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New developments in waste treatment: Filtration and thickening systems for inland farms

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SUMMARY – The intensification of rearing techniques has enormously increased the organic pollution of land based fish farming effluents, representing a problem of increasing concern. During the last years some European private companies have decided to set up a new system for the treatment of fish farm sewage. After preliminary tests, mechanical gravitary devices have been found the most adapted equipment to reduce suspended solids in the effluent, with filtration efficiency up to 80%. Future steps of the work will be the sludge conditioning and disposal to achieve the complete integration of the system. This project is co-financed by the European Commission.

Key words: Intensive aquaculture, effluents, sludge, treatment.

RESUME – *"Nouveaux développements pour le traitement des rejets : Systèmes de filtrage et concentration dans la pisciculture continentale". L'intensification des méthodes d'élevage des fermes aquacoles installées à terre a considérablement accru la pollution organique de leur effluent, provoquant des répercussions de plus en plus importantes. Durant ces dernières années, diverses sociétés privées européennes ont décidé d'étudier et de tester un nouveau système de traitement des rejets de pisciculture. Différents tests préliminaires ont démontré que le filtre mécanique gravitaire représente l'équipement le plus adapté en pisciculture pour réduire les quantités de matières en suspension, avec une efficacité allant jusqu'à 80%. Afin de compléter le système, les prochaines étapes étudieront le traitement des boues et leur utilisation ou évacuation. Ce projet est financé conjointement par la Commission Européenne.*

Mot-clés : *Aquaculture intensive, effluents, boues, traitement.*

Introduction

This work has been prepared using preliminary non sensible data collected under the exploratory project FAIR-CT97-8252 and now gained with the project FAIR-CT98-9110, both co-financed by the European Commission. The aim of these works is the development of sustainable and affordable techniques for treatment, disposal and possible reuse of suspended solids in the effluents of intensive land based fish farms. Being the FAIR project still in progress, the following results are somehow not complete or still under field-test evaluation.

Waste treatments: State of the art for freshwater and saltwater fish farming

As a consequence of the establishment of well standardised intensive fish farming techniques in on-land aquaculture for salmonids and for seabass and seabream, the source of pollution due to the increasing amount of faeces and uneaten food is becoming a major problem.

This pollution is mostly in the form of organic particulate matter, for which only the physical removal of the solid fraction will lead to an effective and affordable purification of the farm outlet. In a fish farm effluent, the ratio between the suspended solids and the effluent volume is extremely low, forcing sewage pre-treatment through separation and concentration, before any other form of handling, disposal or reuse.

Suspended solids are very difficult to estimate only considering the farm yearly output in terms of biomass, their quantity and quality depends in fact on several factors such as: (i) feed quantity; (ii) feed quality; (iii) feeding methods; (iv) water renewal rate; (v) tank hydrology; and (vi) fish density.

At the moment, in Europe, apart some Scandinavian producers of salmonids and few eel producers in Denmark, very few fish farms treat their effluents. The most important reasons for that could be summarised as follows: (i) lack of precise and common regulations; (ii) available systems are expensive and not complete; (iii) sludge is difficult to thicken and to dispose; and (iv) no one well knows how to categorise removed solids.

Different methods of solid separation: Comparative approach

Many types of filters could "theoretically" be used for solids separation in fish farm effluents. Among these the most widely used are: (i) the gravitary systems; (ii) the mechanical systems under pressure; and (iii) the mechanical gravitary systems.

Gravitary systems

Standard settlement tank

This method is the most familiar to the fish farmer and consists in large ponds where the effluents are temporarily hosted before their reintroduction into the receiving natural water body.

The system can be divided into three parts: (i) the collector basin where the turbulence is very high; (ii) the settlement tank where solids loose their kinetic energy and settle; and (iii) the effluent basin where water is collected after the treatment.

This solution needs very large surfaces and an attentive management to maintain its efficiency at maximum. The dimensioning takes into account the water flow and the residence time, which has to be set to around 90 to 120 minutes for a safe settlement.

Considering the surface needed and the investment costs, this system has no real application neither in coastal aquaculture which is always competing for land with tourism, nor with salmonids farming, always paying special attention to budget problems.

Lamellar settlement tank

It is based on the same principle of the settlement tank but here the kinetic energy of transported solids is more quickly and efficiently reduced interposing physical obstacles along their path.

This kind of device was frequently used in the past in some recirculating systems, but nowadays with the arrival on the market of compact microscreens they are seldom used. If compared to the previous system the total surface needed is smaller, but the need of much complicate cleaning operation keeps high its running costs.

Hydrocyclone tank

This device is realised as a very large circular concrete basin with conical shaped bottom, in which the sewage water enters at the peripheral top of the tank, thus making the liquid moving in spiral pattern towards the tank centre and bottom.

The rotational flow makes heavier particles to move centrifugally against the hydrocyclone wall. Spiral flow moves downward at the outer wall and upward near the centre where the "clean" water is discharged. This system was frequently used in small hatcheries or for water pre-treatment at farm inlet (as a sand trap) but due to difficult construction and low flexibility is now seldom used.

Mechanical systems under pressure

These are the most diffused filters in the industry. Generally three types are available: sand filters, bag filters and cartridge filters. The principle allows a very good separation of solids but these devices cannot be considered for effluent treatment since they need a significant extra energy to work (increased pump power to overcome the higher water head) with respect to gravitary systems, increasing a lot the farm running costs. Moreover, their rather complicate backwashing (automatic or manual) limits the amount of water to be treated to less than 200 l/s.

Mechanical gravitary systems

These systems are available in a wide range of materials, configuration and sizes. Apart from the simple rotatory belt, three are the most common types: vibratory screen, rotary drum microscreen and rotary disc microscreen. Gravitary equipment for effluent's solids removal have been mainly developed for intensive water recirculation systems and are mostly used in the northern part of Europe (Denmark, Holland and Norway) where environmental conditions (water scarcity or low temperatures) oblige to adopt semi-closed circuits for eels and catfish farming.

Vibratory screen

Two types are commonly used, with radial and axial flow, respectively. In the type fed with axial flow, the water passes over the screen and the sludge is moved along the screen by the vibratory motion. Filtered water flows over the screen and comes out. Screen fed with radial flow are circular in shape and are designed in a way that sludge is collected at the periphery of the filter and water passes vertically through the screen by gravity. The problem of this kind of filters is the maintenance costs because of the high wear and tear due to the heavy mechanical work induced by the vibratory movement.

Rotary drum microscreen

These kind of filters are actually the most commonly used microscreens for aquaculture applications. The principle is the continuous separation of solids attached to a screened surface perpendicular to the wastewater flow (Fig. 1).

Fig. 1. Hydrotech drumfilter functional diagram.

The device consists of a rotating drum whose cylindrical body is entirely covered with a screen (polyester or stainless steel net) and has the proximal side open and the distal one closed. Wastewater enters axially at the open side of the drum and gets out radially through the screen by gravity.

When the level inside the filtration chamber is increasing, due to the progressive screen clogging, a sensor level starts the drum rotation and the screen backwashing, spraying water at high pressure over the opposite surface of the screen. The backwash water loaded with the solid deposits is collected in a gutter and transported by gravity out of the filter. Rotary drum microscreens operate with a minimum of 20 cm head loss, allowing the filtration of large volumes of water down to 6 microns with no additional energy employed.

Rotary disc microscreen

This device (Fig. 2) represents a novelty in the family of industrial microscreens since it combines the same performances and affordability of the common drum filter with an increased constructive compactness. The "volume" occupied by the drum filter is here somehow squeezed to a lenticular shape, thus obtaining the same surface area with a significant dimensional reduction.

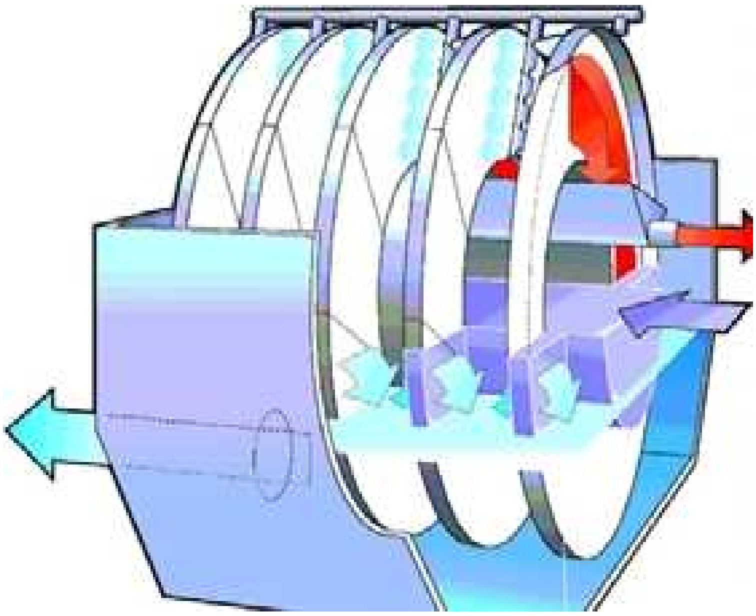

Fig. 2. Hydrotech disc filter functional diagram.

Practical experience during the last years: First identification of a system for waste treatment

In June 1996 a first group of companies, STM Aquatrade (Italy), Hydrotech (Sweden) and Ittica Ugento (Italy), starts a series of preliminary tests on the quantitative and qualitative evaluation of effluent filtration and sludge concentration. The aim was to gain a preliminary knowledge to verify some theoretical solutions and lately set up a larger research programme on the subject.

From a first analysis made on the different systems for solids separation, as described in the previous heading, mechanical gravitary systems were considered as the best way to solve the problem. It would then be preferable to optimise those gravitary microscreens, also for waste thickening rather than to focus the attention on other more complex and efficient, but more expensive, systems (e.g. centrifugation).

In order to identify where to concentrate the efforts, a series of field tests have been run using a drum filter connected to different thickening devices as: (i) a second drum filter; (ii) a vibrating belt filter; and (iii) a cylinder-conical sedimentation tank.

The effluent tested was originated by a group of 12 tanks (625 m^3 each) of intensive sea bass and sea bream ongrowing, with a fish density around 15 kg/m^3 and a total water renewal of 250 l/s in summer and 100 l/s in winter. Solids measured in the effluent ranged from 10 to 60 mg per litre with a maximum of 250 mg per litre during stressed conditions.

These tests confirmed the possibility to remove suspended solids from the effluents of intensive fish tanks with an acceptable efficiency (up to 80%) and the use of sedimentation devices or mechanical filters as a first approach for solid thickening.

The waste removed by the mechanical filters came out with a very high water content, around 99%, and thus has to be treated again before any stocking or disposal can be implemented.

Since a large quantity of water is retained in the sludge even after a second mechanical concentration (water content was rarely below 97%), more laboratory tests with flocculants have been run in order to verify their future possible use.

The use of mechanical gravitary filters for effluent filtration: Case studies

From the information and data gathered during the first exploratory phase it results that the setting-up of a treatment system will not entail exclusively the "mechanic design and optimisation of a filtration/thickening system" but rather the stabilisation, the stocking and the possible reuse of the removed solids.

In fact after these tests, it results very clearly that a good solution to remove a large part of organic solid matter from the effluents has been found. However, pollution has only been transferred from water to land.

Following this consideration the original theoretical approach of the project design was adjusted to cover other topics and find a way to settle the final technical solution for the farmer. A schematic description of the project steps (Fig. 3) allows a better comprehension of all important tasks for a complete design of a treatment system.

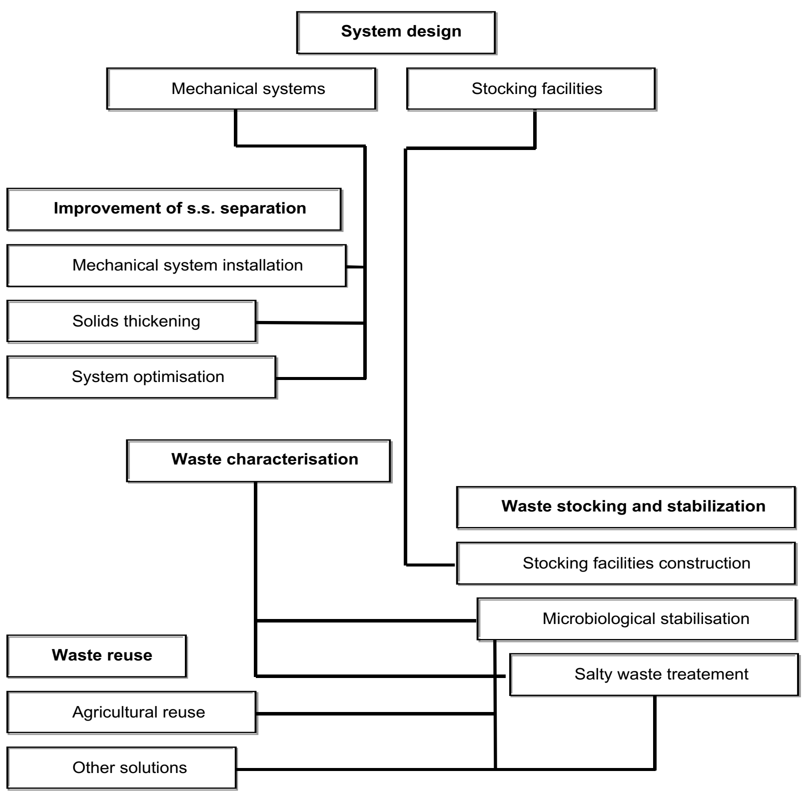

Fig. 3. Flowchart of the fish farm waste treatment system design.

Moreover, in order to have a chance of application for the industry, the solutions found should met as much as possible the following requirements: (i) be environmentally friendly; (ii) have cheap investment costs; (iii) adapted to available space; (iv) have an easy maintenance; (v) be simple; and (vi) cover running costs by waste reuse.

During the middle of 1999, two large filtration systems have been designed and installed on selected sites, for research purposes: the first one, Piscigaume, in an intensive trout farm and the second one, Ittica Ugento, in an intensive seabass and seabream farm.

Piscigaume

Piscigaume is a trout farm located to the South of Belgium (Gaume region) with an annual production of around 100 t. The total flow of the farm varies from 450 l/s to 850 l/s. Water is coming from the river Ton through a sand decanter and a grid which removes floating material.

The filter chosen is a drum filter made in AISI 304 (HDF-1607-2L-304) (Fig. 4) with a single belt drive and the back washing apparatus located on the top. The set-up chosen is a light model without self-containing tank, specially conceived for fish farm effluent application. The filter capacity is 500 l/s with a mesh size of 90 microns and a quantity of suspended solids of maximum 10 mg/l.

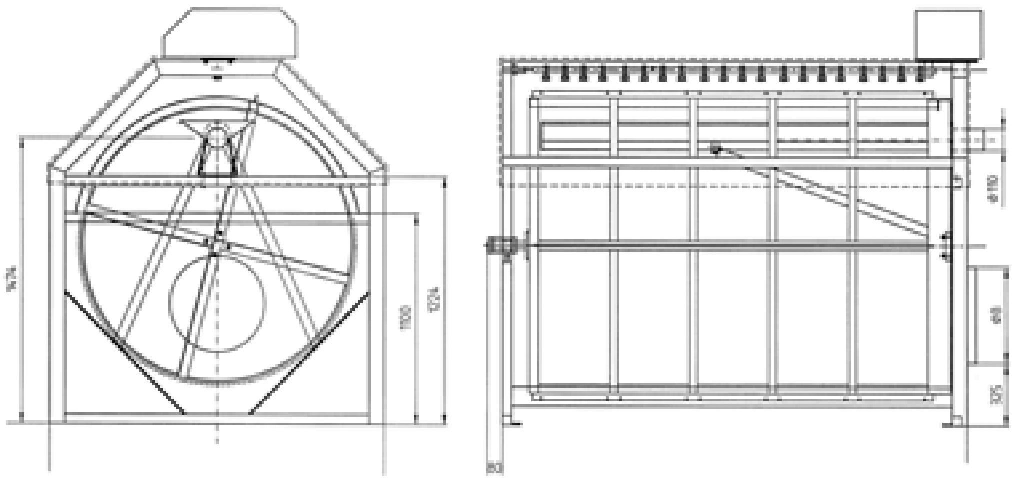

Fig. 4. Drawings of HDF-1607-2L-304.

For the sludge coming out from the filter, an experimental mixing tank for the use of flocculants has been built (Fig. 5). This device is necessary to concentrate the sludge, as the material coming out from the backwashing is too liquid.

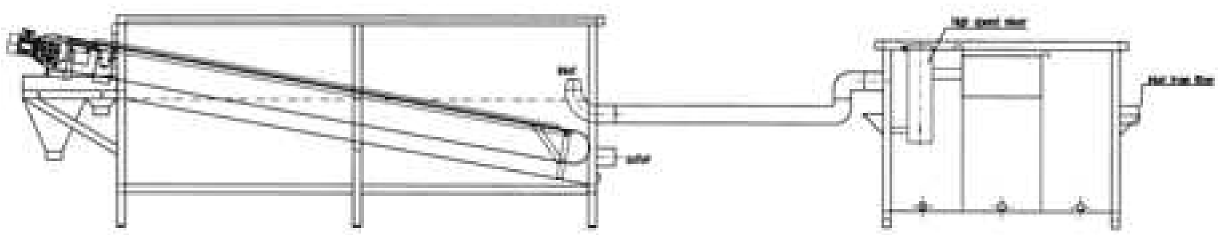

Fig. 5. Thickening prototype.

The sludge thickening process, by using chemical flocculation/coagulation in combination with a belt filter, is a totally new process for fish farming application. This method is commonly used in human waste treatment plants, with very good success in solid thickening.

A stainless steel tank divided into three compartments has been designed: one for the addition of the coagulation agent, the second for the flocculation reagent and the third one for a gentle mixing before the transport to the belt filter. There, the sludge is slowly separated from the water and transported towards a reservoir for stocking and further tests.

Ittica Ugento

Ittica Ugento is a seawater fishfarm located on the Ionic coast of Italy and covering around 24 ha of land (Fig. 6), prospecting a water reservoir connected to the sea. The farm consist of 2700 m^2 of covered area plus 36 tanks of 50 m^2, 22 tanks of 240 m^2, 48 tanks of 625 m^2 and 4 semi-intensive earth ponds with a yearly production of around 400 t.

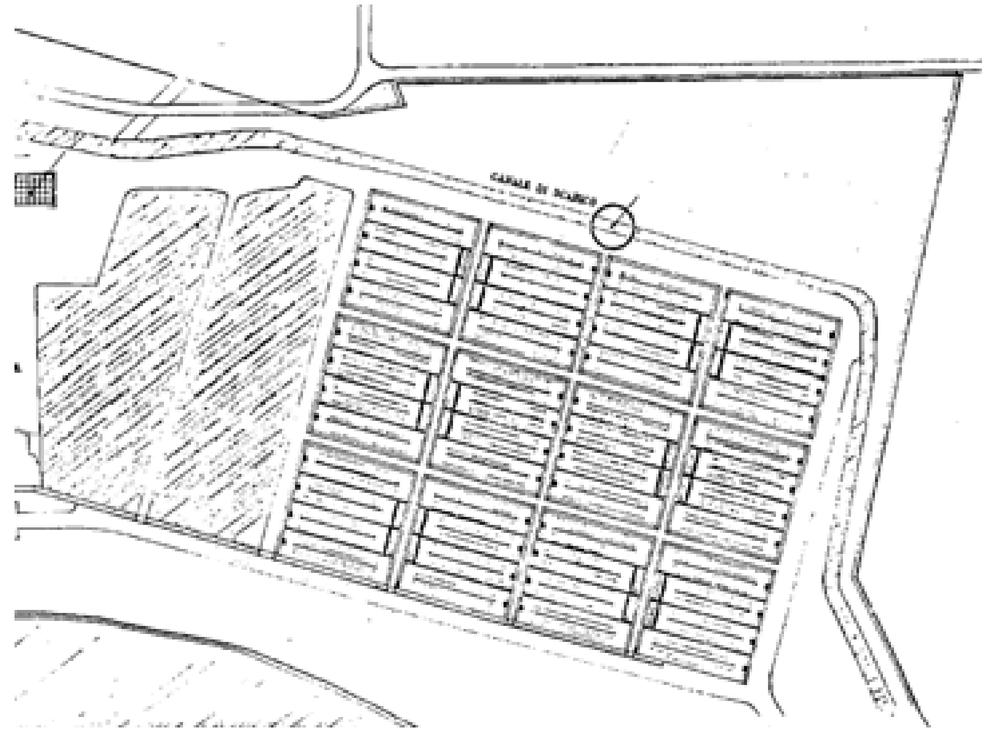

Fig. 6. Ittica Ugento, ongrowing general plan and filter location.

As the total flow of the farm is around 1800 l/s, it was impossible and not necessary for the purpose of the project to set up a filtration system able to treat the whole amount of water. It has been decided to install the filter at the outlet of 24 ongrowing tanks, allowing the treatment of a medium water flow with max. 600 l/s.

The first problem for the filter installation has been its location. In fact no place was available for the whole treatment system close to the tanks outlet. We have been obliged to build a concrete tank in the main outlet channel.

Because of the reduced space available, it has been decided to install a type of mechanical filter different from the one foreseen in Piscigaume. A disk filter has been chosen because of the important filtration capacity compared to its dimensions.

The filter (model HDF-2106-2H) (Fig. 7.) has been manufactured in AISI 316 to avoid corrosion and for its cover three different materials are tested to verify the best choice for sea water installation. This equipment, equipped with a mesh size of 60 microns, can filter 600 l/s of seawater having a SS content of max. 15 mg/l.

The thickening device is similar to the one installed in Piscigaume: a mixing tank with three compartments and a belt filter, in addition tests will be run with a secondary sedimentation tank in order to compare efficiency, consumption and investment costs.

For the same reason of space shortage it has been decided to place the whole thickening system at 250 meters from the filtration unit. This location will also give the opportunity to test waste transport methods on "farm scale".

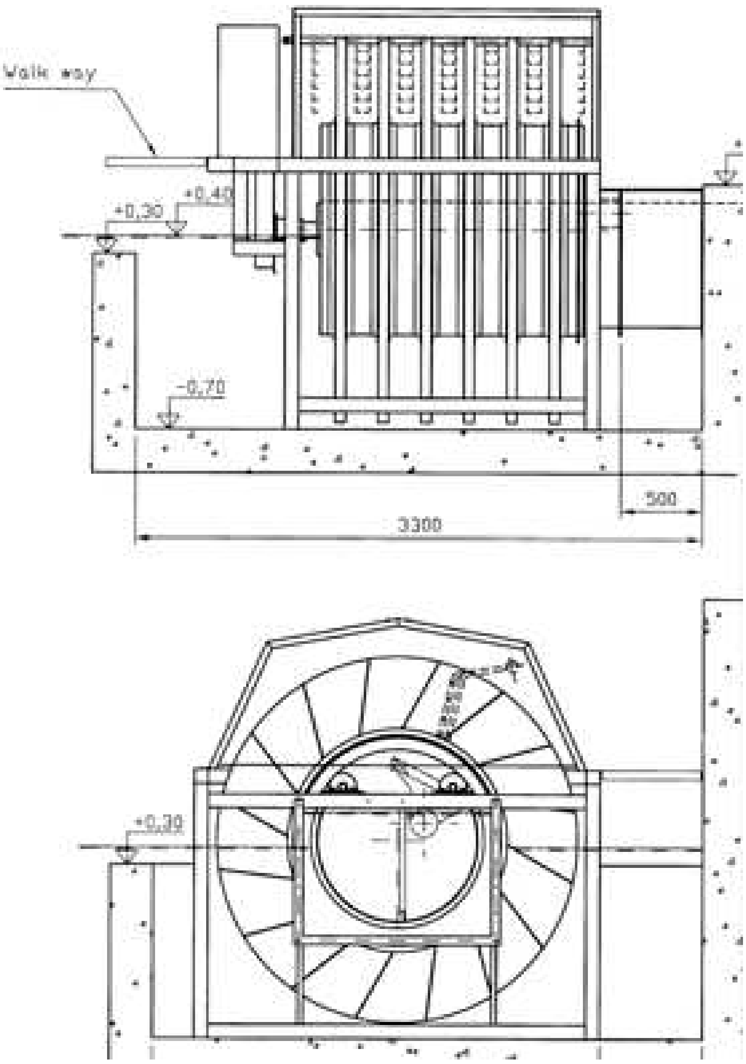

Fig. 7. Drawings of HDF-2106-2H.

Conclusion

Being the research project still in progress very few conclusions are possible concerning the design of the whole system. Our latest experiences have demonstrated that the filtration of large effluent is feasible on fish farm scale, and with the use of a well designed mechanical system is possible to remove up to 80% of solid matter from fish farm outlet.

Due to the large amount of water in the filtered effluent, the thickening treatment is of sound importance for the whole process and is possible with the help of physic-chemical processes. Further steps will consider the sludge microbiological stabilisation for a long stocking period and its reuse or disposal.