PARTICLE SIZE DISTRIBUTION IN THE TILAPIA RECIRCULATING AQUACULTURE SYSTEM

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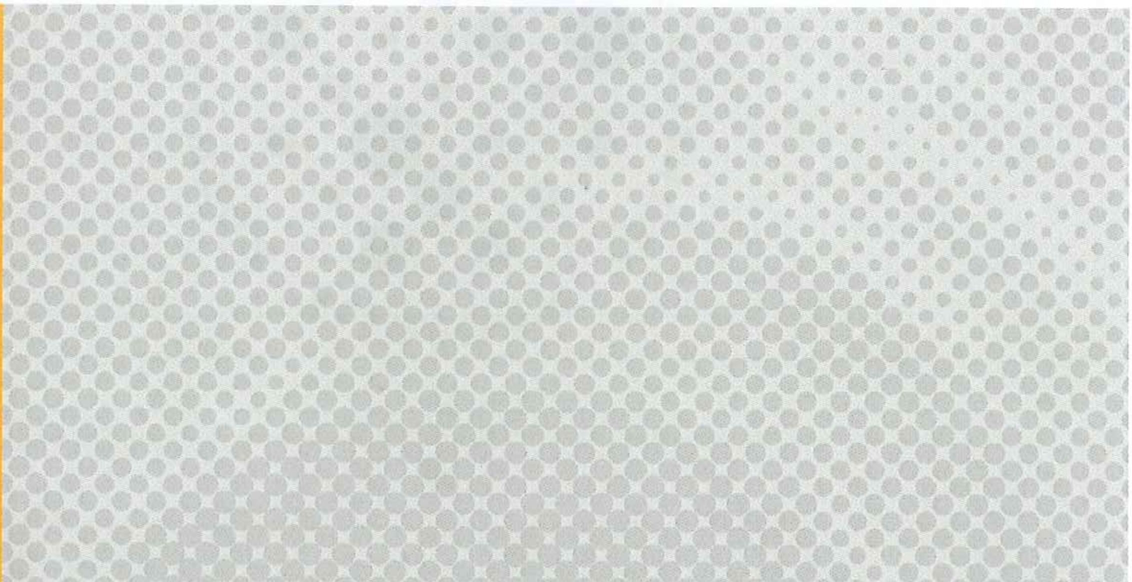

Particle size distribution in the Tilapia Recirculating Aquaculture System

By

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ABSTRACT

This study was to evaluate methods for measuring and describing particle size distribution from three different spots in Tilapia recirculating system at University of life science in Ås, Norway. For this purpose serial filtration over different mesh size and parallel filtration over different mesh size methods were compared. Water samples were taken from before drum filter, after drum filter and after bio-filter (MBBR) and filtrated through eight different mesh size classes and calculated in mg suspended solids per liter (mgSS/l). Serial method is telling about suspended solids between two filter sizes, while parallel method tells about suspended solids bigger of a given filter size. Each filtering method was done three times in three different days. Results of serial filtration showed large difference in mgSS/l between days, especially between 0, 45 – 10 µm. Small particles (< 30 µm) are dominating in both methods. Water before drum filter contains a lot of large particles which are reduced after treatment in the drum filter. First and third days of serial filtration were more effective for the total suspended solids (TSS) after drum filter, unlike the second day which showed no decrease of TSS after drum filter: 9, 71 mgSS/l before drum filter, and 10 mgSS/l after drum filter. In the first day TSS before drum filter was 23, 58 mgSS/l and after drum filter it was reduced to 8, 8 mgSS/l. In the third day experiment showed 27, 73 mgSS/l before drum filter, and 14, 37 mgSS/l after drum filter. Water after Moving Bed Biofilm Reactor (MBBR) resulted in increase of TSS in the first two days, whilst the third day showed reduction of TSS value.

Parallel filtration method can be calculated as comparing samples, same as serial filtration method. This way of calculations of parallel filtration gave negative values for some of the particle size groups which bring into question the accuracy of the method. More further developing of methods are needed in order to get accurate results.

Keywords: Evaluating the methods; suspended solids; particle size distribution; recirculating aquaculture system.

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1 Introduction

The aim of this study was to describe particle size distribution at different water treatment spots in a RAS for Tilapia and to evaluate methods for measuring particles distribution. Two filtrating methods were used: serial filtration compared to parallel. For this purposes water samples were taken from three different sampling spots: before drum filter, after drum filter and after Moving Bed Biofilm Reactor (MBBR). Great importance was the way of calculating as well as making size classes. These experiments showed the effectiveness of the drum filter and changes in total suspended solids (TSS) concentration across recirculating aquaculture system (RAS).

Suspended solids in recirculation system mostly depends on type of culture system and its management, the feed used and size and type of aquatic species cultured (Rijn, 1996). Suspended solids are result of matter of metabolic origin, residual feed and carcass debris (Brinker and Rösch, 2005). In recirculating aquaculture system (RAS) they are produced from uneaten feed, faeces, algae, pathogens and bio-filter cell mass (Bergheim, 2007). Suspended solids are one of the main components of the effluent from flow-through and open culture systems which require treatment and improving water quality (Cripps, 1995). In flow-through facilities suspended solids can pose severe ecological problems, where the waste is discharged directly into the environment (Brinker and Rösch, 2005). Removing solids waste material from the water in recirculation system must be conducted continuously. Very small solids remain suspended in the water. Decomposition of these solids consume oxygen and produce ammonia, thus the low level of suspended solid may help in protection fishes' gills as well as stimulating the growth of microorganisms (Masser at.al., 1999). The importance of solids removal lie in the fact that particles cause gill damage and reduces fish resistance to diseases, also reduce growth rates and induce mortality, clogging of biological filters, increase biochemical oxygen demand and mineralization to produce ammonia (McMillan et. al. 2003). The aim of removing of fine solids from the recirculation aquaculture system (RAS) is to improve water quality and fish health and thus enhance production yield and decrease cost (Viadero and Noblet, 2002). Furthermore, high levels of organic matter in the water inhibit the nitrification rate in the biofilter.

Removal of particles can be done by settling techniques (sedimentation), micro-screen filters, granular media filters, membrane filters and by flotation (Bergheim, 2007).

According to one study of distribution of suspended solids on salmon smolt farms in Sweden and Scotland, using particle characterization techniques, the majority of numbers of particles were smaller than 30 µm, and the total of these particles were much lower than infrequently occurring particles larger than 30 µm (Cripps and Bergheim, 2000). In this study much greater reduction of SS is achieved using smaller pore size such as 60 µm.

1.1 Background for the experiments

This chapter is about earlier studies that are telling about the available methods for particle removal from recirculation system and measuring its size and distribution. For applying some method for removing particles, it is necessary to understand the nature of the wastes (Cripps and Bergheim, 2000). Treatment techniques are to separate particles from the primary effluent flow (Cripps, 1995). Removal of solids waste is a long-lasting process. It is the most critical process in RAS (Summerfelt and Penne, 2005).

1.1.1 Mechanical methods for particles removal

Many mechanical methods are available for treatment of waste and removing solids such as straining, sedimentation, impaction, interception, adhesion, flocculation, chemical and physical adsorption and biological growth. But the most used mechanical methods are settlement, screening/filtration and flotation (Bergheim, 2007). According to Cripps and Bergheim the most popular method of mechanical particle removal in recirculation aquaculture system is by the use of screens (Cripps and Bergheim, 2000).

1.1.1.1 Settling techniques (sedimentation)

Sedimentation is the traditional and widespread method for the removing solids. It is simple to operate, as well as moderate running costs, but take up a lot of space (Bergheim, 2007). Particle removal is usual done by settling and mechanical filtration process (Chen et.al. 1993). Sedimentation is dependent upon flow rate, specific density of the particles and the size of particles (Johnson and Chen, 2006). Sedimentation is the process where the suspended solids with a greater density or specific density than water can settle out of suspension and thus be separated from the main flow (Cripps and Bergheim, 2000). Under the force of gravity, particles that are heavier than water will fall through the water with increasing speed until it reaches a terminal value for its settling velocity (Timmons et.al. 2002) and it will not remove fine particles from the water (smaller than 30µm) because they have low settling velocity that makes gravitational removal method impractical.

According to these authors denser and larger particles will settle out faster than smaller, less dense particles. Moreover, the best technique for maintaining large particles is to remove those particles before any pumping has occurred.

1.1.1.2 Mechanical filters and Screening (micros-screening)

Mechanical filters are designed to remove particles greater than 80 µm, while smaller particles accumulate (Chen at.al. 1993). Micro-screen filters require minimal labor and space and can treat large flow rates of water with little head loss (Ebeling et. al. 2005). According to these authors solids can be removed by virtue of physical restrictions or straining on a media when the mesh size of a screen is smaller than particles in the wastewater. Solids from the waste are further processed before final discharge. Solids content will vary based on screen opening size, influent total suspended solids (TSS) load on the filter. If particles are too big, surface of the screen might block, so particles have to be removed to avoid blockage (Lekang, 2007). Of huge importance for mechanical filters or screen to be used for removing smaller particles is to prevent blockage. Solids are removed from the screen by rotating the clogged screen surface with the high pressure jet of water (Masser at.al. 1999). Two types of screens are available: static and rotary (Lekang, 2007). Rotary screens can be classified by how screens rotate into: axial rotating screen, radial rotating screen (drum), rotating belt, horizontally rotating disc. Nevertheless the optimal removal is achieved when the suspended particles are large with a minimum specific gravity. Bergheim state that beside all advantages of micro-screen filtration it requires energy and also high installation costs (Bergheim, 2007).

1.1.1.2.1 Drum filter

Drum filter is most commonly used system for filtration in RAS. It consists of rotating gauze micro-screen through which waste water is passing. For the best drum filter performance particles should be attached very gently to the filter gauze by hydraulic pressure and lifted out of the water as the screen rotates. The turbulence should be kept to a minimum because high turbulence can break the particles. At the drum filter there are two ways of passing the flow. Those are flow passing from the inside to the outside of the drum filter and from the outside to the inside. “Outside-in” mechanism has the advantage because of low turbulence and therefore allows more successful removal of fragile particles (Bergheim, 2007). Typical RAS treatment system for solids removal usually using micro-screen sieving, such as rotary drum filtration, or rotary disc screening in a wide range of screen mesh sizes (from 60 to 200 μm) (Viadero and Noblet, 2002).

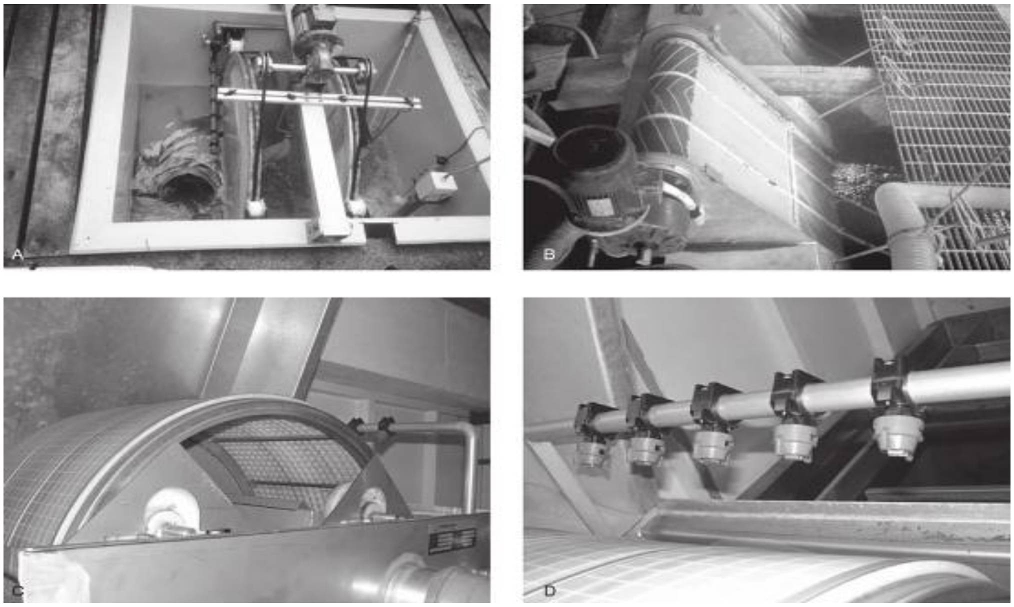


Figure 1: Different types of rotating filters with automatic back-flushing. (A) Upper side of a disc filter, where radial rotating screens are vertically placed to the water flow direction. (B) A rotary belt filter where the water passes through the belt, while particles are transported to the surface. (C) Drum filter with the straining cloths. (D) Part of a drum filter used for back-flushing the straining cloths (Lekang, 2007)

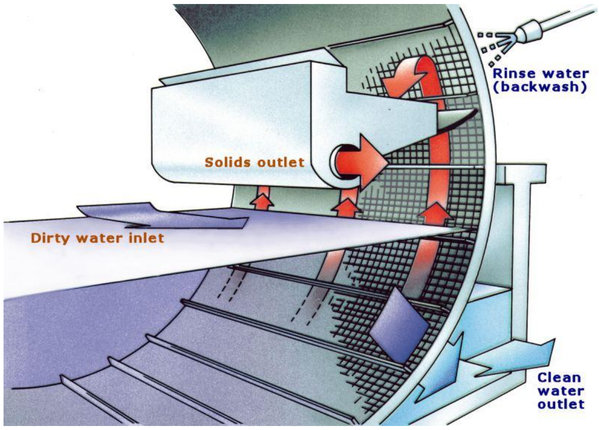


Figure 2. Rotating drum filter. Water enetrs the open end of a drum and passes through the screen High pressure jet of water (from outside of the drum) washes the solids off the screen and into an internal collection trough leading to a waste drain (Masser, et.al. 1999). (Picture is copied from Hidrotech homesite)

1.1.1.3 Fine filtration techniques (membrane filtration)

Membrane filtration is using for removal of very fine solids in recirculating system because of high pressure required and low flow. But it's highly susceptible to clogging, also highly energy demand and extremely high head loss (Bergheim, 2007).

There are three different grades of filtration: (Bergheim, 2007)

a) Micro-filtration with 50 nm pore size (macro pores) – is achieved using hydrostatic pressure difference. This method allows larger dissolved solutes to pass;
b) ultra-filtration with pre size 2-50 nm (mesopores) – also using hydrostatic pressure difference and along with microfiltration allow the permeation of water and small molecules.
c) Nano-filtration where is less than 2 nm pore size is used (micro pores) and achieved by using dense material with smaller pore size.

Microfiltration (MF) can be done in a two ways such as "dead-end" and "cross-flow" mode. In "dead-end" mode feed flows vertically to the membrane and only clean water leave the filter housing (Viadero and Noblet, 2002). Particles that are retained on the membrane continue to accumulate and making a cake on the filter. In cross-flow mode the feed flows passes parallel to the membrane surface using permeate and retentive stream. By using this mode caking and clogging are reduced (Berheim, 2007).

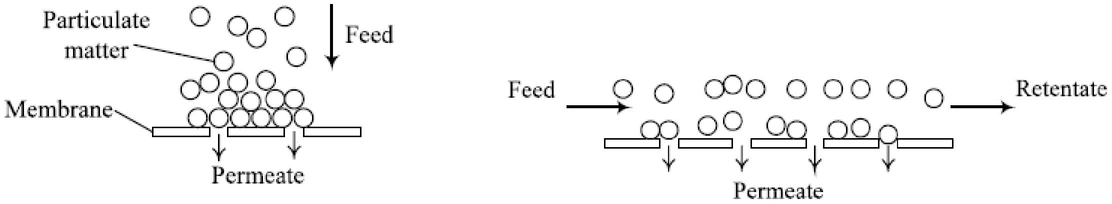


Figure 3: Illustration of microfiltration system operating. "Dead - end" filtration (left) and "Cross - flow" filtration (right) (Viadero and Noblet, 2002)

“No perfect method for all aquaculture systems”. All methods have their advantages and disadvantages. The best solution would be to use multiple treatment methods for particle removal and thus achieve the optimal results. The effectiveness of all techniques depends on particle size distribution and specific density of the particles. Bergheim also states that the significant consideration is the economic viability of different techniques (Bergheim, 2007).

1.2 Features of solids

The most interesting spots in RAS (tilapia fish laboratory UMB) for particle analysis is outlet pipe from the fish tank (water is taken before comes to drum filter), after drum filter and after bio-filter. The biggest particles are in the outlet pipeline and come from fish tanks. Tilapia is herbivore. For their feeding they use plant feed and these particles are not as big as particles from salmonid production. The more quickly particles are removed from water, the less time they have to break down and less oxygen they will demand from the culture system. When they become smaller it is harder to remove from the culture system.

Suspended solids are particles that are trapped on the filter mesh. Two most important characteristic of suspended solids are: specify density and particle size (Timmons et.al. 2002). Specific density of the particle depends mostly on their organic nature and that particles originate from uneaten fish feed, fish excretion, or bacteria grown in the system (Chen et.al. 1993). Particles of suspended solids originate of feces and uneaten feed, thus they differ in their size and specific density. Because of that they respond differently on different control mechanisms. As specific density is determined by the source of the particles, it’s defined as a ration of wet particles to that in the water (Timmons et.al. 2002). Particle size ranges over less than 1 µm in diameter to larger particles up to more than 200 µm. Configuration of particles is variable and they tend to become more complex with size. Even though, large particles have tendency to become small particles and rapid and efficient removal of the settleable (large > 100 µm) particles is necessary. Fine particles are more difficult to remove in the system (Timmons et.al. 2002) and (Bergheim, 2007). Very small (fine) particles (< 30 µm) have low settling velocities that make gravitational removal methods impractical, so sedimentation techniques will not remove these kinds of particles.

1.3 Describing the recirculation system (RAS)

Recirculating Aquaculture System (RAS) is a closed system for rearing fish with efficient water utilization, independence from climatic conditions and reduced effluent volume (Chen et al. 1993). In RAS it is very important to have adequate water treatment components with proper functioning to handle solids removal (Pfeiffer et.al. 2008). Recirculating aquaculture systems provide constant and adjustable rearing medium with slightly and slow variations and minimal head loss (Blacheton, 2000). The recirculating system was designed to ensure a constant and stable supply of solid waste to filter tested. RAS is controlled and maintained to enhance the efficiency and intensity of fish production with no influence by external factors (Steicke, 2007). The major units in RAS that are considered for the maintenance, is solids removal, ammonia removal and aeration/oxygenation (Twarowska et.al. 1997). Recirculating aquaculture system consist of mechanical and biological filtration components, pumps and fish tanks and includes water treatment for improving water quality and provide disease control within the system (Hutchinson et.al. 2004).

Fish laboratory at the university has three sections:

- Feeding lab has 10 tanks each 250 L and 10 tanks each 100 L. All tanks are connected with reuse system;
- Reproduction lab has 5 tanks each 400 L, 8 aquariums each 250 L and a hatchery. Of these only the big 5 tanks are connected to the reuse system; and
- Water treatment section the most important for this study.

The design of RAS tilapia (water treatment section) (Figure 4) includes drum filter (removal of big particles), bio-filter (to remove ammonia), air blower (to aerate the water and keep the bio-filter media moving), circulating pump and electric heaters. The bio-filter is built as a "Moving Bed Biofilm Reactor". In recirculation system for tilapia more than 99% of water is reused. The flow is an average 150 l/min and water temperature is 26℃. The total water volume in RAS is 7000 L (Table 1). Each tank has an individual aerator to keep oxygen at an acceptable level for some hours if the circulating pump or the central air blower fails. Oxygen, pH and temperature are measuring continuously and the total ammonia nitrogen (TAN) and nitrite (NO2) are measuring every second week (Fish laboratory information).

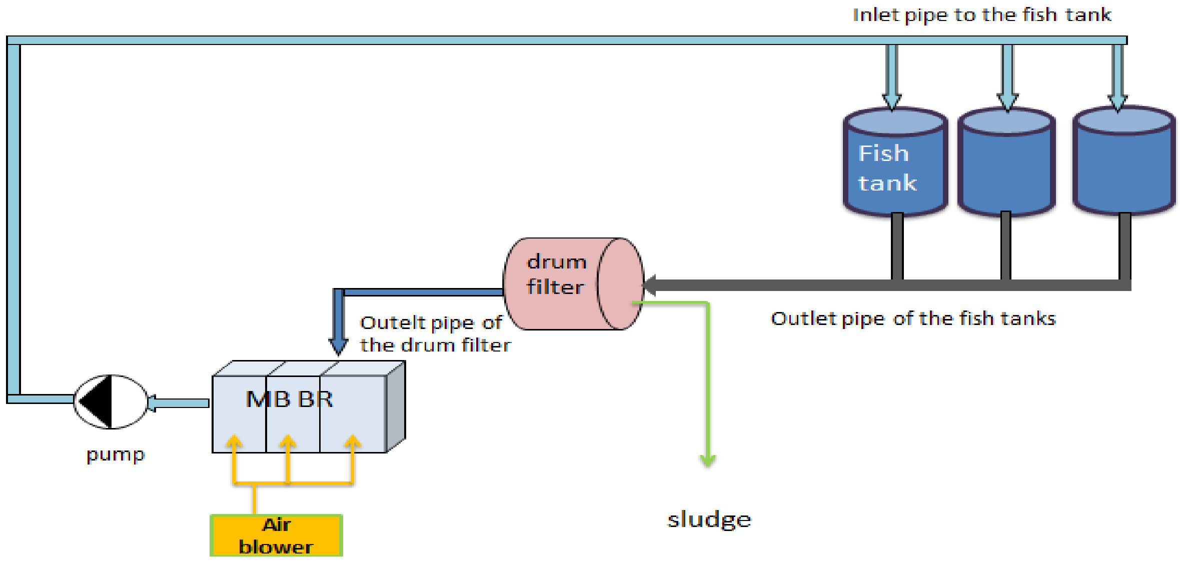


Figure 4: Main components of recirculating system (RAS) tilapia at UMB: fish rearing tanks, component for mechanical water treatment (drum filter, model HDF 501 – 1H), component for biological treatment (bio-filter, MBBR) and pump.

Table 1: Operation data for the tilapia reuse system during 2010 (Fish laboratory information)

Temperature	26°C
Oxygen, inlet fish tanks	85-90% saturation
pH	6.8-7.2
TAN	0.2-0.4 mg/l
Nitrite (NO2)	0.4-0.8 mg/l
Biomass	150 kg
Flow	150 l/min

2 Materials and methods

This experiment was conducted using filtrating method. The aim was to indicate particle size and distribution in tilapia recirculating system in order to achieve better water quality and better fish production and their health on the first place.

The work was done in the RAS units of the fish laboratory located at the University of the Life Science in Ås, Norway.

Water samples were taken for particle size analyses at three different locations or spots in the RAS:

- From the outlet pipe from the fish tank (before drum filter)

- After drum filter (before biofilter) and
- After biofilter.

First experiment was filtrating water from fish tank outlet pipe. The aim of such filtration was to find particles and determine their distribution and size before they come through drum filter. It is preferable for mechanical filtration to be as close as possible to the outlet of fish tank in order to avoid breaking the larger, more easily removed particles into smaller particles (Blancheton, 2000).

Particles in the fish tank resulting from food and feces produced by fish. With water they come to drum filter, where that water going to be filtrated and normally some amount of particles accumulate to the walls of pipe. Water stay in the pipe because the fish tank is situated on the higher level than the water treatment system, which means drum filter, bio-filter and pump that pumping water up to the fish tank again. Drum filter is on the lower level than fish tank and that difference is 10 cm thus the water is always in the pipe. Particles in that water are attached to the pipe walls. This fact is very important for taking samples. When taking a sample, the principle is to let that "old" water out by tilting the tube down in order to get "fresh" water with the "fresh" particles. Particles that are in the pipe before the water flow out 1 minute are not a good indicator of the actual state of the particles in the fish tank. To determine size and frequency of distribution prior to their entry into the drum filter it need to let water flowing out 1 minute. Particles in the pipe will sediment when velocity is lower than 0, 5 m/s. Letting water out velocity will increase. After drum filter water sample is taken by putting the canister under the water source that comes from outlet pipe from drum filter (Figure 10). For the filtering water samples after MBBR, canister is submerged into the water after MBBR (Figure 12).

In this study two different experiments were compared. Two basically different filtrations include different amount of water. These are:

1. Filtration in series. In this experiment 15 liters of water were used: 5 liters from each spot.

2. Filtration in parallel. 5 liters of water were used for each spot (40 l in total for whole experiment).
3. Filtration series vs. parallel, combination of serial and parallel filtration. In total 45 liters are used and only one location was used in experiment.

Equipment used in this study:

- Plastic buckets 5 liters volume
- Filters cloths , round 200 µm, 120, 90, 60, 30, 20, 10 µm pore size (supplied by HydroTech AB)
- Glass micro fiber filter 0, 45 µm for fine particles (GF/C, company Whatman®) with good flow rates, high loading capacity and retention of very fine particles
- Erlenmeyer form
    - Erlenmeyer bottle, 100 ml capacity (or collecting bottle, 1 L) with side-arm socket
    - Glass-filter unit with glass filter plate for all membrane filters.
    - Top for the glass filet unit with the flange 200 ml
    - Electric pump for supporting the vacuum
- Digital drying scale for particle analysis (company Ohaus ®, model MB45). Scale has accuracy of 0,001 g, 0, 01% moisture and capacity 45g. Also, provide information about % of solids, time, temperature, weight, and drying curve.

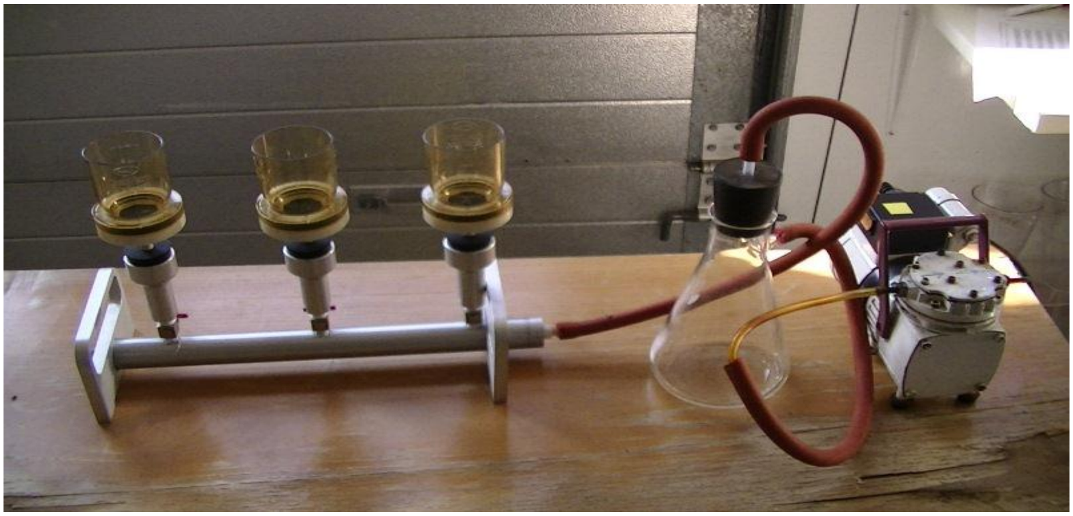


Figure 5: Filtering setup: glasses with the filter plate, Erlenmeyer bottle with side-arm socket and electric pump for supporting the vacuum.

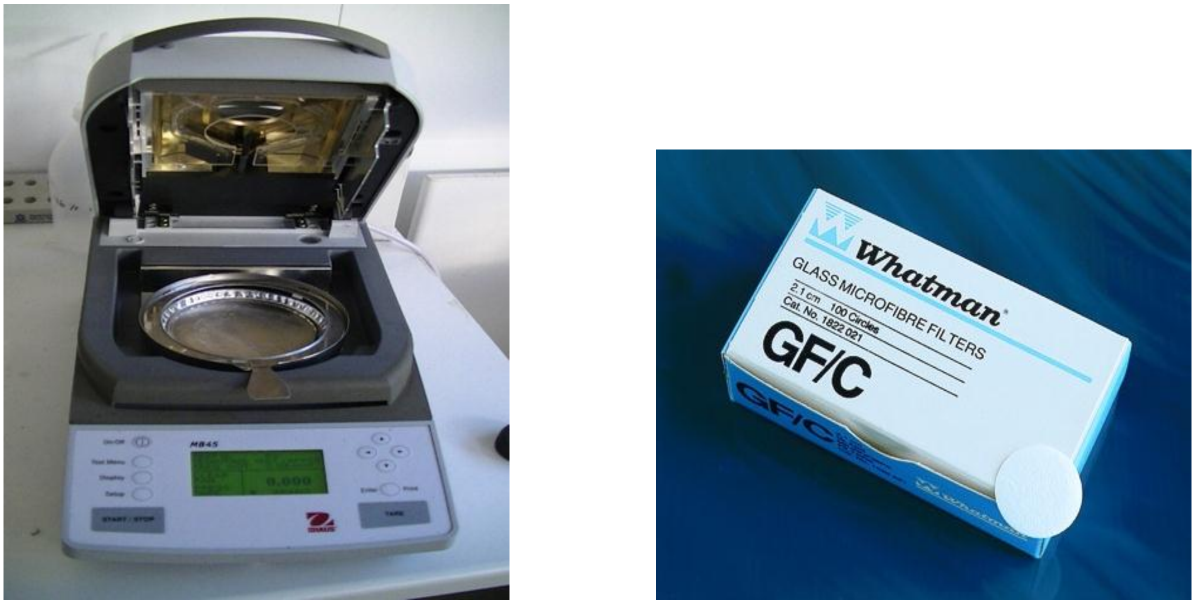


Figure 6: Digital drying scale for particle analysis (company Ohaus ®, model MB45) for calculating the weight of residue retained on the filter. Scale has the accuracy of 0,001 g (1,0mg), 0, 01% moisture and capacity 45g. Also, provide information about % of solids, time, temperature, weight, and drying curve (left) and Glass micro fiber filter 0,45 µm for fine particles (GF/C, company Whatman®) with good flow rates, high loading capacity and retention of very fine particles (right.)

2.1 Serial filtration

The experiment was conducted using filtrating method. Serial filtration was done in a three different days and then calculated in average for a given location. First day was 22. October, second day was 23. October and third day was 24. October 2011. For this study water samples were taken from three spots: before water comes to the drum filter (Figure 7), after water treatment through drum filter (Figure 10) and after water treatment in bio-filter (Figure 12). All three spots covered one day experiment. Samples were collected by piping out the water into the bucket or canister. In experiment before drum filter, water is taken by tilting tube down (outlet pipe from the fish tank) and letting the water flow out 1 minute. That is to pipe clean out of particles that stay in the pipe longer time. After that time 5 liter canister was put under the tube and filled with the water. After drum filter water sample is taken by putting the canister under the water source that comes from outlet pipe from drum filter. For the filtering water samples after bio-filter, canister is submerged into the water after bio-filter. After taking samples, before it starts with filtering, it is significant to carefully stir the water. This is because the large particles would be raised from the bottom and mixed with other particles over the entire surface. If the mixing water not done, large particles would remain on the bottom and thus would not get correct results on distribution and size of particles passing through or that remain on filter of a certain mesh size. In the bucket, water stirring is done by carefully taking water with hand from the bottom to top, so the entire amount of water is mixed together. Also, if the water is in canister, slightly turn it up and down several times water is stirring and particles are mixing together. Mixing of water is necessary not only to do before filtering, but also several times during the operation. Stirring must be very carefully because turbulence that occur in rough stirring of water contributes to break down of suspended solids into smaller ones.

Water samples were taken at the same time in three canisters, each 5 L contains, taken from each spot: 5 L from outlet pipe (before drum filter), 5 L after drum filter and 5 L after a bio-filter.

The whole process of filtering in serial was divided into three parts: before drum filter, after drum filter and after bio-filter. All three parts contain the same amount of water. After sample preparation which involves collecting water into the canisters and stirring the water it is filtered through the filters. Serial filtration is done by using one canister of 5 L water sample from each spot for all filter sizes. Sample was passed sequentially through a series of eight different pore size filters; first through 200 µm and 120 µm, then 90, 60, 30, 20, 10 and 0, 45 µm (Figure 8). Glass fiber filters (GF/C company Whatman®) were used to obtain fine particles in the water sample. Glass fiber filters have good flow rates, high loading capacity and retention of very fine particles.

Each experiment was conducted in three days to be able to compare results in order to get higher accuracy of a method. Sample volume used for the suspended solids is ranged from 0,200 to 5 L.

Poured samples were then analyzed for the total suspended solids (mgSS/l). Each filter with collected solids was put in the drying machine where its weight was measured. To be able to measure the weight, it must reach 0,500 grams. Usually filters are less than 0,500 g, but adding distillated water, desired weight can be reached. Before analysis each filter is dried properly and tare. After filtering, particles were analyzed using a digital drying machine (Ohaus®, model MB45). A well-mixed sample is filtered through a standard glass microfiber filter and the residue retained on the filter is dried to constant weight (30 sec stable) at 103-105℃.

Digital machine is calculating the weight of residue that retained on the filter in grams, which is used in calculations for making results (Part 2.4).

Figure 7: Fish tank outlet pipe, spot where the water sample before drum filter is taken (left). The tube is tilted down and held for 1 minute to "old" water flow out. After that time, 5 l canister was put under the tube and filled with the water (right).

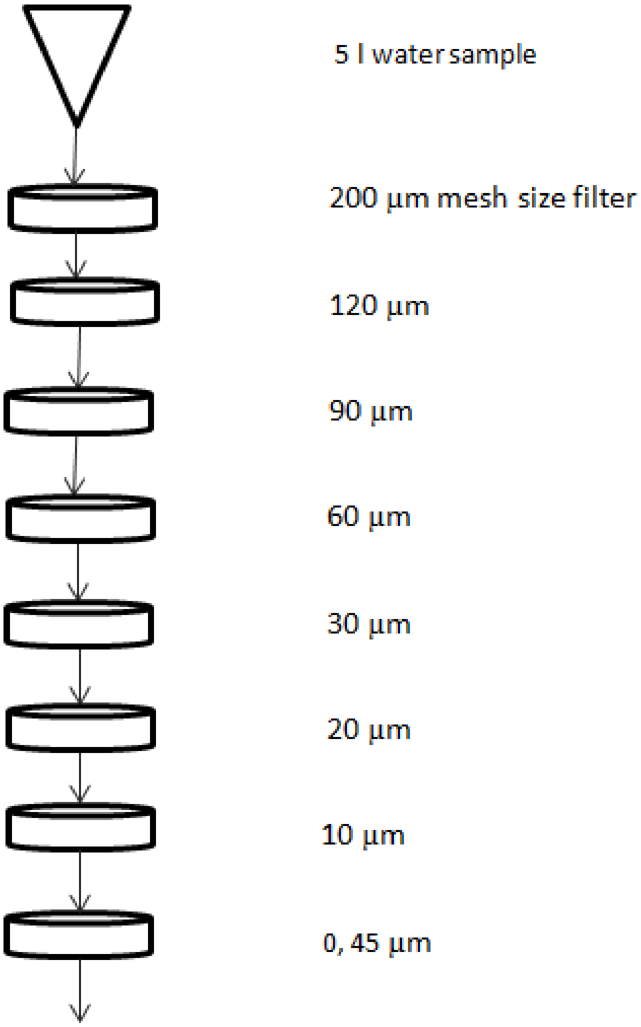


Figure 8: Schematic explanation for the serial filtration for solids analysis. One water sample (5 L) used for filtration throughout eight different filter sizes.

2.2 Parallel filtration

This experiment was also conducted at fish laboratory using filtrating method. Water was taken from reuse system from three locations: from outlet pipe from fish tank (before drum filter), after water treatment in drum filter and after water treatment in the bio-filter. Filtration in parallel was done in three day 1. – 3. November 2011. Samples were collected into canisters each 5 L contains to provide a total sample volume of 40 L. For this experiment eight different pore size filters were used: 200 µm, 120, 90, 60, 30, 20, 20, 10 and finally 0, 45 µm for fine particles.

After taking samples, before it starts with filtering, it is significant to carefully stir the water. This is because the large particles would be raised from the bottom and mixed with other particles over the entire surface. If the mixing water is not done, large particles would remain on the bottom and thus would not get correct results on distribution and size of particles passing through or that remain on filter of a certain mesh size. In the bucket, water stirring is done by carefully taking water with hand from the bottom to top, so the entire amount of water is mixed together. Also, if the water is in canister, then slightly turn it up and down several times water is stirring and particles are mixing together. Mixing of water is not only necessary to do before filtering, but also several times during the operation. Stirring must be very carefully because large particles can break.

Parallel filtration was divided into 3 days. Throughout three days of parallel experiment, samples (8 buckets with content of 5 L water each) were filtered through eight filters pore sizes. Water was taken from outlet pipe from the fish tank (before drum filter), after drum filter and after bio-filter.

Parallel filtration is done by using eight canisters filled up with 5 L water sample in each. It starts with filtering 5 L water through 200 µm filter, then another 5 L water through 120 µm, 5 L through 90 µm, 60, 30, 20, 10 and 5 L through 0,45 µm (Figure 9). Thus it shows the amount of particles on each filter pore size obtained from each 5 L sample.

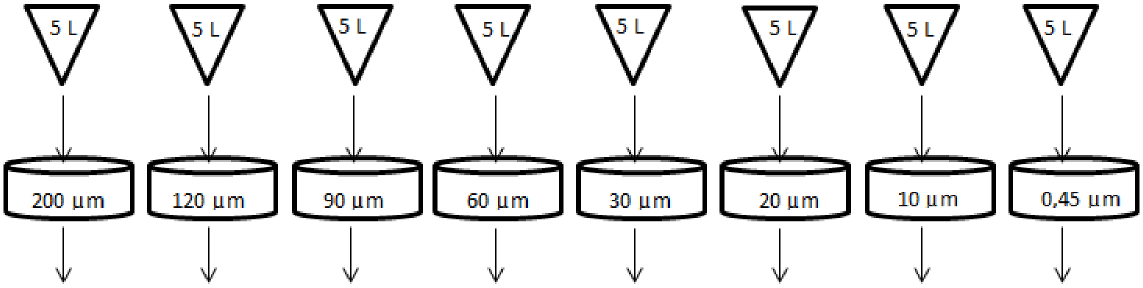


Figure 9: Schematic explanation of parallel filtration. For each filter size new 5 L of water sample is used for filtration.

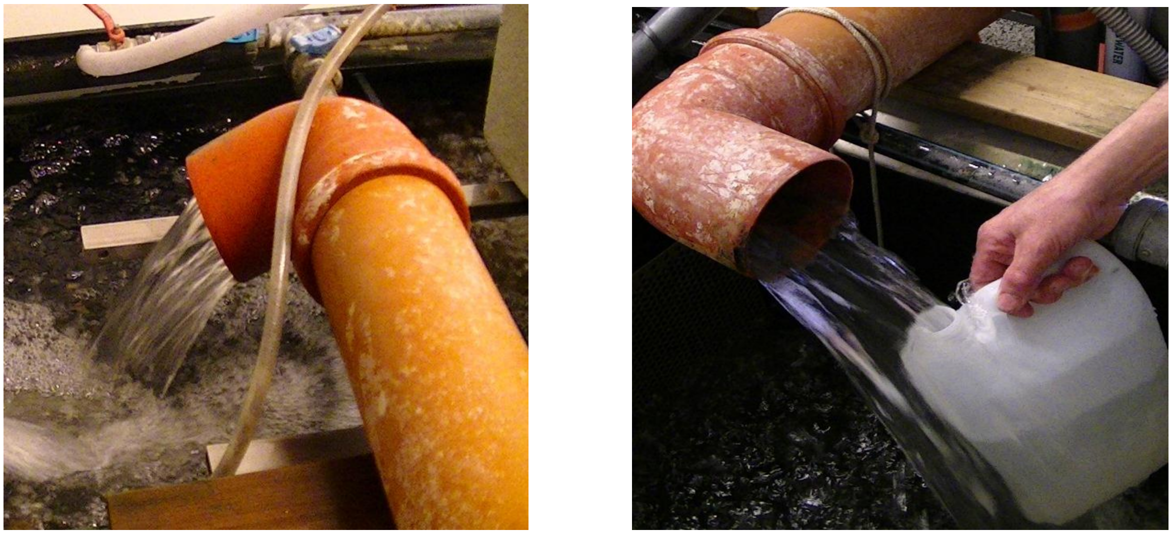


Figure 10: Spot where water sample after drum filter is taken (drum filter outlet pipe) (left). Water sample is taken by putting the canister under the water source that comes from outlet pipe from drum filter (right).

2.3 Serial vs. Parallel

This is a combination of serial and parallel filtrating. For this filtration which was done at one day, 7. November 2011, water samples were taken from only one spot and it was from outlet pipe from fish tank, before water filtered through drum filter. The amount of water was as same as in both filtrating methods, 5 l for serial part and eight bucket with 5 L in each for parallel part of filtration. Water sample were filtrated through 200 µm, 120, 90, 60, 30, 20, 10, 0, 45 µm. This experiment was done in one day and only one location is chosen. Moreover, water before drum filter contains the largest particles that come directly from fish tank and these particles are very easy to remove comparing with the fine one. As the largest particles are removed they will not be crushed into smaller one in the drum filter and thus will not be as difficult to remove as fine particles.

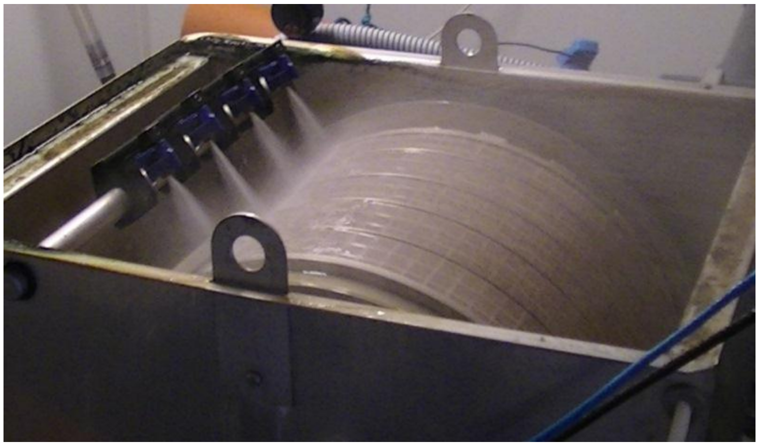


Figure 11: Image of the drum filter (model HydroTech HDF 501 – 1H) during back-flushing installed in the RAS tilapia. Back-flushing occurs every 1 min depends on how dirty the water is and takes 10 seconds.

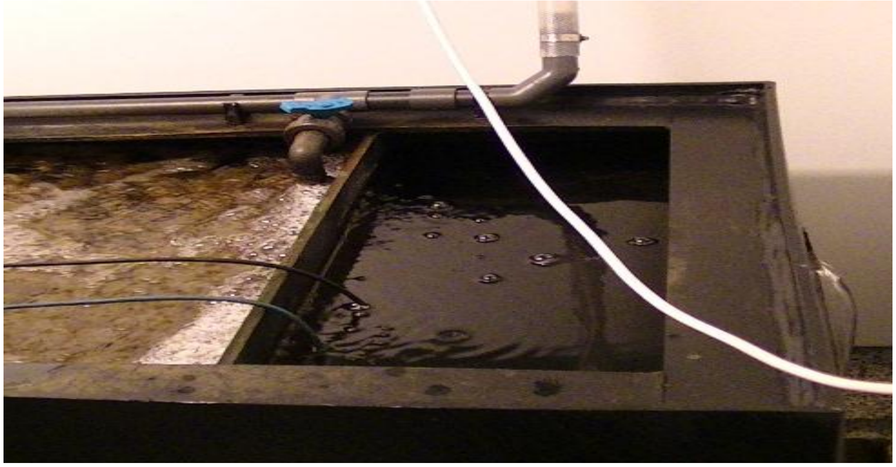


Figure 12: Water after MBBR, location where the samples have been taken. Samples are taken by submerging a canister into the water after biofilter.

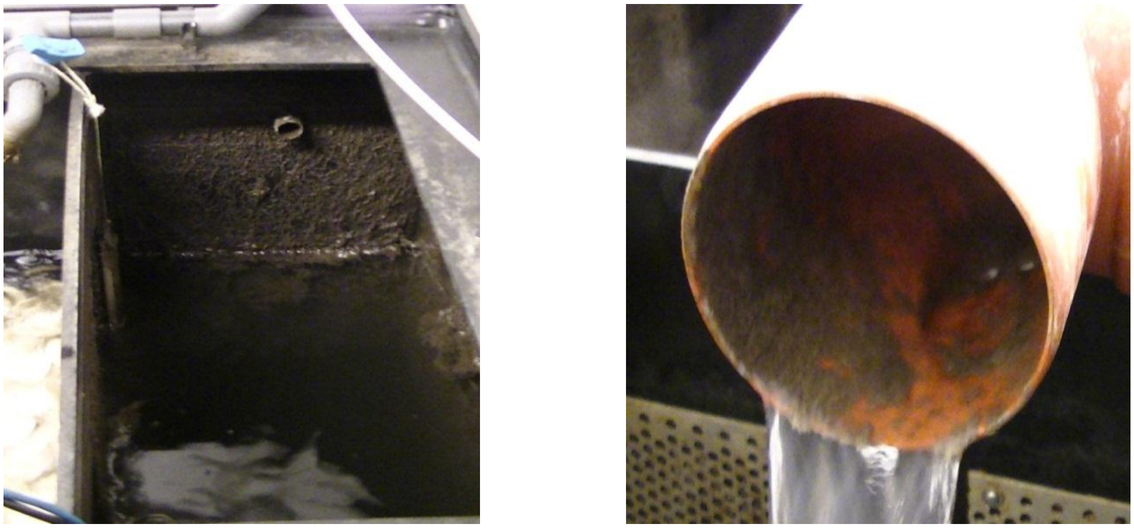


Figure 13: Chamber with water after MBBR (left). Outlet pipe from the drum filter inner side. Solids fasten to the pipe wall (right).

2.4 Calculations

Purpose of these calculations is to determine the percentage of particles that are bigger of a given mesh size filter. The amount of suspended solids is expressed in mg/l and it is calculated with the formula:

$$\text{mg SS/l} = (A-B) \times 1000 \text{ ml} / V$$

A = weight of filter + dried residue,(mg)
B = weight of filter, (mg)
V = Sample volume (ml)

$$\% \text{ of total collected on one filter plate} = (\text{mg/l} / \sum \text{mg/l}) * 100$$

3 Results

3.1 Serial filtration

3.1.1 System function at serial filtration

This experiment showed different values of dry matter obtained by filtering the water from outlet pipe from the fish tank (before drum filter), outlet pipe from drum filter (after drum filter) and after a bio-filter. Variations in mgSS/l can be noticed especially in the experiment that was performed with water before drum filter (Table 2). In RAS fine particles (particles smaller than 30 µm) are the most dominate in water.

Table 2: Serial filtration in three days with water sample from outlet pipe from fish tank (before drum filter) and total mgSS/l. Filtering was done through eight different mesh size filters (µm) in mg, mg dry matter per l and percentage of dry matter and sample size.

filter size, µm	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	mg dry matter/l			%		
		Day 1		**Day 2**		**Day 3**	**D1**	**D2**	**D3**	**D1**	**D2**	**D3**
> 200	5	17	5	9	5	9	3,4	1,8	1,8	14,42	18,54	6,49
120 - 200	5	13	5	2	5	2	2,6	0,4	0,4	11,03	4,12	1,44
90 - 120	5	10	5	2	5	5	2	0,4	1	8,48	4,12	3,61
60 - 90	5	6	5	4	5	4	1,2	0,8	0,8	5,09	8,24	2,88
30 - 60	5	9	5	6	5	8	1,8	1,2	1,6	7,63	12,36	5,77
20 - 30	5	7	5	5	5	4	1,4	1	0,8	5,94	10,30	2,88
10 - 20	1,7	2	3,2	4	1,5	2	1,18	1,25	1,33	5	12,88	4,81
0,45 - 10	0,6	6	0,7	2	0,2	4	10	2,86	20	42,42	29,43	72,12
TSS							23,58	9,71	27,73			

Experiment before drum filter showed a large variations among three days of filtration the water samples. Up until 20 µm filter, the same amount of water was used for filtration, but obtained mg/l differ a lot. Very big difference was in a first day at 200 µm filter, 17 mgDM obtained, while second and third day 9 mgDM obtained, as well as in between 120 – 200 µm (13 mg DM, 2 mgDM, 2 mgDm) and 90 – 120 µm (10 mgDM, 2 mgDM and 5 mgDM). Total suspended solids (TSS) shows a big variations among days of filtration (Table 2).

Table 3: Serial filtration in three days with water sample after drum filter and total mgSS/l.. Filtering was done through eight different mesh size filters (µm) in mg, mg dry matter/l and percentage of dry matter.

filter size, µm	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter		mg, dry matter	mg dry matter/l			%		
		Day 1		**Day 2**		**Day 3**	**D1**	**D2**	**D3**	**D1**	**D2**	**D3**
> 200	5	2	5	6	5	2	0,4	1,2	0,4	4,55	12	2,78
120 - 200	5	2	5	4	5	4	0,4	0,8	0,8	4,55	8	5,57
90 - 120	5	5	5	2	5	2	1	0,4	0,4	11,36	4	2,78
60 - 90	5	2	5	2	5	1	0,4	0,4	0,2	4,55	4	1,39
30 - 60	5	2	5	4	5	5	0,4	0,8	1	4,55	8	6,96
20 - 30	5	6	5	2	5	5	1,2	0,4	1	13,64	4	6,96
10 - 20	5	5	5	4	2,2	4	1	1	1,82	11,34	10	12,65
0,45 - 10	2,5	10	0,8	4	0,8	7	4	5	8,75	45,45	50	60,9
TSS							8,8	10	14,37			

Filtrating water after biofilter showed increase of TSS in the day two, 10 mgDM/l (Table 3) compared to TSS before drum filter 9, 71 mgDM/l (Table 2).

Table 4: Serial filtration in three days with water sample after MBBR and total mgSS/l. Filtering was done through eight different mesh size filters (µm) in mg, mg dry matter/l and percentage of dry matter.

filter size, µm	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	mg dry matter/l			%		
		Day 1		**Day 2**		**Day 3**	**D1**	**D2**	**D3**	**D1**	**D2**	**D3**
> 200	5	2	5	2	5	2	0,4	0,4	0,4	1,82	3,33	3,77
120 - 200	5	5	5	2	5	2	1	0,4	0,4	4,55	3,33	3,77
90 - 120	5	2	5	2	5	2	0,4	0,4	0,4	1,82	3,33	3,77
60 - 90	5	2	5	2	5	2	0,4	0,4	0,4	1,82	3,33	3,77
30 - 60	5	4	5	4	5	2	0,8	0,8	0,4	3,64	6,66	3,77
20 - 30	5	6	5	6	5	2	1,2	1,2	0,4	5,46	9,98	3,77
10 - 20	1,8	2	4	7	2,5	8	1,11	1,75	3,2	5,06	14,56	30,19
0,45 - 10	0,6	10	0,6	4	0,4	2	16,67	6,67	5	75,83	55,48	47,17
TSS							21,98	12,02	10,6			

Values mgSS/l obtained by filtering the water sample after drum filter is obviously less (Table 5). Filtering the water sample through 10 µm filter, 4, 07 L water could passed through and 1, 27 mg/l obtained. Higher values of SS are evident between filter 0, 45 and 10 µm where is obtained 5, 92 mg/l DM in 1, 37 L water. In water after a bio-filter values of total solids mainly arise from 200 µm to 0, 45 µm (Table 5). A significant difference was seen at 0, 45 µm filter where was obtained 9, 44 mg/l total solids in only 0, 53 L water. Values are slightly decreasing up to 30 µm where is obtained 1, 53 µm mg dry matter/l

Table 5: Three days average values of serial filtration. Presented values are DM in mg dm/l and percentages obtained by filtering the water sample taken before drum filter, after drum filter and after a MBBR in between different size classes (µm); TSS and purification efficiency (PU) after drum filter and after MBBR. Percentages removed indicate how much of suspended solids are removed from the given filter size.

size classes, µm	before drum filter			after drum filter					after a biofilter				
	Sample size, l	mg dm/l	%	Sample size, l	mg dm/l	%	mg/l removed	% removed	Sample size, l	mg dm/l	%	mg/l removed	% removed
> 200	5	2,33	13,15	5	0,67	6,44	1,67	71,43	5	0,40	2,97	0,27	40,00
120 - 200	5	1,13	5,53	5	0,67	6,04	0,47	41,18	5	0,60	3,88	0,07	10,00
90 - 120	5	1,13	5,40	5	0,60	6,05	0,53	47,06	5	0,40	2,97	0,20	33,33
60 - 90	5	0,93	5,41	5	0,33	3,31	0,60	64,29	5	0,40	2,97	-0,07	-20,00
30 - 60	5	1,53	8,59	5	0,73	6,50	0,80	52,17	5	0,67	4,69	0,07	9,09
20 - 30	5	1,07	6,37	5	0,87	8,20	0,20	18,75	5	0,93	6,41	-0,07	-7,69
10 - 20	2,13	1,25	7,56	4,07	1,27	11,34	-0,02	-1,55	2,77	2,02	16,60	-0,75	-58,74
0,45 - 10	0,5	10,95	47,99	1,37	5,92	52,12	5,04	45,98	0,53	9,44	59,49	-3,53	-59,62
TSS		20,34			11,06					14,86			
PU					45,64					-34,45			

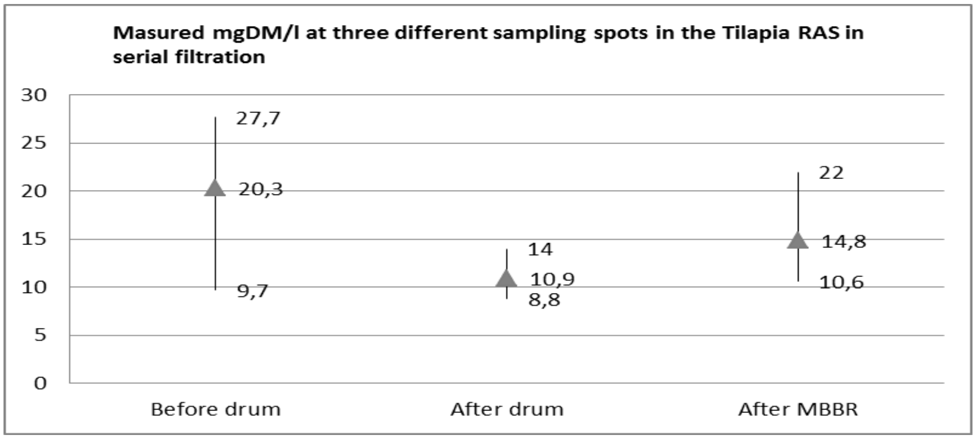


Figure 14: The measurement of accuracy of suspended solids. Maximum, minimum and mean values over all size classes

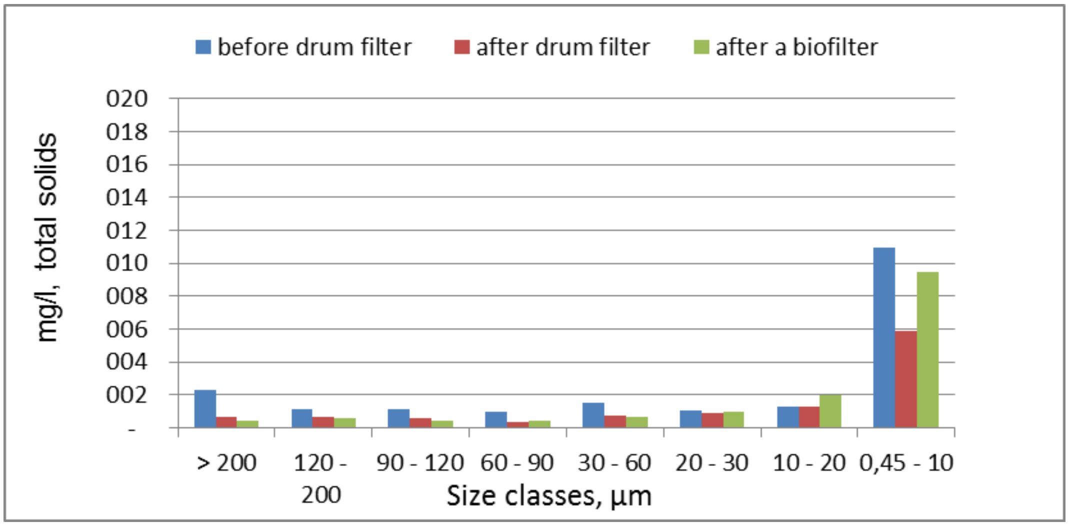


Figure 15: Distribution of total solids (mg/l) between a different mesh size filters (µm) in RAS throughout serial filtration in water before drum filter, after drum filter and after bio-filter.

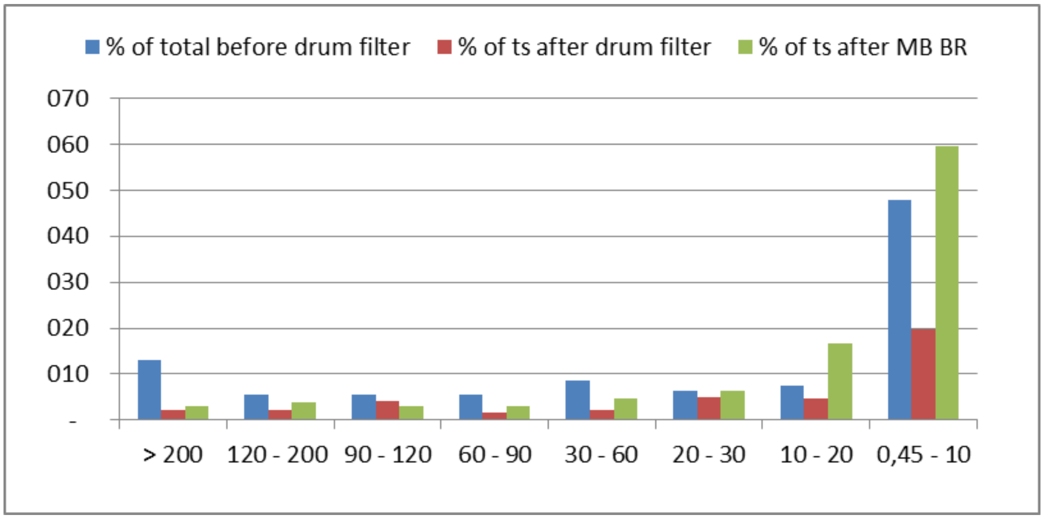


Figure 16: Distribution of solids (% of total mgSS/l) between a different mesh size filters (µm) in RAS throughout serial filtration in water before drum filter, after drum filter and after a bio-filter.

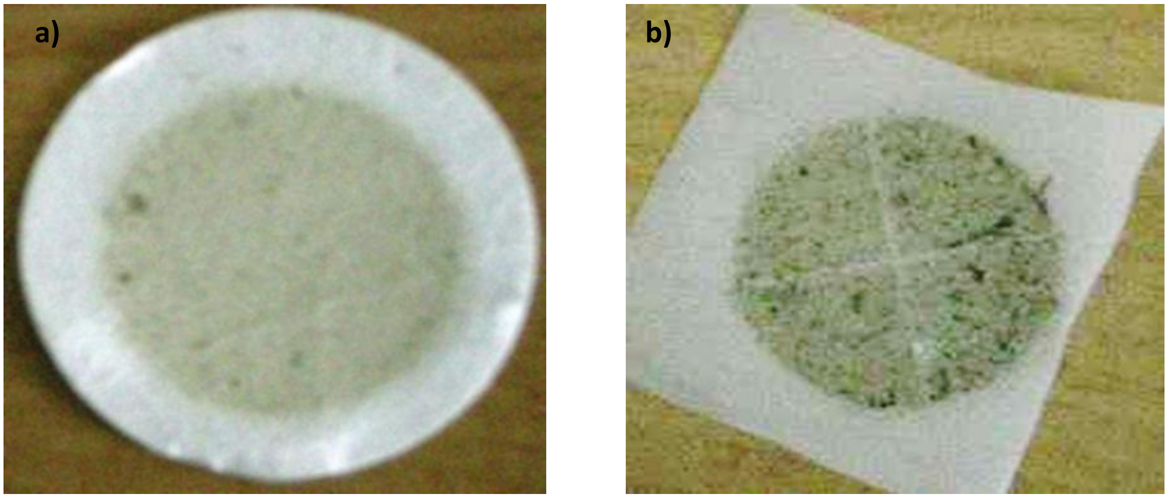


Figure 17: Suspended solids in the water sample after drum filter collected on the (a) 0, 45 µm filters and (b) 30 µm in serial method.

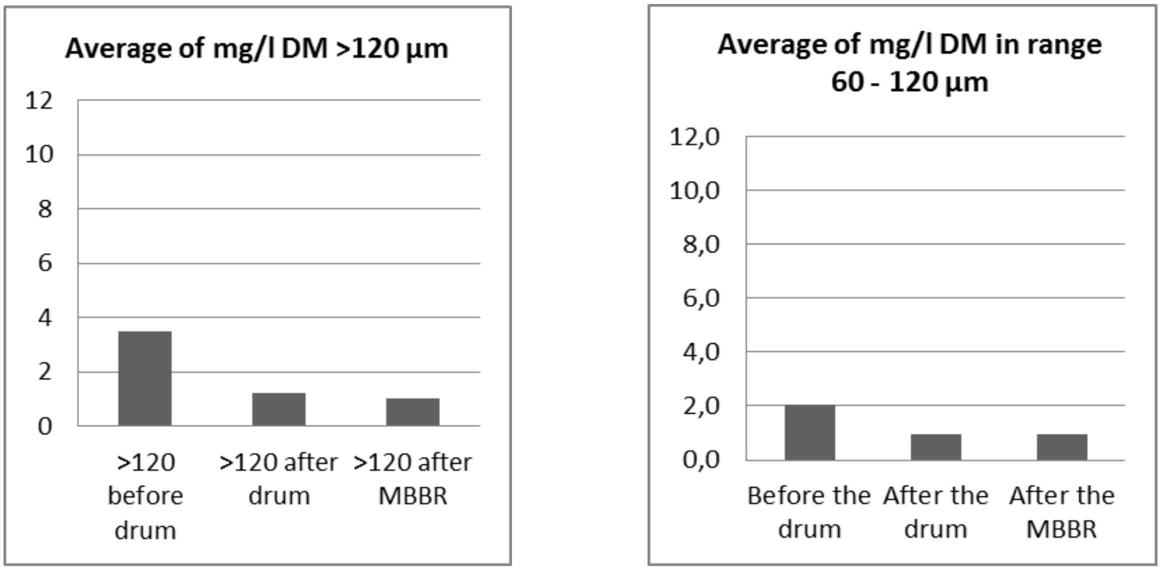


Figure 18: Distribution of particles before drum filter, after drum filter and after biofilter that are bigger of 120 µm (left) and in range 60 – 120 µm (right).

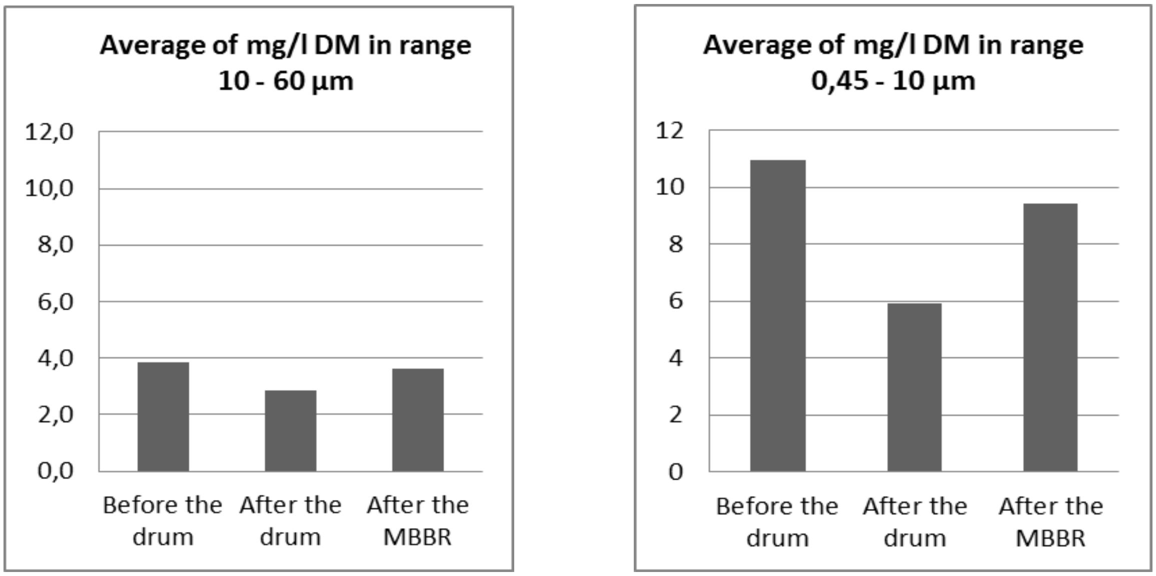


Figure 19: Distribution of particles before drum filter, after drum filter and after biofilter in rabge 10 - 60 µm (left) and in range 0, 45 – 10 µm (right).

3.2 Parallel filtration

3.2.1 System function at parallel filtration

In parallel filtration the results are shown as values of mg/l dry matter and percentages of dry matter that are bigger of given size filter (Table 6, 7 and 8). Increasing values of dry matter in mg per liter from higher to lower filter sizes is more noticeable in the water samples before drum filter, especially for total solids greater than 0, 45 µm (Table 6). Looking at the percentages of total solids on 0, 45 µm filter was significantly greater in the water samples from taken after bio-filter 76, 92 %; 70, 77% and 33, 78%. Water samples before drum filter did not give such a different values (mg/l) from 200 to 20 µm if compared three days of parallel filtration (Table 6). In a range size 0, 45 – 10 µm there is a significant difference in mg/l total solids, so it is 30; 11, 62 and 8 mg/l total solids (dry matter) in day 1, day 2 and day 3.

Table 6: Parallel filtration of water samples before drum filter and total suspended solids (TSS) of mg dm/l. Filtering was done through eight different mesh size filters (µm) in mg, mg dry matter/l and percentage of dry matter bigger then given filter size (%). Different amount of water used for each filter size (Sample size, l).

filter size, µm	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	mg dry matter/l			%		
		Day 1		**Day 2**		**Day 3**	**D1**	**D2**	**D3**	**D1**	**D2**	**D3**
> 200	5	4	5	5	5	2	0,8	1	0,4	1,82	4,32	2,14
> 120	5	5	5	4	5	6	1	0,8	1,2	2,28	3,46	6,41
> 90	5	8	5	7	5	5	1,6	1,4	1	3,65	6,05	5,34
> 60	5	7	5	6	5	7	1,4	1,2	1,4	3,19	5,19	7,47
> 30	5	11	5	11	5	7	2,2	2,2	1,4	5,02	9,51	7,47
> 20	3	8	4	8	4	10	2,67	2	2,5	6,08	8,65	10,68
> 10	1,2	5	1,4	4	1,5	5	4,17	2,86	3,33	9,51	12,36	17,79
> 0,45	0,2	6	0,6	7	0,5	4	30	11,62	8	68,44	50,45	42,7
TSS							43,84	23,08	19,23			

Table 7: Parallel filtration of water samples after drum filter and total suspended solids (TSS) of mg dm/l. Filtering was done through eight different mesh size filters (µm) in mg, mg dry matter/l and percentage of dry matter bigger then given filter size (%). Different amount of water used for each filter size (Sample size, l).

filter size, µm	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	mg dry matter/l			%		
		Day 1		**Day 2**		**Day 3**	**D1**	**D2**	**D3**	**D1**	**D2**	**D3**
> 200	5	5	5	2	5	2	1	0,4	0,4	6,86	3,35	2,75
> 120	5	2	5	2	5	4	0,4	0,4	0,8	2,75	3,35	5,49
> 90	5	2	5	4	5	4	0,4	0,8	0,8	2,75	6,7	5,49
> 60	5	2	5	2	5	5	0,4	0,4	1	2,75	3,35	6,86
> 30	5	7	5	6	5	6	1,4	1,2	1,2	9,61	10,06	8,24
> 20	5	4	5	7	5	6	0,8	1,4	1,2	5,49	11,73	8,24
> 10	2	7	3	2	2	5	3,5	0,67	2,5	24,03	5,59	17,16
> 0,45	0,3	2	0,6	4	0,6	4	6,67	6,67	6,67	45,77	55,87	45,77
TSS							14,57	11,94	14,57			

Table 8: Parallel filtration of water samples after MB BR and total suspended solids (TSS) of mg dm/l. Filtering was done through eight different mesh size filters (µm) in mg, mg dry matter/l and percentage of dry matter bigger then given filter size (%). Different amount of water used for each filter size (Sample size, l).

filter size, µm	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	Sample size, L	mg, dry matter	mg dry matter/l			%		
		Day 1		**Day 2**		**Day 3**	**D1**	**D2**	**D3**	**D1**	**D2**	**D3**
> 200	5	4	5	13	5	2	0,8	2,6	0,4	2,05	7,36	1,35
> 120	5	7	5	4	5	8	1,4	0,8	1,6	3,59	2,26	5,4
> 90	5	10	5	2	5	7	2	0,4	1,4	5,13	1,13	4,73
> 60	5	7	5	5	5	9	1,4	1	1,8	3,59	2,83	6,08
> 30	5	9	5	7	2,5	11	1,8	1,4	4,4	4,62	3,96	14,86
> 20	5	4	5	7	1	8	0,8	1,4	8	2,05	3,96	27,03
> 10	2,5	2	2,2	6	2	4	0,8	2,73	2	2,05	7,72	6,76
> 0,45	0,2	6	0,2	5	0,3	3	30	25	10	76,92	70,77	33,78
TSS							39	35,33	29,6			

In parallel filtration using the water before drum filter significantly lower number of solids are obtained on the 200 µm compared to average values in serial method (table 8 and 5). During filtration of water samples before drum filter it was noted that on 20 µm the filtration rate slowed after the 4, 33 L where we get 2, 22 mg/l dry matter (table 9). With decreasing size of a filter, the amount of water sample that could pass through a filter start reducing, but the numbers of mg/l increase. Clogging was the most evident on 0, 45 µm filter before drum filter where only 0, 43 L of water sample could be filtrated and it was obtained 16, 56 mg/l total solids (table 9). In column after drum filter the obtained values are less when it is compared with column before drum filter which proves the absence of large particles from that part of the system. In the water after bio-filter it was noticed that the higher values of total solids obtained especially on the 0, 45 µm filter and it was 21, 67 mg/l in 0, 37 L of water (table 9). Clogging was obvious on the 30 µm filters where 4, 17 L water was possible to filtrate and the amount of solids was 2, 53 mg/l (table 9). Results that are obtained from parallel filtration are presented in two different ways (table 9). It is primarily shown as values bigger of a given size, but the other way of calculation is between two filter sizes, the same as in serial filtration (Table 9 and 5). Using calculations for comparing samples gave negative results on the filter 120, 60 and 20 µm in experiment after drum filter and on the filter 10 µm in experiment after bio-filter (Table 9).

Table 9: Three days average values of parallel filtration. Presented values are: dry matter in mg/l, percentages (%) of TS, mg/l of compared samples as another way of calculation in parallel filtration, removed mg/l and removed %; TSS and purification efficiency (PU) after drum filter and after MB BR. Values are obtained by filtering the water sample (L) that is taken before drum filter, after drum filter and after a MB BR through eight different sizes of filters (µm).

size classes, µm	before drum filter				after drum filter						after a biofilter					
	Sample size, l	mg dm/l	%	mg dm/l compared samples	Sample size, l	mg dm/l	%	mg dm/l compared samples	mg/l removed	% removed	Sample size, l	mg dm/l	%	mg dm/l compared samples	mg/l removed	% removed
> 200	5	0,73	2,74	0,73	5	0,60	4,32	0,60	0,13	18,18	5	1,27	3,59	1,27	-0,67	-52,63
> 120	5	1,00	3,99	0,27	5	0,53	3,86	-0,07	0,47	46,67	5	1,27	3,75	0,00	-0,73	-57,89
> 90	5	1,33	4,97	0,33	5	0,67	4,98	0,13	0,67	50,00	5	1,27	3,66	0,00	-0,60	-47,37
> 60	5	1,33	5,22	0,00	5	0,60	4,32	-0,07	0,73	55,00	5	1,40	4,17	0,13	-0,80	-57,14
> 30	5	1,93	7,27	0,60	5	1,27	9,30	0,67	0,67	34,48	4,17	2,53	7,81	1,13	-1,27	-50,00
> 20	4,33	2,22	9,24	0,29	5	1,13	8,49	-0,13	1,09	49,00	3,67	3,40	11,01	0,87	-2,27	-66,67
> 10	1,37	3,45	13,06	1,23	2,33	2,22	15,59	1,09	1,23	35,63	2	1,84	5,51	-1,56	0,38	20,61
> 0,45	0,43	16,56	53,50	13,10	0,5	6,67	49,13	4,44	9,89	59,73	0,37	21,67	60,49	19,82	-15,00	-69,23
TSS		28,56				13,69			14,87			34,64			-20,95	
PU						52,08						-153,07				

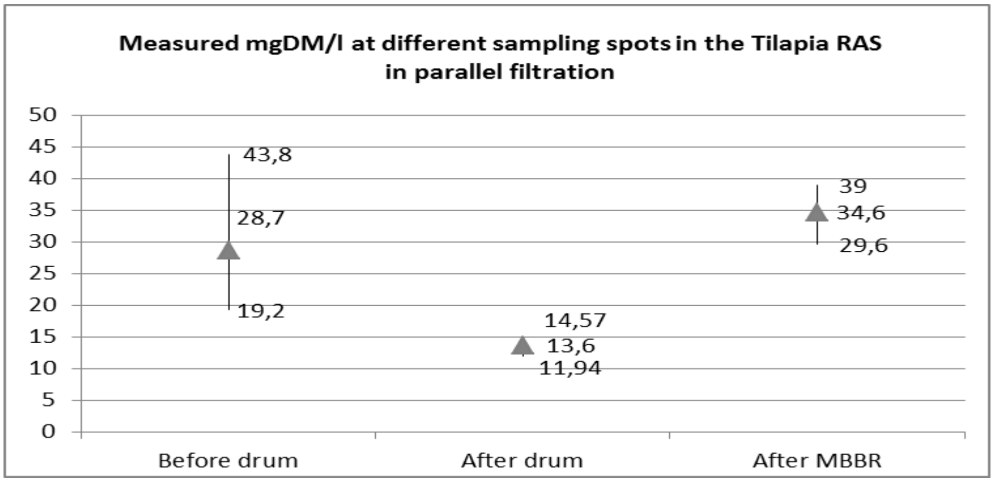


Figure 20: The measurement of accuracy of suspended solids. Maximum, minimum and mean values over all size classes

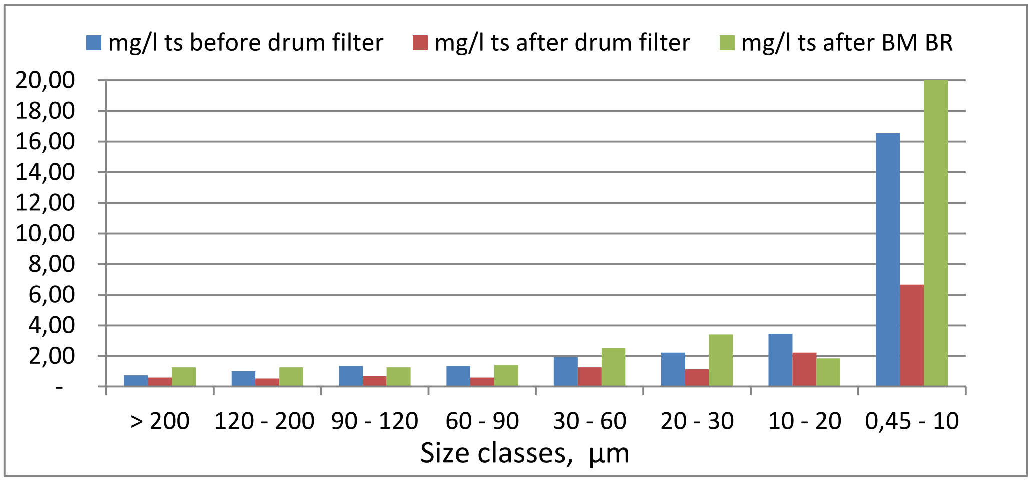


Figure 21: Distribution of total solids (mg/l) in intervals between a different mesh size filters (µm) in RAS throughout parallel filtration in water before drum filter, after drum filter and after a bio-filter.

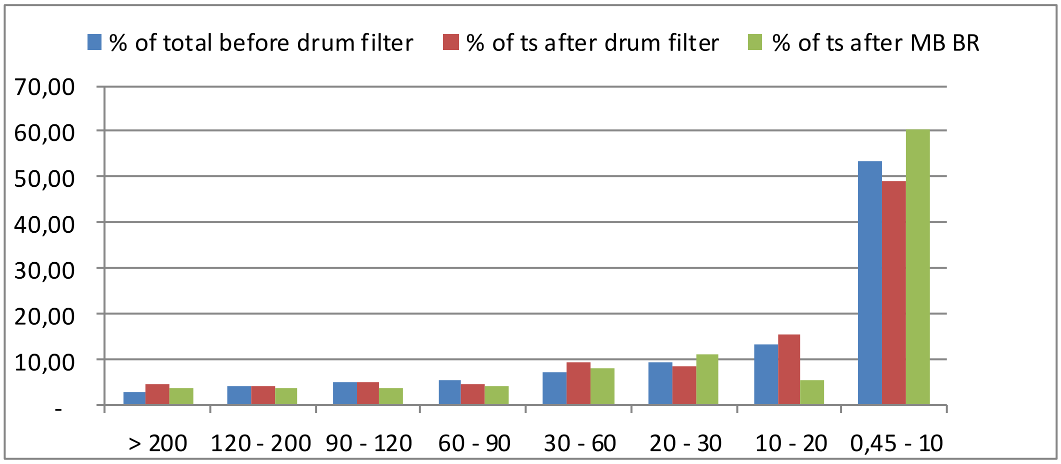


Figure 22: Distribution of total solids (%) in intervals between a different mesh size filters (µm) in RAS throughout parallel filtration in water before drum filter, after drum filter and after a bio-filter.

3.3 Results of serial vs. parallel filtration

In serial method in the water before drum filter TS concentration was low at the beginning of the study on 200 µm until 60 µm (0, 4 mg/l) then increased to 1, 2 mg/l on the 30 µm (1, 2 mg/l) (Table 10). On 20 µm the value of TS was 5 mg/l in 2, 8 L water sample. The highest value total solids reached between 0, 45 and 10 µm (14 mg/l). There is a big difference in amount of water samples used in serial filtration, as well as in parallel method between 200 and 0, 45 µm (Table 10 and 11). Looking at percentages in serial filtration substantial increase between 10 – 20 and 0, 45 – 10 µm is noticed. Only 1, 75 % of suspended solids are bigger than 200 µm. The same percentage value is followed up until range size 60 – 90 µm. Serial method showed that 61, 40 % suspended solids are bigger that 0, 45 µm (Table 10). At parallel method the values are varying up and down starting from 200 µm, over 120, 90, 60, 30, 20, 10 and 0, 45 µm. On the 20 µm 4 L of a water sample was used; on 10 µm 2 L water used and on 0, 45 µm only 0, 5 L used (Table 11). At parallel method 12, 70 % suspended solids are bigger that 120 µm compared to serial filtration where 1, 75 % was bigger of a same filter size. Since parallel method showed higher percentage values than serial method at almost all filters size, on 10 and 0, 45 µm the situation is inverted. Hence experiment showed that 13, 23% and 31, 75% of solids are bigger than 10 and 0, 45 µm at parallel method (Table 11).

Table 10 and 11: Filtrations in series and parallel using water sample before drum filter. Presented values are dry matter in mg, mg/l and % of samples in between two sizes (serial) and bigger of a given size (parallel). In this experiment water was used from only one location in which 5 L of water sample filtered through all filter for serial filtration, while in parallel it was used particular 5 l for each filter size.

	serial filtration before drum filter			
µm	**sample size, l**	**mg d.m.**	**mg d.m./l**	**%**
> 200	5	2	0,4	1,75
120 - 200	5	2	0,4	1,75
90 - 120	5	2	0,4	1,75
60 - 90	5	2	0,4	1,75
30 - 60	5	6	1,2	5,26
20 - 30	5	5	1	4,39
10 - 20	2,8	14	5	21,93
0,45 - 10	0,5	7	14	61,40
TSS			22,8	

	parallel filtration before drum filter			
µm	**sample size, l**	**mg d.m.**	**mg d.m./l**	**%**
> 200	5	2	0,4	2,12
> 120	5	12	2,4	12,70
> 90	5	8	1,6	8,47
> 60	5	11	2,2	11,64
> 30	5	9	1,8	9,52
> 20	4	8	2	10,58
> 10	2	5	2,5	13,23
> 0,45	0,5	3	6	31,75
TSS			18,9	

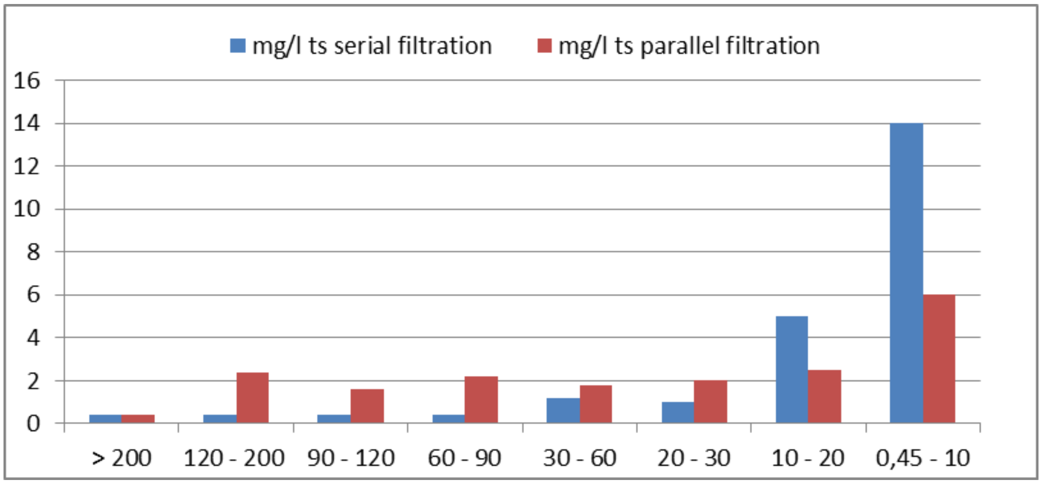


Figure 23: Distribution of total solids (mg/l) in intervals between a different mesh size filters (µm) in RAS through serial and parallel filtration.

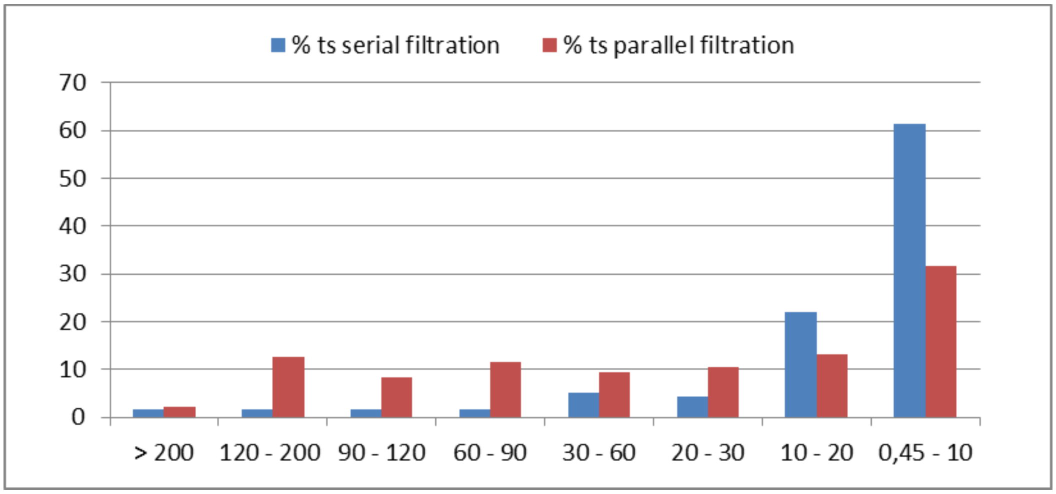


Figure 24: Distribution of total solids (%) in intervals between a different mesh size filters (µm) in RAS through serial and parallel filtration.

4 Discussion

Two filtrating methods that have been described in this study were to calculate particles distribution from recirculating system (RAS) for the different size classes. The aim was to evaluate the proper way for particle distribution in the system. Suspended solids adversely impact all aspect of recirculating system (RAS) so the objective of any recirculating treatment scheme is the removal of solid wastes (Pfeiffer et. al. 2008).

In the drum filter particles can be crushed into small particles again, even smaller than the original. Solids which do not get captured during their first pass through the drum filter have little chance of getting captured during subsequent passes because they get broken into smaller once in the interim (Counturier et. al. 2009). Before the drum filter, water contains a lot of large particles which during filtration separate on the filter. Filter size 200 µm was very efficacy in solids removal in serial filtration (71, 43% removed) after drum filter, whereas in parallel same size filter was the least efficient of all the rest filters apertures (18, 18 % removed). Drum filter used in recirculating system where all experiments were done is 40 µm filter openings, so all particles smaller than 40 µm are expected to pass through the filter. Even though, despite the expectations that drum filter will remove all large particles, some remained after drum filtration as indicated by the treatment efficiency value of 45, 64%, considering that TSS refers to the large solids.

There was no reduction of suspended solids after bio-filter at all filters classes in serial method. Moreover, TSS values 20, 34 mg/l (before drum filter), 11, 06 mg/l (after drum filter) and 14, 86 mg/l (after MBBR) tell that bio-filter creates particles.

A most effective filter size was 60 – 90 µm producing a maximum concentration reduction for total solids after drum filter in serial method (64, 29% removed). Substantial reduction of solids was between 30 – 20 and 20 – 10 µm in parallel method. Serial filtration resulted in reducing total solids after drum filter in range of 1, 67 mg/l – 5, 04 mg/l.

As a result of filtering the water sample (Kelly et.al. 1997) using meshes size < 200 µm; 200 – 100 µm; 100 – 60 µm; 60 – 30 µm and < 30 µm, the most efficiencies for SS was in range size 100 – 60 µm, approximately 80 % in a period of peak waste output i.e. tank cleaning.

Results indicated that very small particles (in range 0, 45 – 10 µm) dominated the particles by numbers. Serial method after MBBR showed 59, 50% and in parallel method even 60, 50% of total solids in range 10 – 0, 45 µm. Difference in values is also due to different amount of water sample that could be filtrated (20 µm; 10 µm and 0, 45 µm). The moment when filter cloths start to clog it's overestimating particle size. Water after drum filter is already mechanically treated in the drum filter, so the dominated particles are smaller ones. Using filter size 250 and 120 µm wide range of SS removal efficiencies (16 – 94%) achieved (Cripps and Bergheim, 2000). While in other tests was achieved an average 40 % suspended dry matter (SDM) removal using 350 and 60 µm pore size screens.

Studies showed that only 50 – 60 % of suspended solids in the rearing tanks are removed from the water in a mechanical filter equipped with 60 – 80 µm micro-screen panels. In the recirculating system fine particles accumulate and 40 – 70 % of suspended solids concentration are particles smaller than 20 µm. Suspended solids that are not removed from recirculating flow are partly dissolved and broken apart mainly in the pump and their decay in the bio-filter increases the ammonia production and the oxygen demand of the rearing system (Blancheton, 2000).

4.1 Purification efficiency regarding TSS

The effectiveness of the drum filter was shown through purification efficiency (PU). Purification efficiency was calculated to determine the amount of total suspended solids (TSS) that were removed of each location. The mass balance calculations indicate that the micro-screen drum filter removed 40 – 45 % of TSS daily from the recirculating system using solid settling device (Davidson and Summerfelt, 2005). The same results indicate that drum filter treatment prevents elevated TSS concentration from accumulating within recirculating system.

In serial filtration purification efficiency was less than 50 % (45, 64%) compared to parallel in which reduced 52, 08 % TSS.

Particle distribution for different filtrating methods was measured at different period of time. There is no huge difference in the distribution of solids in range 120 – 60 µm before and after drum filter between serial and parallel method. Nevertheless, both methods showed that after bio-filter there is great difference between solids at all size classes, especially above 0, 45 µm (21, 67 mg/l) at parallel and solids bigger than 0, 45 µm (9, 44 mg/l) at serial method. This difference might be also due to different filtrating system or different water quantities used for each method.

When taking samples before drum filter, pipe was tilted down to pouring water into the canister. This process leads to the increasing of water velocity. When velocity is lower than 0, 5 m/s, particles in the pipe will sediment. Passing through outlet pipe some solids temporary fasten inside tubes and pipes and aggregate but when water velocity increase some of these aggregate will loosen. One of assumptions is that sedimentation and changing velocity can affect results.

Outlet pipe from the fish tank is made of polyethylene, with 90 ° angle. This angle can break particles into smaller ones which could cause a larger number of small particles in the water before drum filter. Moreover, in a period of tank cleaning (ones a week) and flushing out of the water, particles can loosen from the tank wall.

In a period of taking samples, fish were fed with experimental feed produced by Feed technology department at University of life science in Ås, Norway. This kind of feed is not water stable and produces a lot of dust.

Intermittent solids loading increases can occur as a result of intermittent tank cleaning operations (Cripps and Bergheim, 2000) or from unit processes that function irregularly such as back-pressure activated rotating micro-screens.

Large particles that are expected to be retained by a given mesh size are passing through the filters, and this appear to be common feature in suspended solids derived from fish culture because of the flexibility in changing shape by external forces (Orellana, 2006).

Values of parallel filtration are calculated in two different ways: 1) as comparing samples; and 2) as particles bigger of a filter size. Compared samples gave a negative results in experiments after drum filter (>120 µm, >60 µm and >20 µm) and after bio-filter (>10 µm). It proves that parallel filtration is very difficult method. Accuracy of comparing samples is very low and water sample is not representative. So, comparing samples is not possible. It must be variations in water samples that led to negative results. Normally, suspended solids increase with decreasing size of filter. Small particles are predominant. Since in the parallel filtration one water sample is used for only one filter size it gave an advantage of the method. In fact, parallel filtration will not underestimate particles. It will show distribution of all particles in the water sample bigger of a given filter size. The same as parallel, serial method is also showing exact distribution of particles but only on the filter 200 µm.

Some of results obtained in this study are not as expected. Second day of the experiment in serial filtration showed TSS 9, 71 mg/l before drum filter and 10 mg/l after drum filter. During mechanical treatment of the water in the drum filter, some particles fasten to the wall of the drum (Figure 13). Fouling of the drum filter may affect particle size. Drum filtration changed the particle size distribution, resulting in increase of the smaller particle fraction of the sieved material, thereby indicating a partial breakdown of large particles during the mechanical filtration process (Orellana, 2006). Back-flushing of the drum filter normally occur every 10 seconds and that time is fixed, and running time is 1 minute but can vary 5 – 7 sec depends on how dirty the water is (Figure 11). Taking samples normally took 5 – 10 minutes, which tells that back-flushing could have happened during sampling time

5 Conclusion

Great importance is the way of calculations, filtering and making size classes. Serial and parallel filtrating methods that were evaluated in this study gave improper values in terms of distribution of a different particles size. Serial filtrating method can causes breaking particles, while parallel filtrating method does not give the proper distribution of particles. With both methods was it difficult to achieve accurate results, because it was difficult to take representative samples. Whole water sample could not pass through small filter sizes, because filter starts clogging very fast. The moment the filter cloth starts to clog its overestimating particles. For more accurate analysis further studies are desirable to develop methods for particle size distribution.

The effectiveness of the drum filter in serial filtrating method was measured to be 45, 67%, and in parallel filtration it was measured to be 52, 08%. This cleaning effect is in the expected level (Summerfelt and Penne, 2005).

Biofilter showed rise of particles from 11, 06 mgSS/l TSS after drum filter to 14,86 mgSS/l TSS after MBBR in serial filtration, while in parallel filtration method was 13, 69 mgSS/l TSS after drum filter to 34, 64 mgSS/l TSS after MBBR. This indicates that the biofilter produces organic matter as particles as expected.

Small particles (less than 40 µm) are dominating. Their greater presence in all sampling spots indicates their accumulation in the system.

6 References

Bergheim, A. (2007): Sludge production and the mechanical treatment of waste. Aquaculture engineering: 119 – 151.

Blancheton J. P. (2000): Developments in recirculating systems for Mediterranean fish species. Aquaculture engineering, 22: 17 – 31.

Brinker, A. and Rösch, R. (2005): Factors determining the size of suspended solids in flow-through Fish farms. Aquaculture engineering, 33: 1 – 19.

Chen, S.; Timmons, M.B.; Aneshansley, D. J.; Bisogni Jr, J.J. (1993): Suspended solids characteristics from recirculating aquaculture systems and design implications. Aquaculture, 112: 143 – 155.

Couturier, M.; Trofimencoff, T.; Buil, J. U.; Conroy, J. (2009): Solid removal at a recirculating salmon – smolt farm. Aquaculture engineering, 41: 71 – 77.

Cripps, S. J. (1995): Serial particle size fractionation and characterization of an aquaculture effluent. Aquaculture, 133: 323 – 339.

Cripps, S. J. and Bergheim, A. (2000): Solids management and removal for intensive land – based aquaculture production systems. Aquaculture engineering, 22: 33 – 56.

Davidson, J, and Sumerfelt, S. T. (2005): Solids removal from a Coldwater recirculating system – comparison of a swirl separator and a radial-flow settler. Aquaculture engineering, 33: 47 – 61.

Ebeling, J. M.; Rishel, K. L.; Sibrell, P. L. (2005): Screening and evaluation of polymers as flocculation aids for the treatment of aquaculture effluent. Aquaculture engineering, 33: 235 - 249.

Hutchinson, W.; Jeffrey, M.; O'Sullivan, D.; Casement, D.; Clarke, S. (2004): Recirculating aquaculture system. Minimal standards for design, construction and management. Inland Aquaculture Association of South Australia Inc.

Johnson, W. and Chen, S. (2006): Performance of radial/vertical flow clarification applied to recirculating aquaculture system. Aquaculture engineering, 34: 47 – 55.

Kelly, L. A.; Bergheim, A.; Stellwagen, J. (1997): Particle size distribution of waste water from freshwater fish farms. Aquaculture international, 5: 65 - 78.

Lekang, O. I. (2007): Aquaculture engineering. Wiley-Blackwell Publishing, Oxford 2007.

Masser, M. P.; Rakocy, J.; Losordo, T. M. (1999): Recirculating aquaculture tank production System. Management of recirculating systems. SRAC Publication, 452.

McMIllan, J. D.; Wheaton, F. W.; Hochheimer, J. N.; Soares, J. (2003): Pumping effect on particle sizes in a recirculating aquaculture system. Aquaculture engineering, 27: 53 – 59.

Orellana, J. (2006): Identification and quantification of suspended solids and their effects in modern marine recirculating system. Dissertation.

Pfeiffer, T. J.; Osborn, A.; Davis, M. (2008): Particle sieve analysis for determining solids removal efficiency of water treatment components in recirculating aquaculture system. Aquaculture engineering, 39: 24 – 29.

Rijn, J. V. (1996): The potential for integrated treatment systems in recirculating fish culture-A review. Aquaculture, 139: 181 – 201.

Steicke, C.; Jegatheesan, V.; Zeng, C. (2007): Mechanical mode floating medium filters for recirculating systems in aquaculture for higher solids retention and lower freshwater usage. Bioresource technology, 98: 3375 – 3383.

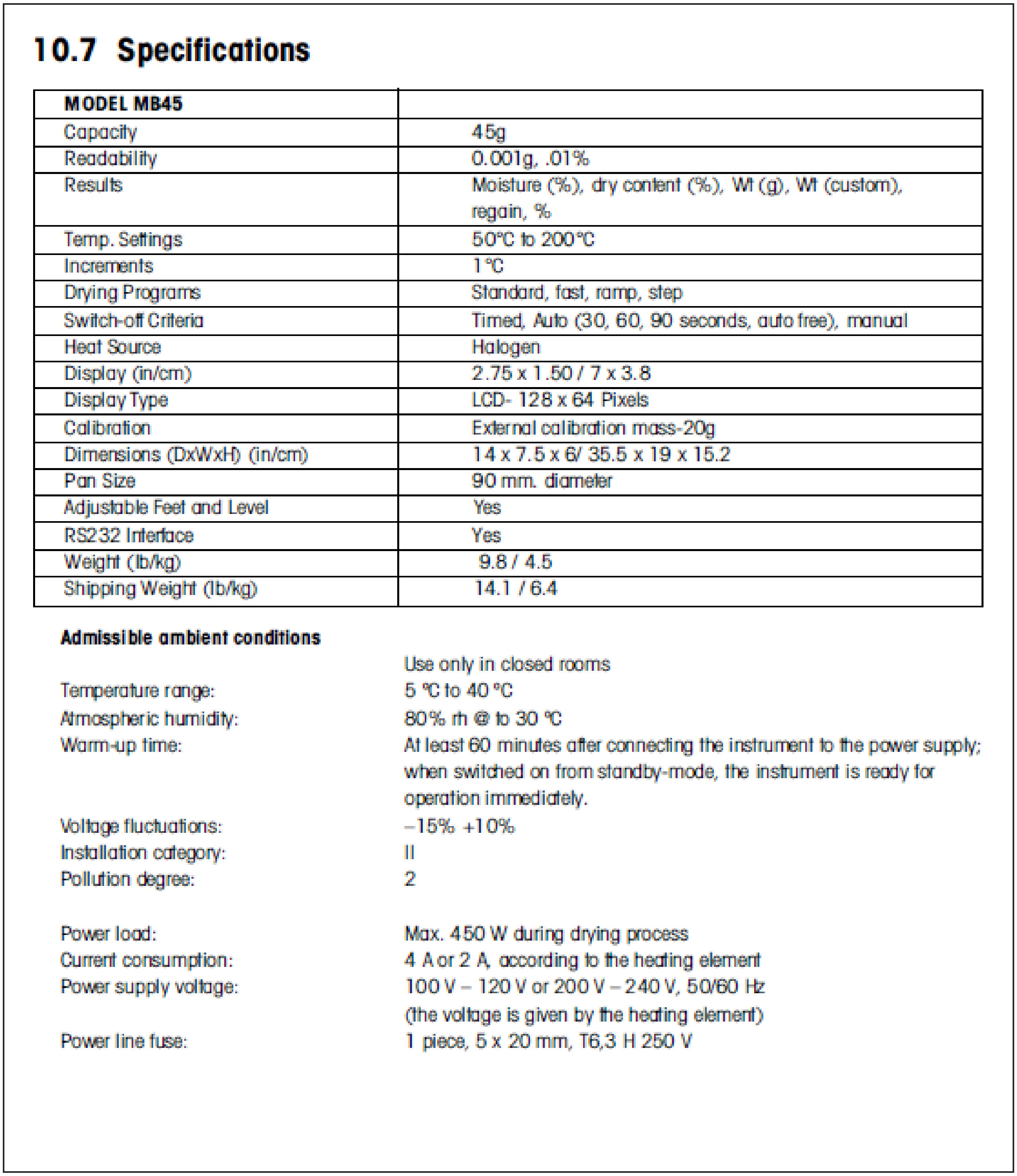
Summerfelt, R. C. and Penne, C. R. (2005): Solids removal in a recirculating aquaculture system where the majority of flow bypasses the micro-screen filter. Aquaculture engineering, 33: 214 – 224.

Timmons, M. B.; Ebeling, J. M.; Wheaton, F. W.; Summerfelt, S. T.; Vinci, B. J. (2002): Solids capture. Recirculating aquaculture engineering 2nd edition.

Twarowska, J. G.; Westerman, P. W.; Losordo, T. M. (1997): Water treatment and waste characterization evaluation of an intensive recirculating fish production system. Aquaculture engineering, 16: 133 – 147.

Viadeo Jr, R. C. and Noblet, J. A. (2002): Membrane filtration for removal fine solids from aquaculture process water. Aquaculture engineering, 26: 151 – 169.

7 Appendix



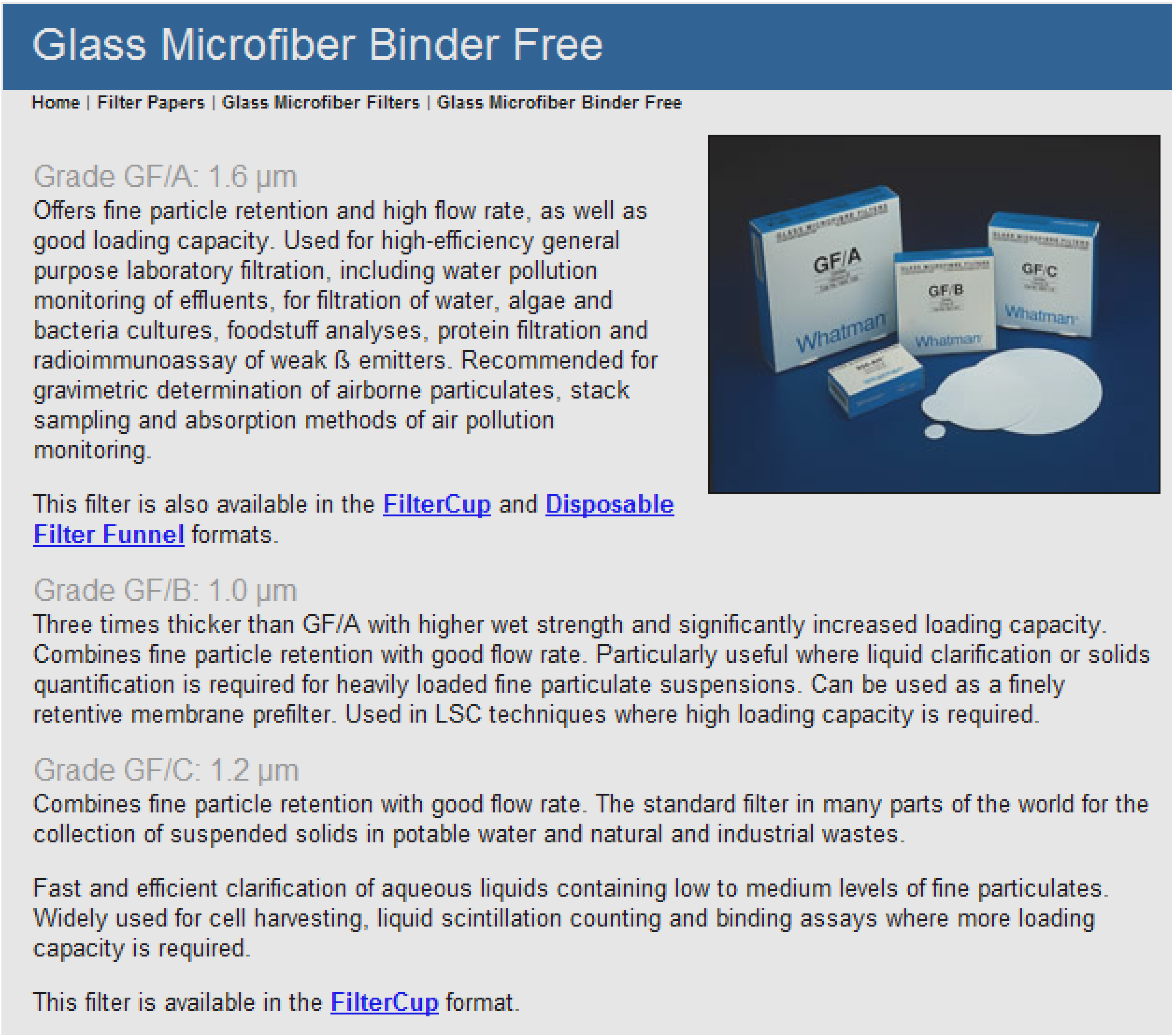
10.7 Specifications

MODEL MB45	
Capacity	45g
Readability	0.001g, .01%
Results	Moisture (%), dry content (%), Wt (g), Wt (custom), regain, %
Temp. Settings	50°C to 200°C
Increments	1°C
Drying Programs	Standard, fast, ramp, step
Switch-off Criteria	Timed, Auto (30, 60, 90 seconds, auto free), manual
Heat Source	Halogen
Display (in/cm)	2.75 x 1.50 / 7 x 3.8
Display Type	LCD- 128 x 64 Pixels
Calibration	External calibration mass-20g
Dimensions (DxWxH) (in/cm)	14 x 7.5 x 6/ 35.5 x 19 x 15.2
Pan Size	90 mm. diameter
Adjustable Feet and Level	Yes
RS232 Interface	Yes
Weight (lb/kg)	9.8 / 4.5
Shipping Weight (lb/kg)	14.1 / 6.4

Admissible ambient conditions

	Use only in closed rooms
Temperature range:	5 °C to 40 °C
Atmospheric humidity:	80% rh @ to 30 °C
Warm-up time:	At least 60 minutes after connecting the instrument to the power supply; when switched on from standby-mode, the instrument is ready for operation immediately.
Voltage fluctuations:	−15% +10%
Installation category:	II
Pollution degree:	2
Power load:	Max. 450 W during drying process
Current consumption:	4 A or 2 A, according to the heating element
Power supply voltage:	100 V – 120 V or 200 V – 240 V, 50/60 Hz (the voltage is given by the heating element)
Power line fuse:	1 piece, 5 x 20 mm, T6,3 H 250 V

Appendix 1: Manual instructions for Ohaus drying scale MB45



Glass Microfiber Binder Free

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Grade GF/A: 1.6 µm

Offers fine particle retention and high flow rate, as well as good loading capacity. Used for high-efficiency general purpose laboratory filtration, including water pollution monitoring of effluents, for filtration of water, algae and bacteria cultures, foodstuff analyses, protein filtration and radioimmunoassay of weak ß emitters. Recommended for gravimetric determination of airborne particulates, stack sampling and absorption methods of air pollution monitoring.

This filter is also available in the FilterCup and Disposable Filter Funnel formats.

Grade GF/B: 1.0 µm

Three times thicker than GF/A with higher wet strength and significantly increased loading capacity. Combines fine particle retention with good flow rate. Particularly useful where liquid clarification or solids quantification is required for heavily loaded fine particulate suspensions. Can be used as a finely retentive membrane prefilter. Used in LSC techniques where high loading capacity is required.

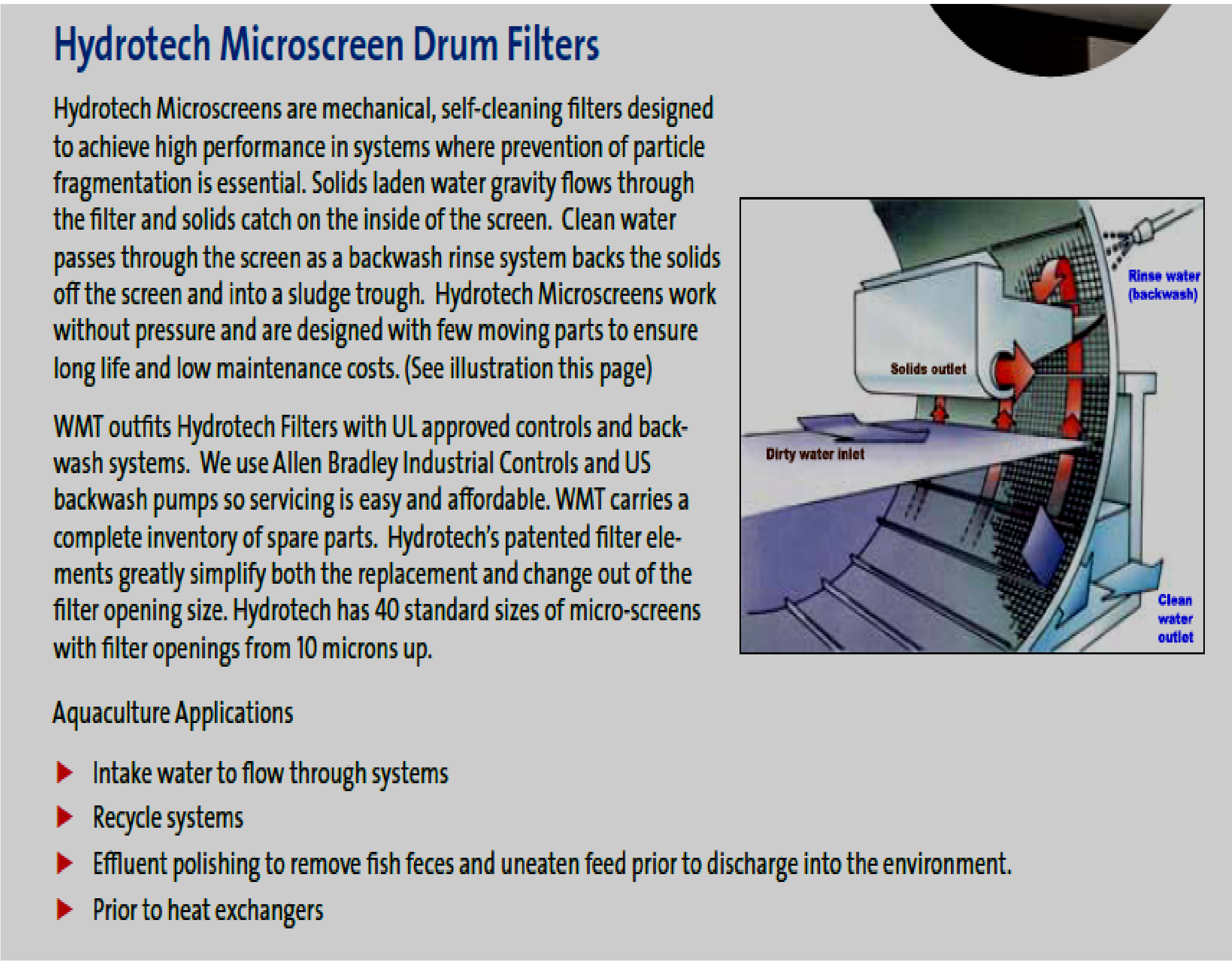
Grade GF/C: 1.2 µm

Combines fine particle retention with good flow rate. The standard filter in many parts of the world for the collection of suspended solids in potable water and natural and industrial wastes.

Fast and efficient clarification of aqueous liquids containing low to medium levels of fine particulates. Widely used for cell harvesting, liquid scintillation counting and binding assays where more loading capacity is required.

This filter is available in the FilterCup format.

Appendix 2: Characteristics of Glass Microfiber filters GF/C



Hydrotech Microscreen Drum Filters

Hydrotech Microscreens are mechanical, self-cleaning filters designed to achieve high performance in systems where prevention of particle fragmentation is essential. Solids laden water gravity flows through the filter and solids catch on the inside of the screen. Clean water passes through the screen as a backwash rinse system backs the solids off the screen and into a sludge trough. Hydrotech Microscreens work without pressure and are designed with few moving parts to ensure long life and low maintenance costs. (See illustration this page)

WMT outfits Hydrotech Filters with UL approved controls and backwash systems. We use Allen Bradley Industrial Controls and US backwash pumps so servicing is easy and affordable. WMT carries a complete inventory of spare parts. Hydrotech's patented filter elements greatly simplify both the replacement and change out of the filter opening size. Hydrotech has 40 standard sizes of micro-screens with filter openings from 10 microns up.

Aquaculture Applications

- Intake water to flow through systems
- Recycle systems
- Effluent polishing to remove fish feces and uneaten feed prior to discharge into the environment.
- Prior to heat exchangers

Appendix 3: Functioning of a drum microscreen filter

Appendix 4: Operational data for the tilapia reuse system during 2010 (an average)

Temperature	26 ºC
Oxygen, inlet fish tank	85 - 90 %
pH	6,8 - 7,2
TAN (tot. ammonia nitrogen)	0,2 - 0,4 mg/l
Nitrite (NO2)	0,4 - 0,8 mg/l
Biomass	150 kg
Flow	150 l/min