ASPECTS ON MECHANICAL FILTERING IN AQUACULTURE SYSTEMS

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Keywords: recirculating aquaculture systems, water, filter, fish

ABSTRACT

Filtering plays an essential part in the process of intensive fish farming, because faeces and unconsumed food remain in the water inside the basins where the fish are raised and in time generate bacteria and infections that lead to the death of fish. Therefore, the water in these basins is permanently recycled in order to be filtered and refreshed, this paper presenting the actuated filtering systems used in the country and worldwide in recirculating aquaculture systems (RAS) for intensive fish farming.

INTRODUCTION

Starting from the phase of designing a recirculating aquaculture system (RAS), one of the main directions that needs to be followed is maintaining water quality in the optimum physical-chemical parameters, necessary for sustaining and developing the culture species [8].

For a recirculating system to operate adequately, it is vital for it to have modern mechanical and biological filtering units for the used water (fig. 1), which besides other auxiliary equipment, to be able to recondition the water that is going to be introduced in the system [8].

When a recirculating system is equipped adequately with all the components needed to raise and maintain the fish material, only then many of the negative effects of aquaculture on the environment will be able to be controlled and reduced [14, 9, 1].

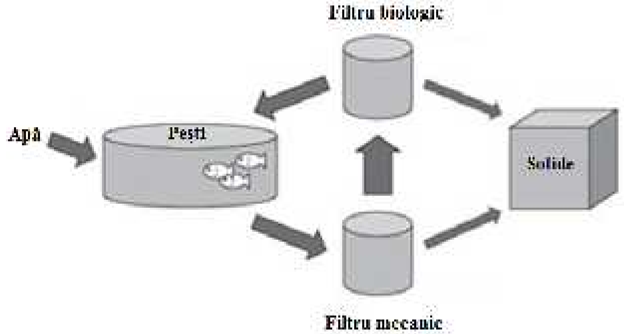


Fig. 1. The main equipment for water reconditioning in the RAS [23]

The removal of residual solids, but also of nitrogen components inside the raising basins represents an important problem that has proven difficult enough in the conditions of increasing the production capacity and the number of water recirculation within a RAS. [15]

The decomposing of organic matter found in growing basins represents the main source generating ammonia. [18] stated that the quantity of residual solids coming from unconsumed food and faeces are estimated between the intervals of 200-300 g for 1 kg of fish [22].

Two of the principles situated at the basis of removing residual solids from recirculating systems are: the quicker the residual solids are removed from the system, the higher is their degree of decomposing but also the oxygen consumption is more reduced. A second principle represents the reverse of the first one, namely, the degree of decomposing but also the oxygen consumption are accelerated if the time spent by them in the system is longer [6].

Solids found in suspension inside the growing basins represent those solids whose specific weight is equal or a little higher than that of water [24].

Specialty literature states that solids remaining in suspension represent that category of solid waste that is the hardest to remove from the water mass, due to the fact that a time interval between 30-60 minutes is not enough for these solids to set on the bottom of a sedimentation basin under the action of their own weight. [10]

MATERIAL AND METHOD

In order to achieve an efficient removal of solids in suspension, was found that sedimentation basins are inefficient and for that cause, other solutions were sought for solving this problem, and one of the most efficient solution is to use mechanical filtering equipment [32].

The principle situated at the basis of mechanical filtering refers to the fact that used water passes through a filtering material, which has the purpose to retain solid particles in the water. The removal of solid particles from the mass of water is depending on the pore size (or hole diameter) of the filtering material, meaning that more solid particles will be retained as pore size is smaller [23].

During the operation of the mechanical filter, in order to prevent the phenomenon of clogging, is necessary to periodically wash the filtering material. The frequency of washing the material depends directly on the used water rate of charge with solid particles that need to be removed from the system [33]

The most frequent types of mechanical filters used in the aquaculture of recirculating systems for removing solid particles, are filters with micro-sieves (drum filters) and filter with granular material [10].

RESULTS AND DISCUTIONS

- ***Mechanical filtering with sieves***

The control of solid particles in suspension is achieved by mechanical filtering equipment in the RAS. It is important to mention that by filtering with sieves are removes only those particles whose size is equal of larger than the diameter of the sieve mesh; sieve filtering is presented in various configurations, each of those having their advantages and disadvantages. [6].

Micro sieve filtering represents the ideal solution for removing low size particles from the system, however it is not recommended to use filters with sieves smaller than 60 µm due to the fact that they can clog rapidly, this way consuming a very large quantity of water for washing the sieves [34].

One of the filtering equipment with large worldwide spread, both in research field and in commercial activities is the drum filter [26].

Regarding mechanical filtration equipment with sieves, they are divided into: stationary sieve filters, axial filters with rotary sieve, radial filters with rotary sieve, filters with chain type rotary sieves, filters with vibrating sieves. Among the consecrated firms that produce mechanical filters to recirculating aquaculture systems we name: Hydrotech - Sweden, FIAP - Germany, Faivre - France, Akva-Denmark.

Mechanical filters with stationary sieve: represent the simplest waste water filtration equipment. The most simplified manner to place the sieves for this type of filter is in vertical position on the water flow, as shown in figure 2 [2, 35]. The use of these types of filters has some disadvantages, one of the major disadvantages that does not recommended them as suitable for super-intensive production systems is their inability to retain particles with a diameter smaller than 1.5 mm [35].

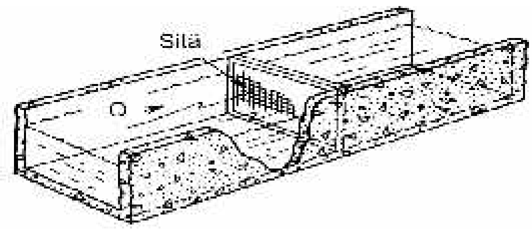


Fig. 2. Mechanical filter with stationary sieves [6, 35]

Another particularly important disadvantage appears in the functioning of filters with stationary sieves, is the phenomenon of sieve clogging, an aspect that leads to slowing the filtering process. The advantage of this type of filter is given precisely by the simplicity of its construction, so that sieves can be fitted and disassembled quickly in order to perform maintenance works [35].

From the desire to reduce the time required for the cleaning process and recommissioning of the filter, other solutions were studied to achieve an automatic cleaning of sieves, two of these solutions that have shown results were: by vibration or by introducing a spraying system, as shown in figure 3 [12].

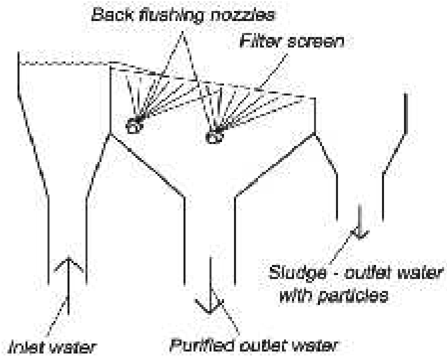


Fig. 3. Mechanical filter with stationary sieves with spraying system and operating scheme of the filter with stationary sieves and self-cleaning system [12]

- *Axial filters with rotary sieve*: the manner of placing the axial filters with rotary sieves is in perpendicular position to the direction of flow of the water. The mechanical filtration equipment that best fits this description is the mechanical filter with disks [7]. Disk filter, as shown in Figure 4 [25], is one of the latest innovations in mechanical filtration, because it combines both the performance and availability of a drum filter.

Fig. 4. Hydrotech filter with disks [25]

From the point of view of construction, mechanical filters with disks are made of several groups of disks arranged at an equal distance on a central drum, the drum being provided with apertures allowing the access of waste water between the disks system. The disks are composed of several semi-disks depending on the size of the filter unit, on which is mounted filtering material (Abbas, 2004).

In the technological scheme shown in figure 5, the wastewater path through the filter can be seen, but also the way in which the washing operation of the disks takes place, which is similar to the one used in the case of drum filters. On the same principle as the drum filter, the solids are removed by a jet of pressurized water on the opposite surface of the disks, and the resulted solid waste together with the water used for washing will be sent in a collector and sent outside the system [36].

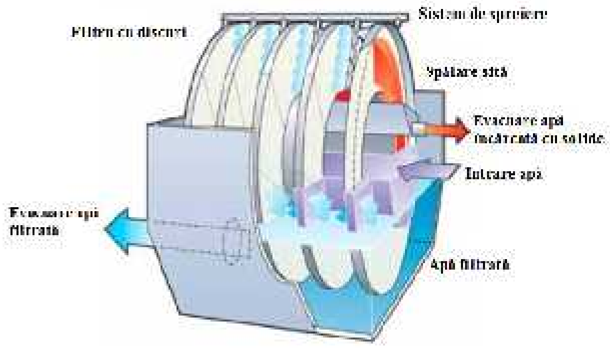


Fig. 5. Hydrotech filter with disks – technological scheme [4]

One of the most recent innovations of Hydrotech is the nozzle system shown in figure 6, which during operation has an oscillating movement for an efficient cleaning of the disk's sieves [53]. Due the more reduced water consumtion also result a decrease of energy consumed by up to 20-25% [21].

Fig.6. Spraying system for the filter with disks [26]

- *Radial filters with rotary screen*

Drum filter, as can be seen in Figure 7, is one of the main equipment for mechanical filtration of wastewater, with large global widespread both within research centres and in commercial recirculating systems [10].

Drum filers are made of a drum on which is fitted a fine sieve, usually the dimension of meshes are between 20-60μm, meaning that only particles with dimensions larger than the meshes are retained [13].

Fig. 7. Hydrotech drum filter [27]

Figure 8 shows the operating manner of the drum filter, being part of the category of radial filters because the entry trajectory of used water in the filter is on axial direction, and the separation of liquid phase from the solid phase is performed on radial direction to the entry direction and, after this stage is completed, the filtered water is sent to the biological filtering unit.

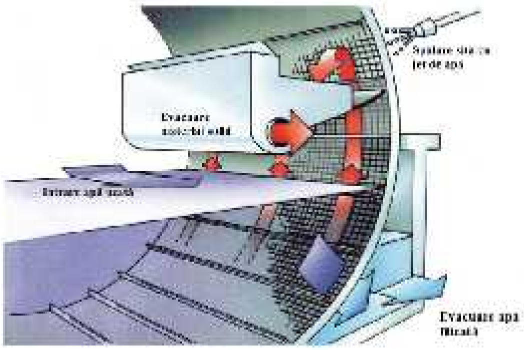


Fig.8. Drum filter – Technological operating scheme [55]

On the duration of the filtering process, a drum filter can usually remove only those particles whose diameter is comprised between 40-100 µm [17].

Table 1 shows, as percentage, the degree or removing residues from the recirculating systems, when on a drum filter are attached 3 types of sieves of different sizes [7].

Table 1

Waste	40 µm	60 µm	90 µm
Total phosphorus	65 – 84 %	50 – 80 %	45 – 75 %
Total nitrogen	25 – 32 %	20 – 27 %	15 – 22 %
Solids in suspension	60 – 91 %	55 – 85 %	50 – 80 %

Another very important aspect that can be observed from the operating scheme is represented by the manner in which the cleaning of sieves is performed through the means of a spraying system with under pressure water jet on the opposite part of the sieve, as can be observed in detail in figure 9. During the washing process, solid particles that are detached from the sieve will be taken by a trough and sent outside the system [19, 11].

The filtering capacity of a drum filter is limited enough in terms of the degree of removing fine particles from the water, nevertheless, two of the advantages of a drum filter, recommending it to be used in RAS are: the need of a relatively reduced space destined for placing the filter and the fact that the operation of washing the sieves can be achieved as many times as needed without perturbing the process of filtering used water [26].

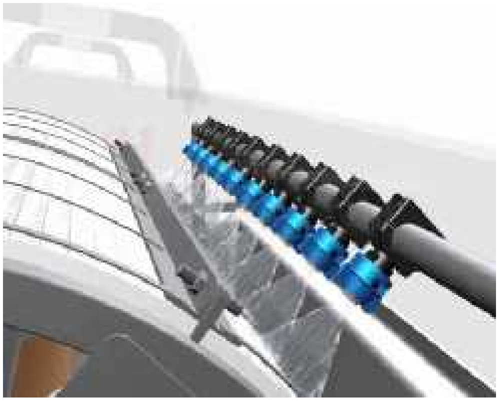


Fig. 9. Spraying systems for drum filters [27]

Another aspect that interests in the process of washing sieves is that mechanical filtering equipment must have a pump (Fig. 10) that circulates, through the nozzle system, a quantity of water with values between 0 2-2 l / sec at a constant pressure in the range of 3-6 bar. Mechanical filtering equipment come equipped with such a pump, and if they do not have one, one has to be acquired so that the sieve washing process can take place [28].

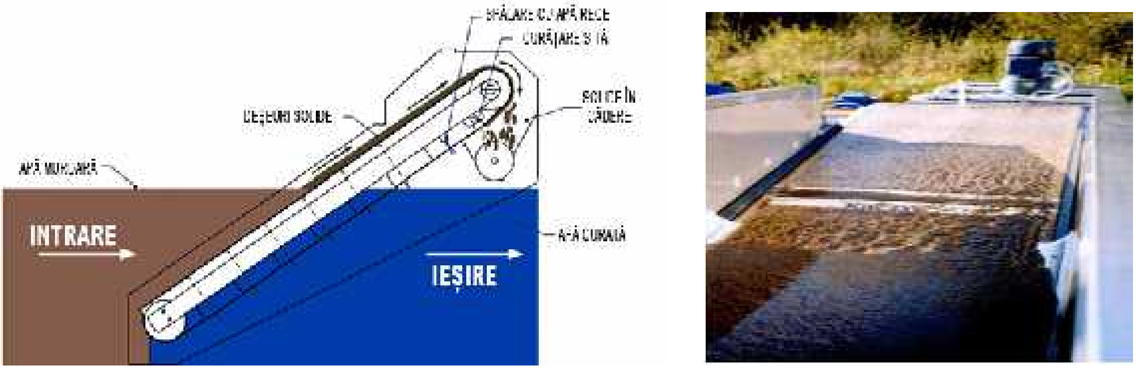
Fig.10. Pump for washing sieves in counter-flow [28]

However, the main disadvantage of these systems is given by the fact that a significant amount of the total volume of water is lost by washing the filter sieves (http://web.utk.edu). The volume of water used for the operation of washing the sieve of a drum filter with under pressure water jet is between 0.2 - 2% of the total volume of water [3].

Due to losses generated by the operation of washing filters, it was resorted to the use for many recirculating systems of basins with double drainage or to the use of other pre-filtering equipment, thereby reducing the burden on the mechanical filter [60].

- ***Mechanical filters with chain***

Represent one of the newest technologies created for managing the volumes of waste from aquaculture, specially designed to reduce the volume of waste by concentrating it before being discharged from the filter [14]. From the constructive point of view, the sieve of this filter is shaped as a funicular strip, made of several articulated panels mounted on a system of drums with horizontal axis as can be seen in figure 11 [43, 6].



a) b)

Fig.11.a -Technological scheme of a filter with rotating sieves on chain (https://www.bluewater-technologies.com)
***b. Filter with rotating sieve on chain used at a salmon farm* [1]**

The efficiency in exploitation of chain filters was proven especially in those situations where used water flow rate was reduced, and the concentration of solid particles was high [12].

- ***Filtering with granular material***

Vigneswaran et al (1990) found that the performance of a filter with granular material (GM) is largely dependent on the particle and pores size composing up the filtering material [16]. The operating principle of filters with granular material is relatively simple: water loaded with solid particles passes through the filtering material, following this process the surface of the filtering material are retained the majority of the solid particles found in the water mass [10].

- *Filters with under pressure sand:* concerning the functioning of filters with under pressure sand shown in figure 12, it is similar to that of gravitational filters, the difference between the two filters is that in the case of filters with under pressure sand, in order to increase filtering speed, the hydraulic load is increased by applying additional pressure in the filtering tank [19]). The material that these filters are made of is polypropylene reinforced with fibreglass and in this regard they are much more affordable than filters made of stainless steel [30].

Fig.12. Filter with undepressure sand [60]

According to statements by Wheaton (1977), the minimum size of the particles that can be removed from a recirculating system using this filter, are closely related to three very important factors such as sand particle size, water flow and not least the characteristics of residual solids [6].

The size of particles comprising the filtering environment of the filter is usually comprised between 0.5-1 mm [30, 31].

One of the advantages of using filters with under pressure sand is constituted by the fact that they have the capacity to remove solid particles smaller than 30µm [6].

The filtering material used in the case of these filters is fine sand, besides the layer of filtering material there is also a support layer constituted by another granular material, usually gravel with sizes up to 5 mm [6].

One of the parameters defining the performance of a filter is also given by height of the filtering material layer, usual is recommended the height of 1.2 m [30].

One of the main disadvantages of filters with under pressure sand is represented by the relatively high costs, both for the investment but also for operating these systems, as a result of the consumption of electric energy [6].

Regarding the use of these filters, filters with under pressure sand are used especially for small scale technological systems, whereas the one with vacuum and the gravitational ones are used more rarely [6].

- *Filters with balls*: are considered the oldest equipment concerning the processes of treating used water [6]. Filter with granular environment, both the ones with sand and the ones with balls are also used in aquaculture installations, the one with balls having the largest spread, due to low loses of presses and reduced requirements for filter washing [20, 10].

The filtering material is composed of plastic balls whose specific weight is approximately equal or smaller than that of water, in order for it to be brought in floating state [6].

Currently, there are several types of ball filters, but the most used ones are those types of filters that use as filtering material ball with a 3-5 mm diameter [6]. The size and density of balls is established depending on the nature of solid particles and on the concentration of TSS [19].

Water charged with solid suspensions passes through a layer of plastic balls whose thickness is comprised between 30-90 cm; in order to clean the filter when the layer of balls is charged with residual solids, it will have to be washed in counter-flow [13].

Ball filters have the capacity to remove solid up to 50 μm [29], but according to [13], ball filters are very efficient due to the fact that after a single water recirculation, they can remove solid particles up to 30μm.

This type of filtering is achieved without significant water loses. When the washing of the filer is performed, the water flow is stopped [29].

During operation, fine particles (<20 microns) are removed at a smaller degree by a process called bio-absorption, as the recirculation number increases, more fine particles are removed [15].

In the case of ball filters, in order to ensure the necessary flow, but also to fulfil technological requirements of RAS, is necessary that for the speed of water in the filter to be situated between 0.5 – 1.5 m/s x min [19].

According to [16], the use of ball filters attracts a series of disadvantages, such as: the necessity to have a moderate pressure inside the filter, a complex installation for washing in counter-flow, high capital and maintenance costs and not last, the incapacity to treat large flows of water [20].

- ***Filtering with porous agents***

Filters with porous agents show an increased efficiency in eliminating solid particles with more reduces sizes, which could not be removed through other process. The porous agent most frequently used is diatomaceous earth (DE), presented in figure 13 [19]. Filters with porous agents are not equipment fit for a mechanical filtering of used water process within a RAS [29].

One of the fields where filters with porous agents are primarily used is fishkeeping; the level of using filters with porous agents in the filtering process is not very high, because filtering is not continuous.

The degree of cleaning used water is very good, taking into account the fact that these filters can filter particles up to 1 μm (https://en.wikipedia.org) and according to [19] or [29], filters with diatomaceous earth have the capacity to filter up to 0.1μm.

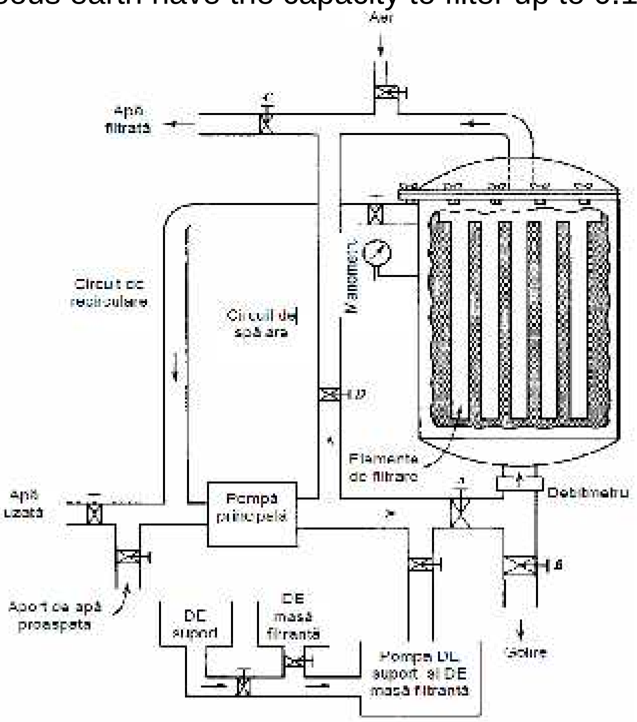


Fig.13. Diatomaceous earth filter under pressure [19]

Filters with porous agents normally have a filtering layer thicker than filters with micro sieves, but at the same time, the pore dimensions are a lot finer than in the case of filters with granular material GM [16].

As operating principle, a resemblance can be observed between the operation manner of filters with porous agents and the one of filters with micro sieves, the resemblance consisting in the fact that water charged with solid suspensions passes through a filtering agent with a micro-porous structure at the level of which the solid phase is retained [19].

The difference in operation between the filters with micro sieves and those with porous agents is that the latter are characterized by more reduced filtering speeds and bigger losses of pressure [43], [16].

According to (Spotte, 1979), the performance of a filter with diatomaceous earth (DE) depends on the characteristics of DE material used, by the equipment used, the exploiting conditions and not lastly by the maintenance conditions [5].

One of the disadvantages of filters with diatomaceous earth is represented by the fact that they can clog very rapidly, which can be avoided by introducing equipment for pre-filtering coarse solids [29].

CONCLUSIONS

Mechanical filtering is one of the oldest and more used method for filtering the water in aquaculture systems and maintaining water quality in the optimal physical-chemical parameters, taking into account that the removal of residual solids and nitrogen compounds in the culture basins is a problem quite difficult in terms of increasing production capacity and the number of water recirculation within a SAR.

Mechanical filtering has the role to retain solid particles and suspensions (fish dejections and unconsumed food) from used water, depending on the diameter of meshes in the filter's sieves.

To prevent the occurrence of the clogging phenomenon is necessary to periodically wash the filtering material, the washing frequency depending on the charge rate of the used water with solid particles that need to be removed from the system.

ACKNOLEDGEMENT

This paper was financed by support of National Authority for Scientific Research and Innovation, programme NUCLEU, no. 8N/09.03.2016, Add. Act no.1/2016, project PN 16 24 03 02 – *Technology and innovative denitrifying installation for aquaculture cultures and* UEFISCDI, programme PARTENERIATE, contr. nr. 182/2004, *Developing a technology for off-season breeding of sturgeon raised in recirculating water systems.*

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