ATTACHMENT H TO WDL
Description of Treatment Facilities

Billund Aqua

Effluent management Whole Oceans production facility

Effluent management from the Whole Oceans facility will comprise well established methods and equipment from the aquaculture industry. Below is a brief description of the design and technology used.

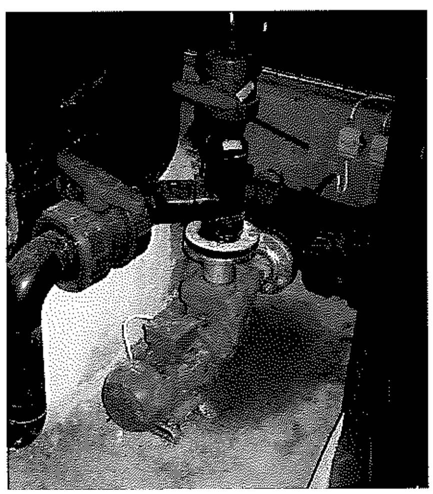
The discharge from a re-circulated fish farm facility comes from 3 different places.

1. Clean water from the fish tanks – type 1
2. Sludge water origin from cleaning of the mechanical filters –type 2
3. Sludge water origin from back flushing of the biological filters – type 3

1. *Clean water from the production system – type 1*

The clean water fraction comprises water at the same quality that enters into the fish tanks so has very low levels of TSS and other elements compared to the sludge fraction and therefore requires much less processing.

The exchange of clean water out of the system is controlled by a discharge water pump. This pump is controlled by the PLC so it is possible to get the desired volume of discharge water simply by programming the PLC.

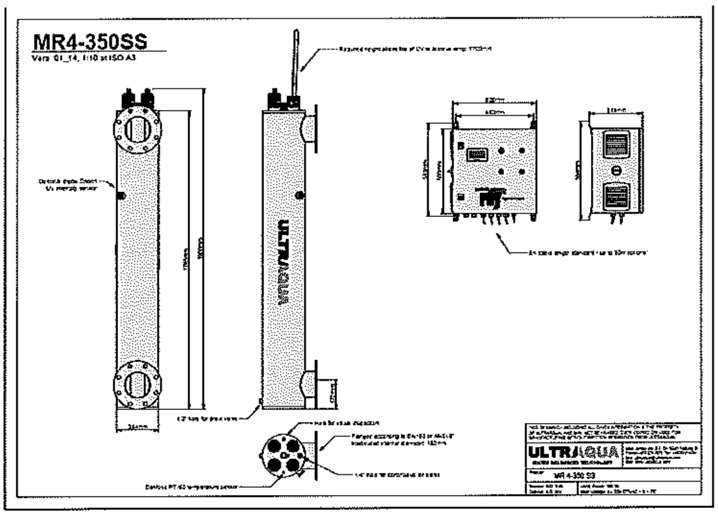


Example of discharge water pump

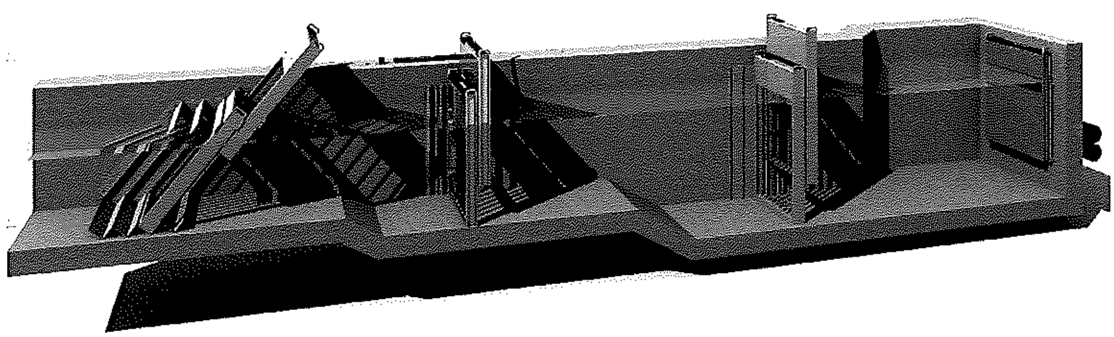
At discharge from the facility the clean water fraction will initially pass through a mechanical drum filter screen of 90-100µm, not only will this ensure that larger particles are not discharged but will also act as the second fish exclusion barrier after the fish tanks themselves.

The water will then pass a final fish exclusion barrier before going to UV disinfection via either a closed UV unit or channel UV in one of the installation types shown in the diagrams seen over the page.

Different strengths of UV are applied depending on the risk associated with the water being discharged. 30mJ/cm2 is applied to the normal production water as this water poses little risk to the environment. However the hatchery and quarantine area where eggs are bought in from an external supplier and where any potential disease problems associated with these eggs would likely occur has a much higher treatment level of 250mJ/cm2 to ensure that no pathogens from this higher risk area are released to the local environment.

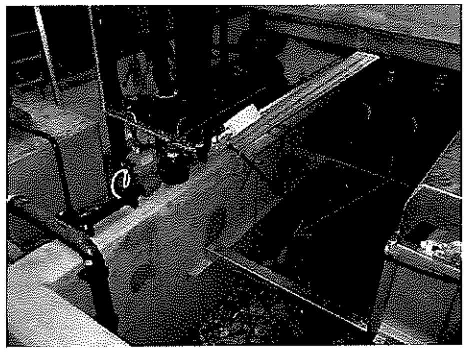


Typical closed UV unit.



Typical channel UV installation

In addition to the predicted exchange of process water, the adding of fresh make up water is also controlled by a level sensor measuring the water level inside the reservoir. When the water level decreases, the PLC commands a motor valve to open and at the same time an inductive flow sensor measures the amount of make up water which is added to the system.

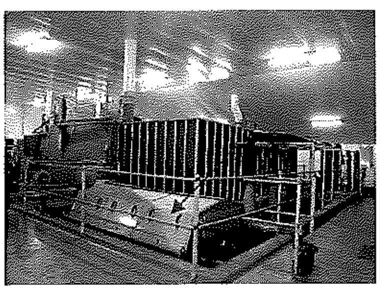


Example of level- and flow sensor

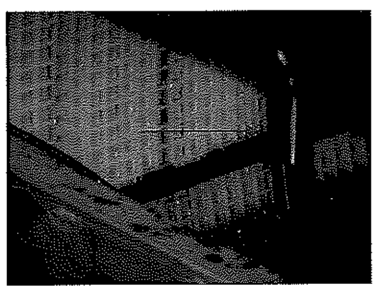
2. *Cleaning of the mechanical filters – type 2.*

The water amount originating from the mechanical filters is approx. 150 – 200 l/kg feed. The dry matter (DM) of the water is varying from 350 – 700 mg SS DM/L, as an average 500 mg SS DM/L equals to 100 g DM/kg feed.

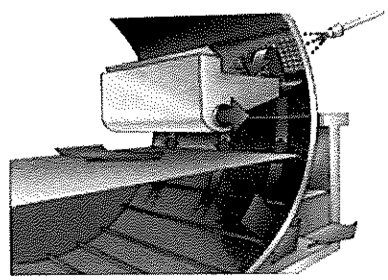
Example is shown in the pictures below. A level sensor inside the drum filter registers when the mesh is clogged and the water level rises. The sensor is commanding the PLC so that the drum filter and the sluicing pump is turned on. The principle of a drum filter is illustrated below. It is possible via the PLC to program the run time for the drum filter and the sluicing pump.



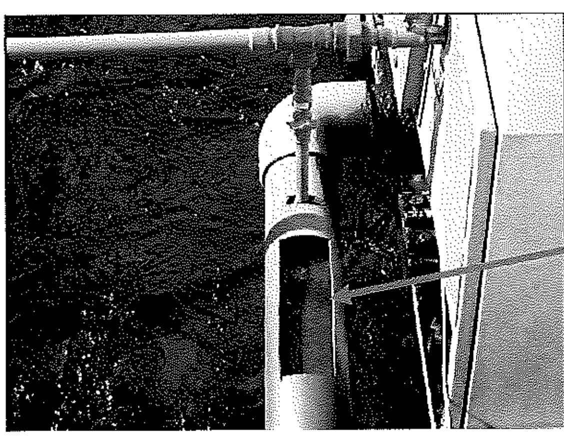
Example of a drum filter.



Level sensor in drum filter



Principle of drum filter



Here the sludge fraction with approximately 0,5% dry mater can be seen exiting the drum filter via the outlet piping, this will lead off to the sludge thickening system

3. *Back flushing of the biological filters – type 3*

Sludge from the growth (yield) of the bacteria in the biological filters. The water amount originating from the back flushing of the biological filters depends of the interval of flushing. As a rule of thumb the biological filters are flushed every 3-4 weeks. The dry matter of the sludge originating from the biological filters is approx. 0,3 % DM. The production of sludge in the biological filters is in average 50 g DM/kg feed.

Billund Aquaculture uses a submerged biological filter called a "fixed bed" biological filter. In our submerged "fixed bed" filters we are using the RK biomedia which in dry conditions has a specific surface volume ratio of approximately 750 m^2/m^3.

The "fixed bed" biological filter serves also as a mechanical filter trapping fine solids inside the biofilm, therefore "fixed bed" gives very clear water with minor content of particles. The buildup of sludge inside the biological filter due to bacterial growth and capture of fine particles the "fixed bed" filters needs to be back flushed every 3-4 week.

Sludge production and thickening

The production of sludge from 1 kg fish feed depends on many different factors like:

- Fish species and fish size
- Feed conversion rate (FCR)
- The quality of fish feed
  - Physical quality (dust)
  - Composition (Oil, Nitrogen, Phosphor, carbonhydrate)
  - Raw materials (animal, blood meal, vegetable)
  - Digestibility (dissolved and un-dissolved waste, amount of excrements)
  - Excrements (consistency)
  - Production methods (extruded pellets, pelleted pellets)
- Feed Management
  - Feeding strategy
  - Feeding levels
  - Feed waste)
- Sludge age
  - whether the sludge has been thickened
  - how long the sludge has been stored and etc.

As a rule of thumb the total production of sludge is approx. 150 g DM/kg feed.

In order to reduce the discharge of sludge from a fish farm, the sludge can be thickened to:

Approx. 2 - 3% DM by use of coagulants and removal of the water by use of a belt filter.

The following coagulants are normally used:

Addition of ferri-chloride ($FeCl_3$) – phosphor dependent - preferable
Addition of aluminum-sulfate ($AlSO_4$) – phosphor dependent, caretakers to avoid accumulation of aluminium in the system.

Addition of ferric-chloride ($FeCl_3$) is normally used as a preferable coagulant. When working with phosphor removal we use the fact that phosphor is mainly bound to particles. Phosphor removal is dependent on coagulation and flocculation where fine particles (less than 1 µm) are captured by bigger sludge particles. When removing phosphor we also achieve reduction in the brownish colour of the water.

Dosing of ferric-chloride ($FeCl_3$)
Dosing of ferric-chloride ($FeCl_3$) is, as a rule of thumb, 1,4 mol iron per mol of diluted phosphor which have to be removed. In practice the following has been observed:

Approx. 1 ml 13 % $FeCl_3$ per 1 liter of sludge produced.

The flocculation phase
After addition of the chemical it is important to achieve good sweep coagulation in order to form flocks that can subsequently be easily separated from the water. The flocculation process requires an energy input in order to be able to create collisions between the growing metal hydroxides and the destabilized colloidal pollutants.

Mixing needs to take place immediately adjacent to the flocculation ponds in the form of 3 separate tanks connected in series. Retention time for the entire flocculation phase, spread over the tanks, is regulated to achieve optimal flocculation.

The mixing speed created by different agitators must always be individually checked to ensure optimum results. Some of the many factors that can influence the required agitation rate are water quality, chemical dose rate, temperature, and retention time.

It is important that the water leaving the flocculation process is not subjected to greater forces than encountered in the tanks. The flocculation tanks should therefore be sited directly adjacent to the separation stage and the water velocity when entering the beltfilter not higher than 0,1 m/s. The speed of the belt must be adjustable from 1 – 15 m/minute.

Approx. 3 - 5% DM by use of coagulants and in addition adding polymer to the sludge water before passing a belt filter.

In practice the following has been observed by dosing polymer:

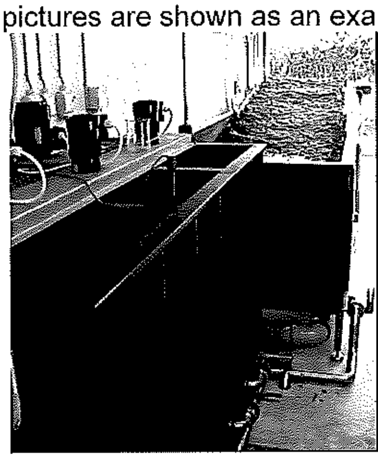
- 1 g polymer/kg feed equal to approx. 5 g/kg DM.
  Others: Approx. 2 ml 0,1 % solution of polymer per liter of sludge produced.

Functional description of the de-phosphor & sludge thickening system

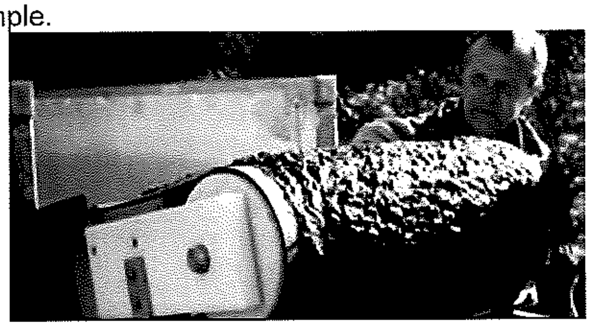
1. Sludge-water from the mechanical- and biological filters are collected in a sludge tank.
2. From the sludge tank the sludge- water is pump to a flocculation tank. The flocculation tank consists of 3 separated chambers connected in series.
3. In the flocculation tank ferri-chloride ($FeCl_3$) and polymer is added and pH is adjusted. In order to achieve good flocculation a gate agitators is connected in each chamber. Retention time for the entire flocculation phase, spread over the tanks, is 15-20 minutes.
4. When the sludge water passes the flocculation chambers sludge particles are growing and when leaving the chambers the sludge particles are separated from the water by passing through a beltfilter.
5. Sludge will be drained on the belt and scraped off at the top of the belt. A Jet system will clean the belt by high pressure water, before it return as active filter surface.

Sludge pump, gate agitators and beltfilter are operated at the same time, controlled by water level inside the tank of the belt filter. In addition the belt filter is operated by a frequency converter to adjust speed of belt.

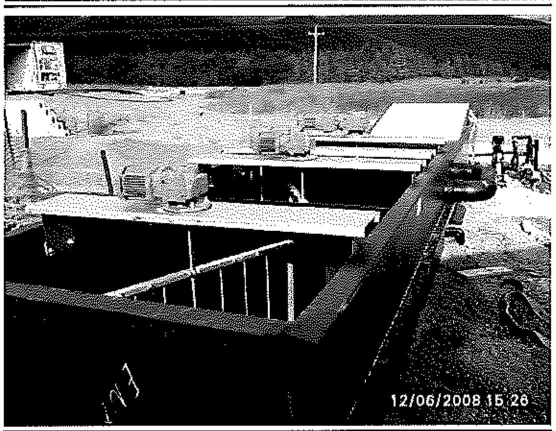
Below pictures are shown as an example.

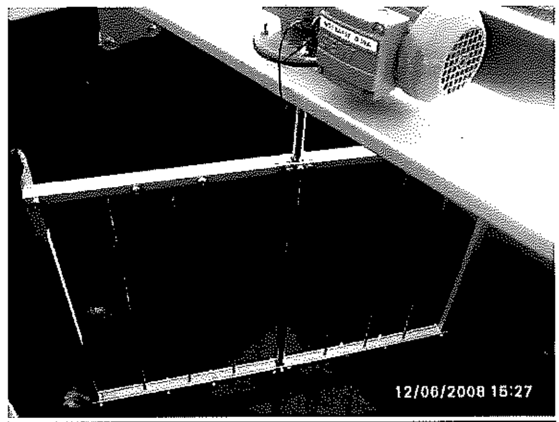


Flocculation tank and beltfilter



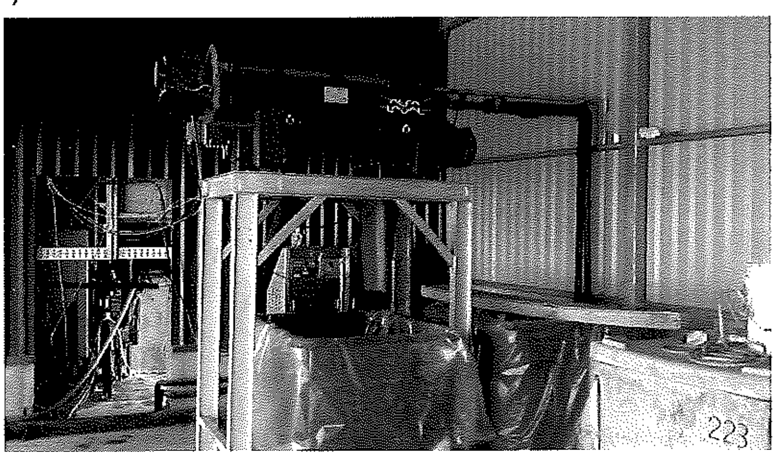
Sludge with high dry matter





Further thickening via Centrifuge

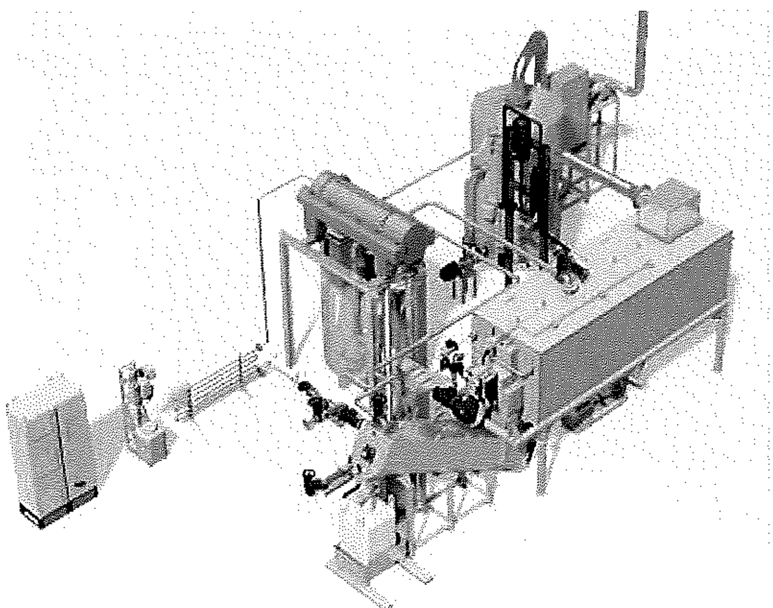
Further thickening of sludge from 4-5% DM up to 30% DM is possible by the use of the dephosphor & sludge thickening system described above in combination with a centrifuge (see picture below).



The centrifuge again uses the addition of chemicals and polymers to aid the flocculation process further and ensure that the clean water fraction is of high quality and can be returned to the clean water discharge process. The higher concentrated sludge has a volume of approximately 20% of the 5% sludge so transport costs can be reduced by increasing the dry matter content.

There are a number of technologies available to increase the sludge concentration, up to approximately 90% with the use of a batch drier. Each step increases energy cost to achieve the higher concentration of sludge so first it must be ascertained what local conditions exist for the removal of the final product. This is a balance between the cost of transport of low concentrations, the energy and equipment cost as complexity increases and what uses are available locally – fertilizer, biogas etc.

Complete integrated systems are available from suppliers who can manage the whole process to achieve the desired output for the farm. An example of an integrated system is shown below.



Basic design criteria and information for discharge management.

Discharge estimate per 1.000T from the Whole Oceans production systems							
Waterconsumption							
Water consumption per kg fish feed		liter/kg feed	600				
Maximum feeding per day		kg feed/day	5.060				
Total water consumption per day		m3 water/day	3.036				
		m3 water/h	126,5				
Type of discharge water							
"Clean" water from fish tanks	395	liter/kg feed		1.999	m3/day	1.999	m3/day
Sludge water from mechanical filters	200	liter/kg feed		1.012	m3/day	1.037	m3/day
Sludge water from biological filters	5	liter/kg feed		25	m3/day		
Clean water							
COD	52,5	mg/l		104,9	kg/day	38.300	kg/year
BOD5	10	mg/l		20,0	kg/day	7.295	kg/year
N	66	mg/l		131,9	kg/day	48.149	kg/year
P	0,9	mg/l		1,8	kg/day	657	kg/year
TSS	10	mg/l		20,0	kg/day	7.295	kg/year
Sludgewater							
COD	650	mg/l		674,2	kg/day	246.099	kg/year
BOD5	390	mg/l		404,5	kg/day	147.660	kg/year
N	45	mg/l		46,7	kg/day	17.038	kg/year
P	22	mg/l		22,8	kg/day	8.330	kg/year
TSS	500	mg/l		518,7	kg/day	189.307	kg/year
GRAND TOTAL							
COD	256,6	**mg/l**		**779,2**	**kg/day**	**284.400**	**kg/year**
BOD	139,8	**mg/l**		**424,5**	**kg/day**	**154.955**	**kg/year**
N	58,8	**mg/l**		**178,6**	**kg/day**	**65.186**	**kg/year**
P	8,1	**mg/l**		**24,6**	**kg/day**	**8.986**	**kg/year**
TSS	177,4	**mg/l**		**538,6**	**kg/day**	**196.603**	**kg/year**
Removal by sludge concentration on bandfilters							
COD	572	mg/l		593,3	kg/day	216.567	kg/year
BOD5	321	mg/l		333,5	kg/day	121.711	kg/year
N	31,5	mg/l		32,7	kg/day	11.926	kg/year
P	21,1	mg/l		21,9	kg/day	7.996	kg/year
TSS	470	mg/l		487,5	kg/day	177.949	kg/year
Total discharge from farm water fraction							
COD	61,2	mg/l		185,8	kg/day	67.832	kg/year
BOD5	30,0	mg/l		91,1	kg/day	33.244	kg/year
N	48,1	mg/l		145,9	kg/day	53.260	kg/year
P	0,9	mg/l		2,7	kg/day	990	kg/year
TSS	16,8	mg/l		51,1	kg/day	18.654	kg/year