reached during this demonstration project, it can be logically expected that
the Hydrotech Discfilter process would have equally retained higher parasitic helminth egg concentrations in the influent. Furthermore, the experimental results highlight the integrity of the system, the absence of critical points for the passage of helminth eggs by areas different than the filter cloths, and that actual differential filtration pressures (up to 200 mm in this project) were not high enough to force the passage of the eggs though the filter cloth pores.

![Discfilter Demonstration Plant](image-url)

**Figure 10.** Lognormal probability distributions of the egg concentration (in logarithmic units) of *Trichuris suis* in water influent and water effluent of the demonstration plant.

As an indication of the durability and reliability of the microscreen discfilters used in this demonstration project, it can be highlighted that the Water Reclamation Plant of El Prat de Llobregat includes 10 Hydrotech Discfilters, with a total filtration capacity of 300,000 m3/day (3.5 m3/s), that have been operating normally since its inauguration in 2004. Furthermore, the simple operating principles (rotation and pressure backwashing) and the high quality building materials (stainless steel) explain the excellent operating record of this technology, widely applied in water treatment plants around the world. Inadequate arrangements of backwashing flow streams and cloth disruption by accidental breakage during disks adjustment and replacement are the main causes of malfunctioning. However, online turbidity monitoring of filtered effluent provides an immediate indication of cloth deterioration. Finally, the official recognition granted to this microscreen discfilter technology by the California Department of Health Services (2003) further supports its ability to produce a high quality suspended solids and turbidity effluent in actual water reclamation facilities, as required by Title 22 of California Reclaimed Water Quality Regulations.

**VIII. CONCLUSIONS**

1. The Hydrotech Discfilter process, provided with a filter cloth of 10 µm pore size, is able to retain all the parasitic helminth eggs present in its influent water, when they reach concentrations up to 3,198 eggs/20L. Considering that effluent water samples volume was 100 litres, that removal efficiency represents 4.2 ulog (log 15,990 eggs/100L).
2. Although available experimental data only reflects an absolute retention of influent parasitic helminth egg concentrations up to 3,198/20L (4.2 ulg if referred to 100L effluent water samples), as observed during this demonstration project, it can be logically expected that the Hydrotech Discfilter process would have equally retained higher parasitic helminth egg concentrations if they had been present in the influent, in accordance with the active retention mechanism: the physical difficulty of parasitic helminth eggs to go across filter pores than are smaller than the eggs themselves.

3. Aside from the actual reasons for the detection of one parasitic helminth egg of *Trichuris suis* in one of the 100 litres effluent samples (9B), it has to noticed that such a concentration is 10 times lower than the maximum allowable limit recommended by WHO guidelines (WHO, 2006) for protecting children below 15 years of age that could be present in fields irrigated with water of such quality, and also lower than the maximum allowable limit (1 egg/10L) established by Spanish regulations (RD 1620/2007) for the most restrictive uses of reclaimed water.

4. Adoption of a Hydrotech Discfilter process, provided with a filter cloth of 10 µm pore size, for reclamation of treated wastewater containing up to 7 eggs/20L of parasitic helminths, as it has been observed in some wastewater treatment plants in Spain, should ensure a complete retention of all the parasitic helminth eggs known, and systematically produce a reclaimed water effluent actually free of those parasites.

5. The ability of the Hydrotech Discfilter process to effectively retain the parasitic helminth eggs contained in filtered water is an important added benefit to the main benefits of this filtration process, such as its low energy consumption, its compact footprint, its minimum equipment and its modular components, its simple automatic control system, its simply interchangeable filtration panels, and its low wash water consumption. All together, they make the Hydrotech Discfilter process an efficient, reliable and competitive technological process alternative able to produce reclaimed water systematically free of parasitic helminth eggs, because it offers an effective and reliable barrier against helminth eggs.

**IX. ACKNOWLEDGEMENTS**

This project was possible thanks to the invaluable assistance of the Faculty of Life Sciences from the University of Copenhagen and especially Professors A. Roepstorff and S. M. Thamsborg and the Coordinator N. P. Hansen from the Department of Veterinary Pathobiology, who provided useful advise and two concentrated samples of *Trichuris suis* eggs. The authors want to express their appreciation to Mr. Tomás Cazurra and Mr. Joaquin Llansó of Depurbaix, to Mr. Josep Maria Obis, Mr. Jordi Pastor and Ms. Gemma Iturbe from Agencia Catalana de l’Aigua, and to Mr. Martín Gullón and Mr. Antonio Palacios from Entitat Metropolitana del Medi Ambient for their approval and support to conduct this demonstration project at the Water Reclamation Plant of El Prat de Llobregat. The authors want also to thank the technical staff of Empresa Metropolitana de Sanejament, and particularly Mr. Pere Aguiló, chief of the Water Reclamation Plant, for all the support, assistance and services offered during the demonstration project. Finally, the authors want to acknowledge the staff of the technical and engineering divisions of VWSI for their help in setting, operating and supervising the demonstration plant.
X. REFERENCES


