Management of recirculation systems

EQF Level 5:

Guided learning hours:

Unit abstract:

The aim of this unit is to supply the student sufficient knowledge on management of recirculation systems for fish culture.

Therefore, **a student should have** thorough knowledge of the varieties of recirculation systems as these were developed by various engineers and also in relation to different fish species to be reared.

A **student should know** all aspects of management of fish culture with regard to sustainability

First important: **a student should have required sufficient knowledge** of how solid particles can be removed from a recirculation system.

Second important: a **student has to understand** how dissolved compounds can be converted into harmless compounds, especially the process of nitrification, and if desired: the processes of denitrification and dephosphatation.

Finally, a student should have thorough knowledge of all aspects of management of a RS

Learning outcomes

On successful completion of this unit a learner will:

1. Be able to judge the quality of incoming water for the RS, in particular with respect to specific sensibility of fish species

2. Understand the necessity of influx of O_2 and efflux of CO_2 through RS

3. Understand the transports of minerals through the fish farm, with respect to production of H^+, NO_3^- and other salts (as measured by EC).

4. Understanding of filtering capacity of RS

5. Understanding of maximal production of fish volume per year as basis of a particular RS

6. Understanding of fish care during fish farming

7. Understanding the start-up of a RS

Unit content:

A leaner will be able to:

1. ***Understand water dynamics and water management of RS***
   (water characteristics:)
   - To know the quality of water to be taken in
   - Knowledge of the sensitivity of particular fish species when kept in particular water quality

2. ***Understand - influx and -efflux of gases during fish production***:
   (*gas dynamics; influx of O_2 and exchange of CO_2*)
   During fish production process a fish farmer has to able to determine:
   - The oxygen demand (for both growing fish and purifying bacteria)
   - The CO_2 to be removed in a proper way
   - What rate of air removal is required from the building where fish is farmed in a RS?

3. ***Understand influx and efflux of minerals during fish production***:
   (mineral dynamics; influx of N-components and production of H^+ and NO_3^-)
   - Is able to install a desired pH (in relation to KH and influx and efflux of culturing water) and:
   - To determine best efflux (and influx) of culturing water (in relation to desired KH, pH, NO3- and sludge to be removed)
   - In detail: To adjust nitrate (NO_3^-) to optimal levels (in relation to rate of effluent and rate of conversion into N_2).
   - To adjust optimal EC (in relation to rates of influent and effluent and amount of added minerals)
   - To determine the rate of water refreshment
   - To remove NO_3^- and PO_4^{3-} from culturing water

4. ***Understand filtering capacity***:
   (dimensioning a RS)
   - Being able to calculate necessary surface of full-grown bacteria in a fish production system (at a certain feeding level)
   - Understand the function and minimal dimension of the sedimentation tank
   - Understand the function and minimal dimension of the oxidation (‘trickling’)filter

5. ***Understand maximal quantity of fish to be farmed***:
   (assessing the quantity of fish/yr)
   - Which quantities of fish can be kept in a specific RS (St St; Standing Stock).
   - As a consequence: what is the maximal fish production from a particular RS per year?
   - Which quantities of food can be supplied during a specific growth rate?

6. ***Care for Fish Health care***
   (*fish health and diseases*)
   - Able to prevent and cure fish diseases

7. **Start up a RS**
   (*starting a biofilter*)
   - Understand starting up of a functional recirculation system

Learning outcomes and assessment criteria:

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 1 Be able to judge quality of incoming and effluent water of the RS	1.1 Determine O_2-content of the water 1.2 Determine organic compounds toxic to fish (NH_4^+, $NO_2^{-)}$ in the incoming water 1.3 Determine anorganic components toxic to fish (Fe^{3+}, Mn^{2+}, S^{2-}, etc.)
LO2 2 Understand gas influx and efflux during fish production	2.1 Assess the demand of oxygen for fish growth or maintenance. 2.2 Supply sufficient air with oxygen to the biofilter, through the air indoors. 2.3 Remove formed CO_2 sufficiently 2.4 Ventilate air within production room sufficiently with respect to necessary O_2 and efflux of CO_2
LO3 3 Understand influx and efflux of minerals during fish production	3.1 Set in optimal level of pH (in relation of KH and rate of water refreshment) 3.2 Assess the quantity of water to be taken in with regard to optimal NO_3^- level 3.3 Assess the amount of NO_3^- from the nitrification filter 3.4 Establish optimal level of NO3- for fish 3.5 Establish optimal level of EC in a production RS 3.6 Remove NO_3^- and PO_3^{4-} from culturing water
LO4 4 Understand filtering capacity	4.1 Calculate volume of sedimentation tank in case of maximal production rate 4.2 Calculate capacity of nitrification filter in case of maximal production rate

LO5 5 Understand maximal quantity of fish to be farmed	5.1 Assess Specific Growth Rate (SGR) 5.2 Calculate Standing Stock (St St) for a particular RS Calculate maximal quantity of fish to be farmed with a particular RS 5.3 Assess maximal production/yr with a particular RS
LO6 6. Care for fish health	6,1 For Prevention: set in optimal pH and/or EC for a specific fish species 6.2 Determine kinds of fish disease 6.3 Cure specific fish diseases
LO7 7. Understand start-up of a RS	7.1 Build up a RS with a specific fish production Capacity 7.2 Occulate a RS with bacteria for nitrification 7.3 Monitor the process of nitrification with respect to conversion to NO_2^- and NO_3^-

Guidance for tutors

attach

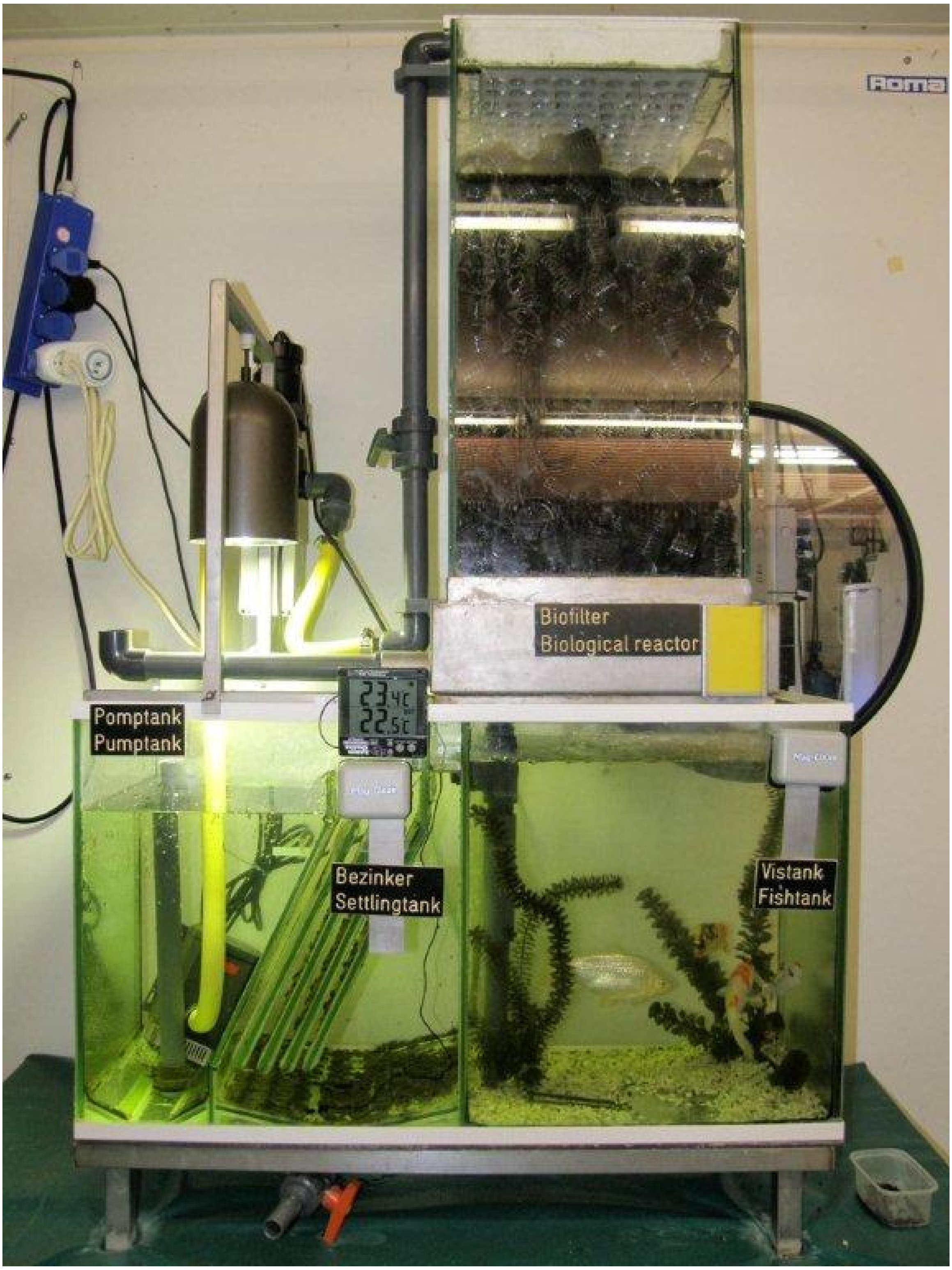
Delivery

Delivery

Tutors delivering this unit have following opportunities to indulge in: site visits (www.fishtechknowledge.nl/education), library resources ([1]) and attached list of most important rules for dimensioning ([2]). Also the use of personal experience would all be appropriate..
It is advised learner construct an own RS on basis of a calculated draught
Health and safety issues relating to working in and around water must be stressed and regularly reinforced, and risk assessments must be undertaken prior to practical activities. Appropriate personal protective equipment (PPE) must be used during practical work (gloves). For performing calculations it is advised to use a professional calculator. For determinations of water parameters it is necessary to use a professional test-kit.

Whichever delivery methods are used, it is essential that tutors stress the importance of animal welfare, sound environment management and the need to manage the resource using legal methods
Tutors should consider integrating the delivery, private study and assessment relating to this unit with any other relevant units and assessment instruments learners may also be taking as part of their programme of study.

1. J. Bovendeur. Fixed-biofilm Reactors applied to Waste Water Treatment and Aquacultural Water Recirculating Systems
2. Recirculation System (RS) as demonstrated at the entrance of Dept. Fish Culture of Wageningen University and Research Centre (WUR); see below
3. Illustration of RS, showing most important parts (below attached, directly after this page)



Recirculation system showing main compartments:

1. Fish tank

2. Settling tank

3. Biological reactor (trickling filter)

4. Plant culture (for removal of minerals; under lamp)

Essential requirements
Learners must have access to a Learners will need access to library resources, and a number of multimedia resources. There have to be possibilities to visit different locations.
It is advised to use below list of general rules for dimensioning a RS

An appropriate first-aid kit should be near by hand.

List with general rules for dimensioning a RS

RULES FOR DIMENSIONING A RECIRCULATING SYSTEM

Rules for Dimensioning a recirculation system, assuming that one (1) kg of food is supplied to fish and that 4 % of food is excreted as NH_4^+ in the water

(feed loading rate : 1 kg).

1. EFFECTIVE SURFACE (LAMELLAE) NEEDED FOR SEDIMENTATION OF SOLID PARTICLES IN A SETTLINGTANK (or: Hydraulic loading rate of lamella separator; m^3 m^{-2} d^{-1}):
   For African catfish: maximal water load: 25 m/day (= 25 m^3 water/m²)
   For eel: maximal load: 10 m/dag (= 10 m^3 water/m²).

   Note: One m² has to be considered as effective surface; in case of surfaces in a slope, effective surface can be obtained by multiplying total surface with cosinus of the angle plates have been installed.

2. SURFACE OF CARRYING MATERIAL FOR NITRIFYING BACTERIA or

   (for conversion of NH_4^+ to NO_3^- by nitrifying bacteria): 0,4 gr NH_4^+/m² or: 75 m² carrying material per kg voer (it is assumed 3 % of food appears as NH_4+ in the water)

3. SPECIFIC SURFACE (surface of carrying material per m^3):
   Rings (old device): 200 m².
   bionet: 150 - 250 m²
   packets of lamellae: 150 - 250 m² (WACON, Maasbree, NL)
   stones of lava: 400 - 800 m²
   sand: 500 - 5000 m² (depending on size of grains and depending on the circumstance it is whirling or not):
   In a funnel with 600 kg sand (ca. 0,25 m^3) NH4+ from 10 kg can be converted (if Sufficient O_2 can be supplied !)

4. WATER RECIRCULATION RATE (m^3 per day):
   Necessary for nitrification: 10 m^3 till 72 m^3 (depending of removal rate of solid particles).
   In praxis of African catfish production: 5 - 10 m^3/kg fish food

5. WATER SUPPLETION RATE (refreshment volume):

0,1 - 0,4 m^3 (depending on the rate of denitrification within the RS).

For African catfish: from 0,03 m^3

In praxis suppletion rate depends on concentration of NO3- or EC above a specific level

6. AIR SUPPLETION RATE (with regard of exchange of CO_2 and O_2):

250 m^3 air (50 m^3 air if NaOH is suppied for neutralizing pH instead of NaHCO3)

7. GIFT OF BICARBONATE (depending on KH of water to be supplied):

Up to 200 grams $NaHCO_3$.

8. HYDRAULIC LOAD OF SURFACE OF OXYDATION FILTER:

Trickling filter : 200 - 600 m^3 per m² per dag
(8,3 - 25 m^3/h).

Submerged filter: 100 - 300 m^3 per m² per dag
(4,2 -12,5 m^3/h).

9. FISH DENSITY(depending on size of fish):

African catfish: 20 kg (young) - 350 kg per m^3
full-grown: till 500 kg/m^3

carp : 150/ m^3

trout : 100 kg/m^3

Eel : glas eel: 10-20 kg per m².
Elvers: 30 kg (10 grs;: 80 kg per m²
Consumable eel: 150-250 gram: maximal: 200 kg/m²

tilapia: 80 kg/ m^3

10. SGR (Specific Growth Rate):

eel : ca. 0,7-0,8 % (growing from 10grams till 150 grams)
African catfish: 4,5 % (from 10 till 1000 grams)
carp : 2 % (from 1 till 500 grams)
trout : 2 %
tilapia: 3 %
turbot: 0,85 % (from10 till 1000 grams)

11. FOOD CONVERSION RATE (at appropriate food and optimal temperature):

Eel :	1,3	(growing from 10 grams till 200 grams)
African catfish:	0,8	(growing from 10 grams till 1000 grams)
Tilapia :	1,3	
Trout	1,0	
Turbot	1,2	
Sea bass	1,0	

Three examples **(Instructions for learners):**

Assess the dimensions (both area of farm and system characteristics) of following fish farms:

1. **A catfish farm for the production of 100 tons per year**
2. **An eel farm for the production of 50 tons per year**
3. **A pike perch farm for a production of 75 tons per year**

   Next questions are important to be answered as basis for the construction of a RS:

Herewith, for the calculation of SGR next formula should be utilized

(cf. Suggestion of dr. ir. Andries Kamstra, The Netherlands):

$$SGR = \frac{\ln Wt - \ln Wo}{t} \times 100$$

Wo: mean body weight at day 0
Wt: mean body weight at day t

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1 **Assess the number of days necessary for growth from 10 grams till 800 grams at mean SGR = 3 %**
2 **What mean Standing Stock of growing fish has to be established at the production farm?**
3 **What mean daily food gift has to be supplied?**
4 **At what rate water has to flow daily?**
5 **Calculate minimal dimensions of water purification units (both sedimentation tank and trickling filter)**
6. **How many fish tanks are necessary at least?**
7. **How large the production hall should be considering the space necessary for proper grading the fish.**
8. **How much HCO_3^- has to be added, if only rain water (KH=0) is available?**
9. **What air refreshment rate has to be applied daily (or m3/day)?**

Elaboration of the example of a 100 tons catfish farm (1) with SGR = 3 %

1. **Assess the number of days necessary for growth from 10 grams till 800 grams at mean SGR = 3 %**

   Utilizing the above presented formula: $SGR = \frac{\ln Wt - \ln W0}{t} \times 100\ \%$

   It follows that t = days

2. **Assess mean St St during growing of fish**

   It is assumed that only 340 days/year are days of fish production (at remaining 25 days fish have to acclimatize or tanks have to be cleaned).
   During 240 days, for attaining 100 tons a year, fish quantity has to grow with 3 % (SGR) = 284 kg.
   100% (St St) = 9466 kg fish (around 10 tons)

3. **What mean daily food gift has to be supplied?**

   284 kgs with a food conversion rate of 0,8: 284 (kg) x 0,8 (FCR) = 227,2 kg of fish food per day

4. **At what rate water has to flow daily?**

   284 x 10 m3 = 2840 m3/day
   Because of resistance of tubes, pumps have to be installed with 50 % overcapacity. Therefore, pumps of this catfish farm need to produce: 4260 m3/day. In praxis at least 5 pumps have been installed; this allows regular repair.

5. **Calculate minimal dimensions of water purification units (both sedimentation tank and trickling filter).**

   Sedimentation by lamellae (standing in an angle of 60 ^{o}; mostly utilized for sedimentation of solid particles in catfish systems in The Netherlands):
   With regard to necessary surface of lamella separators necessary ($25\ m^3/m^2$/day): 2840 : 25 = 113,6 m2 (effective surface)
   If installed at an angle of 60 o and at a distance of 4-5 cm between two lamellae (in order to realize stable flow of water, avoiding turbulence), effective surface is 2 x 113,6 m^2 = 227,2 m^2. If 230 plates of 1 m2 are installed, it means a sedimentation chamber of 11,5 m long and 1 m depth is necessary.
   Sedimentation tanks have been preferably constructed from lamellae because faeces from African catfish have low amount of mucus and disintegrate easily therefore. Faeces from eel or tilapia are packed within a layer of mucus and can better be caught by a triangle-filter or drum-filter. Capacity of is device has to be in accordance with water flow of the system. If a drum filter as separation of solid particles is preferred: the capacity has to be: 118,3 m^3/h (or more).
   If solid articles have to be removed by triangle filter or **drum filter**, only water flow of RS has to be considered. In this case: 2840 m^3/day or 118 m^3/h

The trickling filter has to be dimensioned according to fish food gift per day:

227 kg fish food/day. At 25 ^{0} C (optimal water temperature for African catfish), about 1 m^3 with specific surface 200 m^2/m^3 can be utilized. For this catfish production it means: around 115 m^3 of trickling filter is necessary.
Optimal height of a nitrification tower (in view of purification capacity of bacteria) is 3,5 m. This means, dimensions of trickling filter should be: 3,5 (height) x 32,8 m^2 (around 6 meter x 6 meter and 3,5 high).
Keep in mind: It is to be advised to offer a surplus to dimensions of 25 % of filtering capacity. Reaon: if the market is not willing to buy, fish can be stocked and grow further).

6. How many fish tanks are necessary at least?

This depends on the quantity of fish to be delivered each month and how frequently fish is graded during production. Normally catfish is graded once during production process (at a mean weight of 150 grams, end of production at 800 grams).

In view of variation in growth rate and grading, it can be assumed that 100.000 kg (production/yr) : 12 = 840 kg have to be delivered to the fish processor, this means: two fish tanks with 420 kg of fish every 2 weeks.
If catfish are kept quietly a quantity of 420 kg can be housed in a volume of 1000 liters, preferably – in view of animal welfare – this quantity of fish fish is housed in a fish tank of 2 m^3.
Assuming catfish can grow from 10 grams till 800 grams within 6 months (to be calculated with the formula presented below) and grading occurs at a body weight of 150 grams, following tanks are necessary:

7 tanks for fingerlings (one reserve tank for grading); tanks of 1 m^3 each
7 production tanks (one reserve tank for grading); tanks of 2 m^3 each

7. How large the production hall should be considering the space necessary for proper grading the fish.

Following parts of RS demand space in the production hall:

1. Fish tanks: about 20 m^2
2. Sedimentation tank: 15 m^2
3. Trickling filter: 40 m^2
4. Estimated room for proper grading with production hall: 25 m^2

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5. Surface of catfish production hall: 100 m^2

(ca 10m x 10m)

8. How much HCO_3^- has to be added, if rain water (KH=0) is utilized as production water?

Answer: 200 gram $NaHCO_3$ at each kg of fish food; it means 227 (kg of food) x 200 grams of $NaHCO_3$ = 45 kg of NaHCO3 has to be supplied daily.
In case effluent is used as plant fertilizer, best KHCO3 can be utilized. In The Netherlands, natural water with high content of KH was available for catfish producers; low amounts of $NaHCO_3$ had to be supplied

9. What daily (or m^3/day) air refreshment should be installed?

Answer: 250 m^3 per kg food to be supplied. In view of a daily food gift of 227 kg, this means: 227 x 250 m^3 of air have to be refreshed daily: 56.759 m^3 of daily fresh air (two fans of 12.500 m^3 air/h).

Example II: an eel farm of 50 tons/yr

If food conversion rate (fcr) = below 1 for glass eel and 1,3 for growing eel

For SGR: utilize next formula:

$$SGR = \frac{\ln Wt - \ln Wo}{t} \times 100$$

Wo: mean body weight at day 0
Wt: mean body weight at day t

(in an attempt to work with similar formulae, as proposed by dr. ir. Andries Kamstra, The Netherlands)

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1. **What mean Standing Stock (St St) during growing of fish?**
   Answer: 30 tons of eel

2. What mean daily food gift has to be supplied?
Answer: a daily food supply of 300 kg

3. And what daily water flow should be?
Answer: flow in glass eel compartment:80 m^3/h
Flow in dept. Of growing eel: 450 m^3/h

4. **Calculate minimal dimensions of water purification units (both sedimentation tank and trickling filter).**
   Answer: Most eel growers utilize drumfilters or discfiters. The capacity of such a filter needs to be in accordance with water flow through fish tanks and filtering device (surface to be needed: around 10 m^2)
   A trickling filter with following dimensions has to be installed, if specific surface of carrying capacity is 200 m2/m3: (0,5 x 300) x 1,25 m^3 = 187,5 m^3
   Height of trickling filter preferably should be 3,5 m. So, surface beneath would be at around: 5 (m) x 11 (m) (= 55 m^2)

5. **How many fish tanks are necessary at least?**
   Answer: 8 fish tanks for glass eel: surface: 3 m^2 each tank; total: 24 m^2
   14 tanks for growing eel: 15,2 m^2 each tank; total: 212 m^2

6. **How large the production hall should be considering the space necessary for proper grading the fish?**
   Answer: A surface similar to that for fish tanks and filters together has to be reserved for grading and other activities.
   So area of production hall has to be around: 2 x (10 m^2 +55 m^2) = 130 m^2

7. **How much HCO_3^- has to be added, if only rain water (KH=0) is available?**
   Answer: Bicarbonate gift (in the form of $NaHCO_3$): 200 gram each kg of food to be supplied. It follows: 300 x 200 gram $NaHCO_3$ = 60 kg of NaCO3 to be supplied daily.

8. **What air refreshment rate has to be applied daily (or m^3/day)?**

Answer: 250 m^3 of fresh air per kg food to be supplied. Thus, in this farm: 200 x 250 m^3 fresh air has to be introduced daily.

Example III: a farm for the production of 75 tons of pike perch/yr

(it is assumed stocking density does not exceed 120 kg/m^3)

1 **Assess mean SGR during growing of fish**
Answer: It is assumed that pike perch has a SGR= 1,4 %

2 **What mean Standing Stock of growing fish has to be at the production farm?**
Answer: Growth per day (assuming this farm has 350 days of real growth per year) has to be: 75.000 kg : 350 = 215 kg
215 = 1,4 % of St St. → 100 % (St St) = 15.357 kg

3.What mean daily food gift has to be supplied?
Answer: 215 (kg of fish to be grown) x v.c.= 215 kg x 1,3 = 265 kg fish food

4. **At what rate water has to flow daily?**
Answer: 265 x 40 m^3= 10.600 m^3 per day (442 m^3/h)

5. **Calculate minimal dimensions of water purification units (both sedimentation tank and trickling filter).**
Dimension of sedimentation filter. Preferably a drumfilter (mark: hydrotech) with capacity of 500 m^3/h is utilized (in this case); an area of 20 m^2 is requested
Dimension of trickling filter: 265 :2 = 132,4 m^3 'bionet' (specific area: 200 m^2/m^3). With height 3,5 m and bottom surface: 5 (m) x 7,5 (m) = 37,50 m^2

6. **How many fish tanks are necessary at least?**
Necessary in this farm:
Supposed St St : 15.000 kg. It follows, the volume of fish tanks has te be: 15.000 (kg): 120 (kg) = 125 (m^3)
For fish farming and considering necessary room for growth, four times this volume will be available: 4 x 125 m^3 = 500 m^3
In case a fish tank has a volume of 15,2 m^3 around 500 : 15,2 = 33 fish tanks are desirable

7. How large the production hall should be considering the space necessary for proper grading the fish?
Answer: If stocking density does not exceed 120 kg/m^3,
St St = 15.000 kg,
Volume of fish tanks: 500 m^3
Preferable depth of fish tank: 80 cm.
It follows a bottom surface of 625 m^2 is requested

In the production hall surface has to be reserved for:

Fish tanks:	625
Sedimentation device:	20
Trickling filter:	37,5
Additional apparatus (dephosphatation and so on):	20

Minimal surface for installations required:	707,5 m^2

For such installation usually a production hall of 1.500 m^2 is reserved; 60 x 25 m: it allows enough surface for working activities.

8. How much HCO_3^- has to be added, if only rain water (KH=0) is available?

Answer: at most quantity (depending on KH of incoming water and desired pH): 265 x 200 gram $NaHCO_3$= 53 kg

9. What air refreshment rate has to be applied daily (or m^3/day)?

Answer:

265 x 250 m^3 air per day = 662.500 m^3 air per day = 2760 m^3/h

Attachment (power-point presentation): photographs of essential parts of RS:

I. Devices for removal solid particles
II. Carrying material for nitrifying bacteria
III. Fish tank and attributes
IV. Attention at Management
V. Necessities for sustainable aquaculture

Important management aspects during production process:

1. **How to start-up a recirculation system (with biological filter)?**
2. **When to grade growing fish?**
3. **What quantity of fish feed has to be supplied in relation with eating capacity?**
4. **Prevention of outbreaks of fish diseases**
5. **Allow minimal costs of electrical energy**
6. **Miscellaneous management tools**

Ad 1. **How to start-up a recirculation system with biological filter?**

One can start-up a recirculation system (with biological filter in three ways:

1. Start with fishes without inoculation with nitrifying bacteria the biological filter.
2. Carry over nitrifying bacteria from an already functioning filter
3. Inoculation of the biological filter with lyophilized nitrifying bacteria

In case ([1]) of a biological filter is not inoculated with nitrifying bacteria (thus avoiding the chance to introduce malignant microorganisms), one has to wait about three months before sufficient bacteria have development sufficient purifying capacity. These bacteria enter the biological filter by air and dust in the air, so by chance.
In case ([2]) of a good functioning biological filter is at your disposal, just empty one bucket of water taken in directly from beneath the biological filter, into the RS to be started. It is important that fish are fed properly thus delivering enough food for nitrifying bacteria. Also important is that water parameters are measured and interpreted.
When nitrifying bacteria are daily supplied as described, within one week bacteria in the trickling filter can properly purify the effluent from fish tank,
In case ([3]) one does not trust the quality of available biological filter, it is possible to inoculate with lyophilized nitrifying bacteria, commercially available in many shops for ornamental fish. When a biological filter is started with lyophilized bacteria, it also is recommended to control water parameters daily. When levels of NH_4^+ or NO_2^- appear too high, one can refresh water or add salts (NaCl) diminishing toxicity of NO_2^-.

Ad 2. **When to grade growing fish**?

Due to natural variation in feeding and growth capacity, fish of a certain breed grow at different speed, dependent on fish have been bred on high growth capacity or have been graded before. Therefore, most fish to be kept in a fish farm have to be graded during production process.

a. **With regard to eel**: Eel never have been selected on growth capacity because farmers have to rely on wild glass eel or elvers with natural variation in growth capacity.
   Directly after grading all eel will eat and grow uniformly. Soon, it will become evident that some eel eat and grow less and separate from fast growing individuals. About 30 % till half of eels may remain small by not willing eating. It has to be decided quickly to grade again in order to separate growers from non-eaters. By offering new chances to eat to former starving eel, it is prevented that considerable part of initial eel remain small. It can be decided to grade once in 2 weeks or once in 1 month (dependent on the amount of non-eaters)
b. **Fish species like African catfish, trout, tilapia or carp** are farmed and selected for growth capacity during many decades. Therefore, for farming uniform batches of fingerlings of these species can be obtained. As a result, it is only necessary to grade only once or twice during production process.
   For example, African catfish are graded only once during growing, at a weight of around 150 grams (starting growing from 10 grams; at around 800-1000 grams African catfish are slaughtered).

Ad 3**: What quantity of fish food has to be supplied in relation to eating capacity?**

During feeding by hand, a fish farmer also controls fish health by judging appetite and vividness. When fish are suspected to show signs of a diseases, it is checked immediately under the microscope. If it is seen necessary, alive fish have to be sent to the laboratory of fish diseases as quick as possible, because the cause of disease has to be determined scientifically and a treatment has to be developed.

Fish diseases appeared to be prevented best by salt (NaCl). As an outbreak of a disease occurs, elevating the salt content can prevent bacteria on the skin to grow

(9 out of 10 cases). Fishes as carp, sturgeon, eel and tilapia endure a rise of salt content up to EC = 10. When infection seems to disappear, salt content can be lowered gradually.

Theoretically, EC can be rise till EC= 16 since EC of fish blood = 16.

Eel survives in salt water and brackish water (eel is frequently caught in The Wadden Seas and for spawning the species has to swim to the Sargossa Sea in the Atlantic Ocean, where salty circumstances can be found.

In eel farm utilizing brackish water as an eel farm in Bedum (Groningen, The Netherlands), best eel health can be found because optimal EC for many fish pathogens is slightly above 0 (Pers. Comm.).

Optimal EC for the prevention of outbreaks of bacterial fish diseases are for:

Carp: EC = 2,5 – 3,0
Catfish: EC = 8
Eel: EC = 10

If, during fish production, EC is constant, nitrifying bacteria will adapt to this EC.

Ad 4**. Prevention of outbreaks of fish diseases**

Prevention fish diseases

As a rule, never feed a fish till saturation, because saturated fish do not digest food properly. It is experienced that fish trained to digest their food with best food conversion rate, show best results for both profitability and fish health. Feeding rate of trout, for instance, should be around 60-70% of feeding till saturation. Therefore, for fish farmers feeding by hand is the art of fish culture. Profitable fish farming, therefore, is mainly dependent on the way of feeding the fish. For this reason computer programs have been designed on basis of feed conversion rate and growth rate.

In all cases, fish are not fed to saturation. Feeding apparatus mostly are filled with food once a day, once or twice a day, a fish farmer controls feeding of fish and adds some food by hand, if he feels it is necessary and adjusts the computer program afterwards.

Ad 5. Allow minimal costs of electrical energy

Every entrepreneur knows that minimal costs have te be made for production, mainly costs for electrical energy (for the pumps) and feeding costs.

With respect to energy for pumps, following aspects are important to note:

1. At installation of tubes for transport of culturing water, tubes have to be installed with **maximal breadth of the tube for influent water** (see below with respect to tube resistance). Furthermore, all **sharp angles have to be avoided** (the wille cause resistance for the water stream and less output of water. So sharp angles in tubes result in higher costs for electrical energy and higher cost price of fish to be produced.

Ad 6. Miscellaneous management tools

What assurance companies can tell us.

In The Netherland fish farms can be assured if entrepreneurs take in account following management measures:

1. Alarm on alarm.
2. Control engineering can be accounted for 99 % of failure of production process (i.e. failure of electrical circuits).
3. 1 % of failures can be accounted to lightning
4. An electric generator is a necessity at each fish farm
5. The electric circuit at the farm has to be connected with the electric generator so that – in case of failure of the provider – immediately pumps can be restarted.
6. The generator for emergency has to charged every month at least during at least one hour (also this generator may fail to function).
7. A fish farmer has to be in the neighbourhood of the fish farm in case of failure of the electrical system (eel, for instance, will not survive an interruption of O_2-supply lasting more than 15 minutes. So: a farmer should be present within 10 minutes after failure of electricity.
8. An alarm has to be installed with regard to water levels in the fish tanks; an alarm if water level is too low and an alarm in case water level is too high (in the latter case eel may obstruct water flow).
9. In eel farms a minimum O2-concentration of 4 mg/l has to be insured in the water flow to fish (the basic flow).
10. Also a peak flow has to be insured (otherwise 'gas bubble disease' will be the threat).
11. In case of infection with *Trichodina* (common in eel farming): just swift off UV-filter for 2 weeks and restart again thereafter: the parasite disappeared.
12. Second method to remove *Trichodina* (if present within fish farm): pH has to be set at 5,6- 6,0. At this level of pH the parasite will disappear and NH_4^+ is not harmful to fish