Training course packages targeting food operators on the adoption and management of the technological innovations

AQUACULTURE SYSTEMS

Introduction to Recirculating Aquaculture Systems – Operation and maintenance

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Table of Contents

1. FoodLAND technical innovation for local food supply chains: concepts and approaches

The FoodLAND project has the ambition to impact on a large number of supply chains and communities, hence the process of food operators' capacity development has to be tailored and as much participative as possible. Accordingly, one of the assumptions of FoodLAND is that sustainable and nutrition-responsive farming systems can be achieved basically by strengthening the capacity development, and specifically by **a)** empowering farmers and processors through the implementation of capacity building processes and concrete opportunities; **b)** creating or consolidating cooperation and shared knowledge to overcome the lack of coordination among food operators; **c)** addressing the inefficient use of resources; **d)** trying to address and build resiliency to the high vulnerability of food systems to climate change; **e)** enhancing the integration of supply chains by creating commercial and stakeholders' networks; **f)** improving the responsiveness of the production sector to the market demand.

To implement these elements of capacity development, FoodLAND proposed the adoption of specific innovations, among which the organizational ones, to create strong and responsive links between producers and encompassing all the intermediate actors along the food value chain, such as researchers, SMEs, NGOs, local and national authorities. In order to ease the creation of those links and guarantee the sustainability over time of the results, 14 Food Hubs will be created in 6 countries as part of the organizational innovations. Food Hubs are conceived as multi-actors centers of innovation where to develop or enhance the organizational and operational conditions enabling local food supply chains (D3.6).

Functional to the implementation of the Food Hubs and of the innovations, the training courses were designed – in form of capacity development activities – as a two-phase process. Firstly, a training session focused on general, preparatory topics was provided to farmers as described and reported in D3.5 ("Group Introductory Training", GIT). According to the project GA, GIT broad set of goals were: to enhance the knowledge of consumers’ nutritional needs and market opportunities, and to boost the notions about climate change, sustainability, resilience, and food culture. Secondly, a specific training session were organized to provide food operators with practical information on the adoption and management of the innovations tested at lab / small scale level and to contribute to validating them at appropriate scale.

However, as the whole approach has been designed by FoodLAND to ensure the inclusion of the local actors from the first moment, both the training sessions were set up accordingly. Indeed, yet in the inception phase of the project, an assessment on participatory methods has been run and Participatory Learning and Action (PLA) approach has been eventually assessed as the best one to ensure the inclusion of multiple perspectives. The main purpose of PLA is to support people within communities to analyze their own situation, rather than have it analyzed by outsiders, and to ensure that any learning is then translated into action (Gosling and Edwards 2003). In addition, a gender-sensitive approach has been applied to the trainings that have been designed considering gender roles and power relations; they have provided equal opportunities to participate in the process by caring to times, venues and use of local languages.

The GITs have been conceived as the first step towards the innovation validation and aim at involving the producers, yet from the inception phase. They are just the first step in a sequence of 6, summed up in **Table 1**. After the GITs, where farmers and processors meet and share their vision and goals for the Food Hubs and exchange information about specific topics, the Food Hubs were created and the innovation tested (first in pre-test, then in pilot phase). The constant iteration between researchers and local actors is a key feature of the project: specifically, the practical trainings focused the single innovations (step 5) are aimed at validating the innovations at adequate scale and planned to trigger feedback loops of control and improvement involving developers and adopters.

Table 1. Activities with farmers and food processors (SMEs) and participatory approach

Step	1	2	3	4	5	6
Task	**T3.3**	**T3.3**	**T3.4**	**T4.1¸T4.5**	**T5.1¸T5.5**	**T5.1¸T5.5**
Activity	Group introductory training	Food Hubs creation	Innovation undertaking	Innovation tests	Individual and group practical training	Innovation pilot and validation

2. FoodLAND practical training: aims and scope

According to the project bottom-up and participatory approaches, following the courses on introductory topics GIT organized in the early project phase (T3.3), and as component creating / strengthening the Food Hubs as local innovation centres, FoodLAND has organized a second set of training activities with food operators based on active learning methods and gender equality principle (Task 5.1-5.9). In this regard, specific mechanisms (being aware of the gender roles and power relations; providing equal opportunities to participate in the process by putting attention to the times, venues, use of local languages, etc.) will be lifted to ensure women’s participation. These training packages are aimed at providing the local farmers and food processors with operational instructions on the adoption and management of the validated innovations.

This second set of training activities has been organised – triggering PLA approach – as individual and group practical (demonstration/capacity building) activities to be conducted in parallel to the implementation of the technological research (where relevant) and of the innovation pilots and validation. These technology-centred trainings aim at strengthening the participants’ understanding of novel production and post-harvest techniques, innovative tools and systems (e.g., climate smart/precision agriculture, hydroponics, and integrated aquaculture), new technologies for primary and secondary processing, and supply chain management. Thus they aim at fostering knowledge and operational capacity to deploy, manage, and maintain the validated technological innovations – documented by the released guidelines D4.1 ÷ D4.11 (e.g., training pamphlets, user manuals, flow diagrams, and operational recommendations) and practice abstracts D6.5 – validated jointly at appropriate scale.

3. Second training packages on the adoption and management of the tested innovations: an overview

The second training course aimed at consolidating the food operators' knowledge and practical skills to adopt, manage and validate the project innovations and complement the related guidelines. Specifically, the realized training materials provide local farmers and food operators with a set of notions and concrete information on a series of innovative tools and systems as per the following **Table 2**. It is clear that both the contents and formats of the learning packages widely differ across technologies as well as Food Hubs (when the same type of innovation must be validated in different contexts). The diversity that emerges from the proposed solutions reflects the different needs highlighted by farmers and stakeholders as well as the conditions and opportunities characterizing the local communities. Nevertheless, in order to take into due account the existing heterogeneity inside the local communities, the developed learning materials have been let available on the project intranet so as to be used for further training initiatives across the network of Food Hubs.

4. Second training packages on practical information on the adoption and management of the tested innovations

Aquaculture systems

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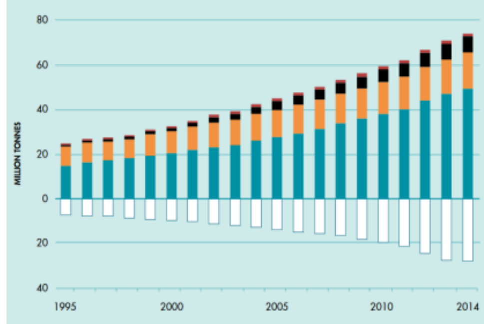
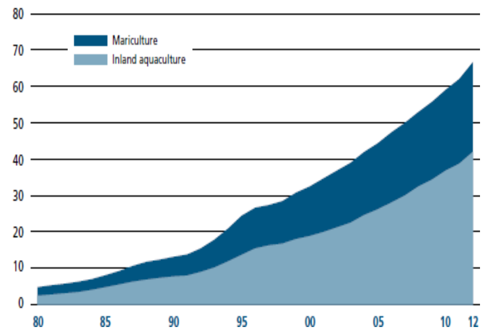
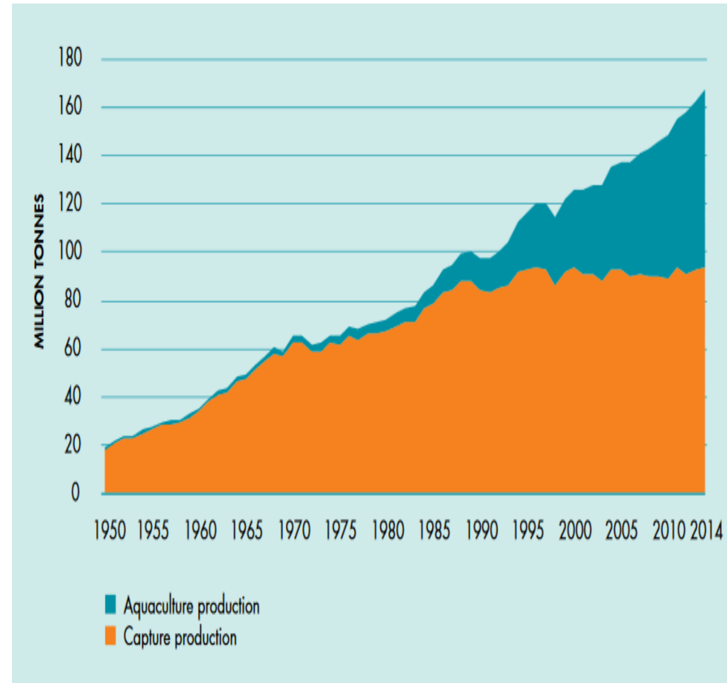
Aquaculture in the world

World capture and aquaculture production volume of aquatic animals and plants (1995-2014)







Source: FAO – Sofia 2016

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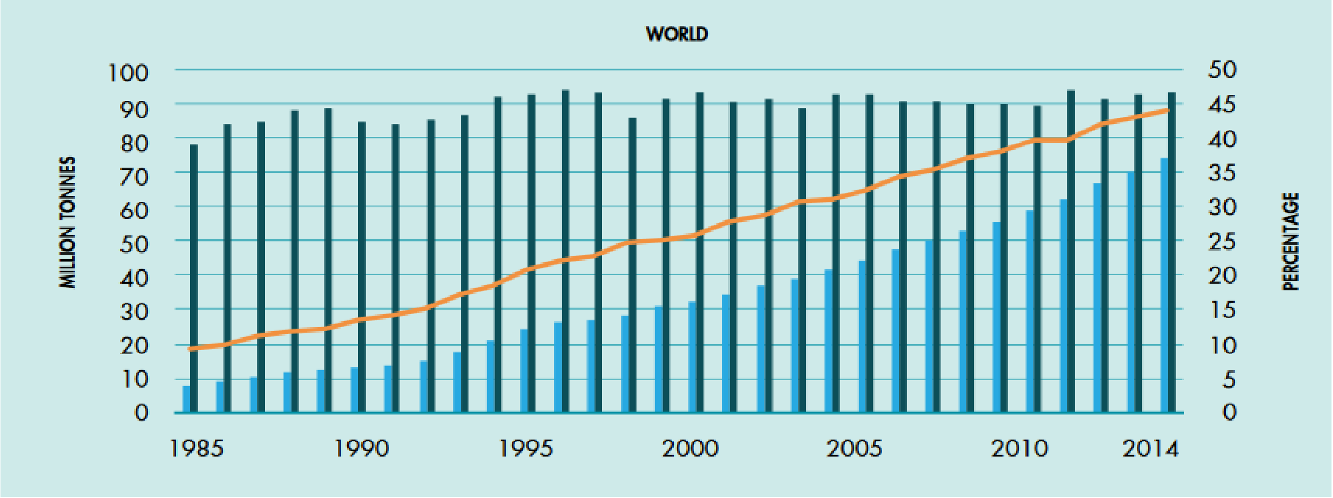
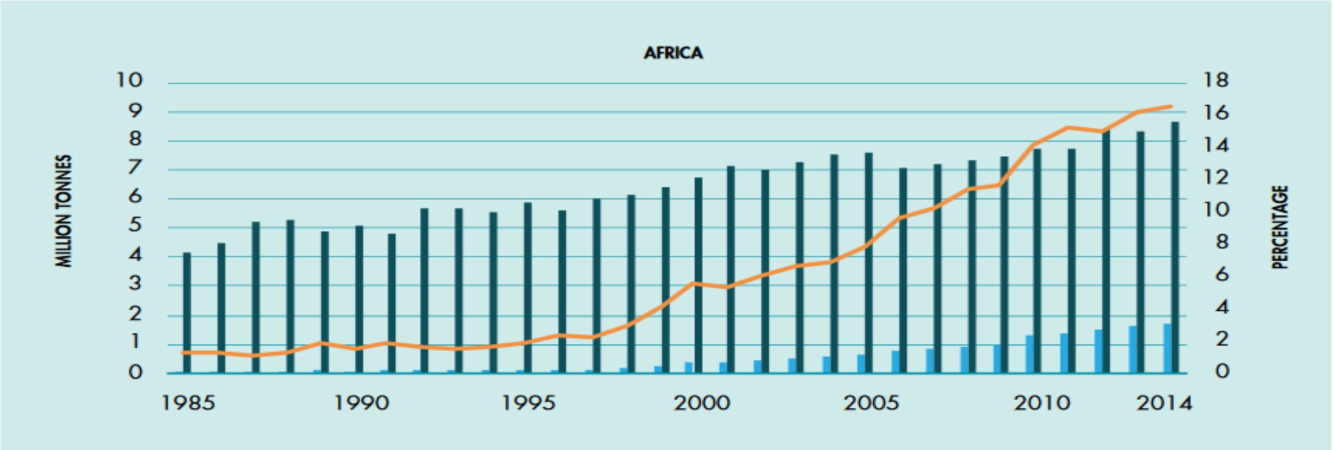
Aquaculture in Africa





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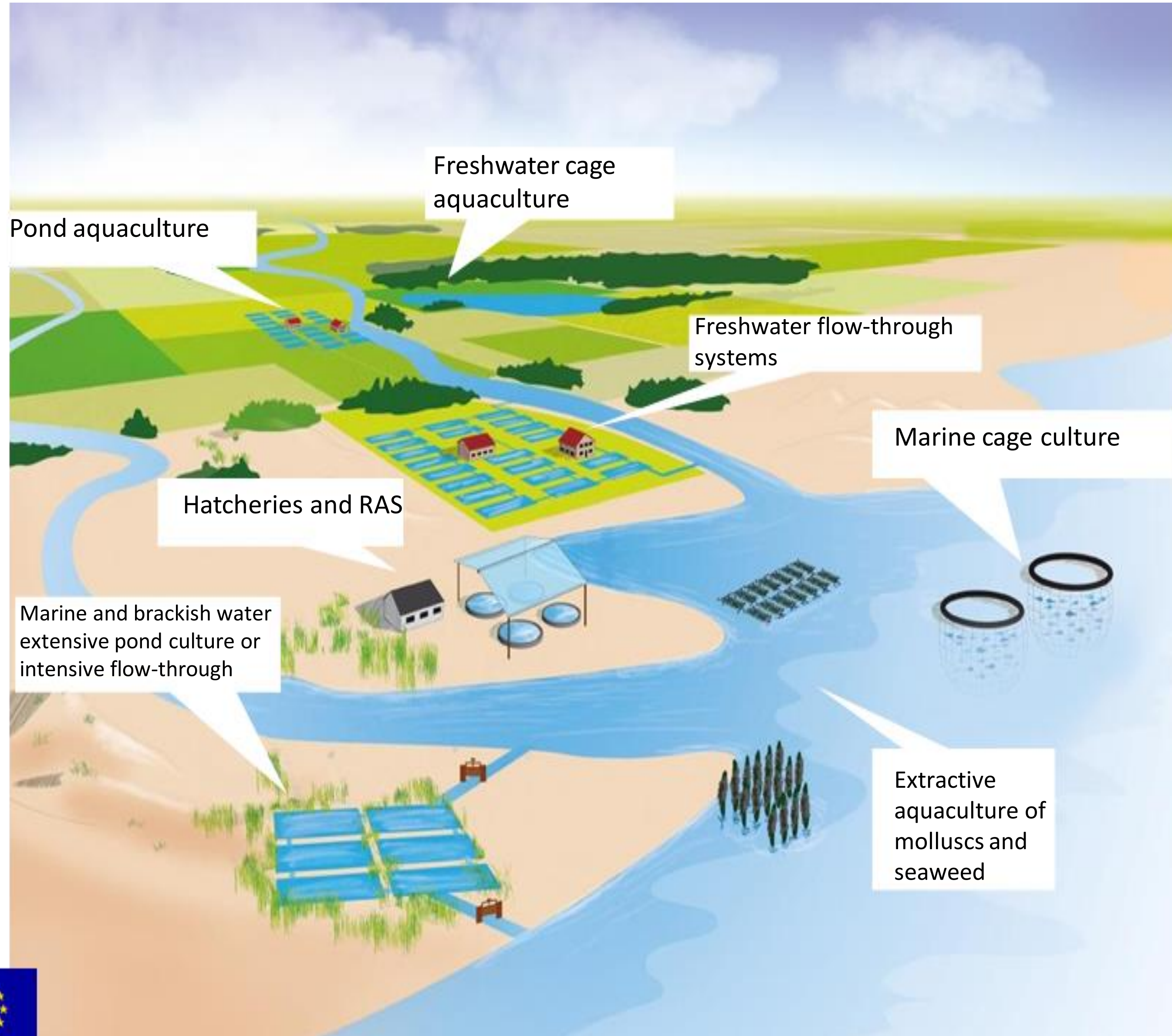

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Definitions

Aquaculture

Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated, the planning, development and operation of aquaculture systems, sites, facilities and practices, and the production and transport (FAO).

Recirculating Aquaculture System

Recirculation aquaculture is essentially a technology for farming fish or other aquatic organisms by reusing the water in the production. The technology is based on the use of mechanical and biological filters (FAO).

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Opportunities and limitations of RAS

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Advantages:
- Reduced water consumption
- Reduced land requirements
- All year-round operation
- Environmental control (control parameters that influence growth)
- Waste management
- Lower impact of pathogens
- Food-safety benefits
- Monitoring feed management is enhanced resulting in lower FCR
- Reduction of stress due to adverse weather conditions, unfavourable temperature conditions, pollution incidents and predation.
- Accurately planned production volume and harvest according to the market needs
- Fresh fish close to the market

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Opportunities and limitations of RAS

Limitations

- The production costs are usually higher than in cages or flow- through systems
- Needs high level of expertise and continuous development of staff members

Development trends

- RAS optimised feed development
- Energy optimisation
- Resource efficiency

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Opportunities and limitations of RAS

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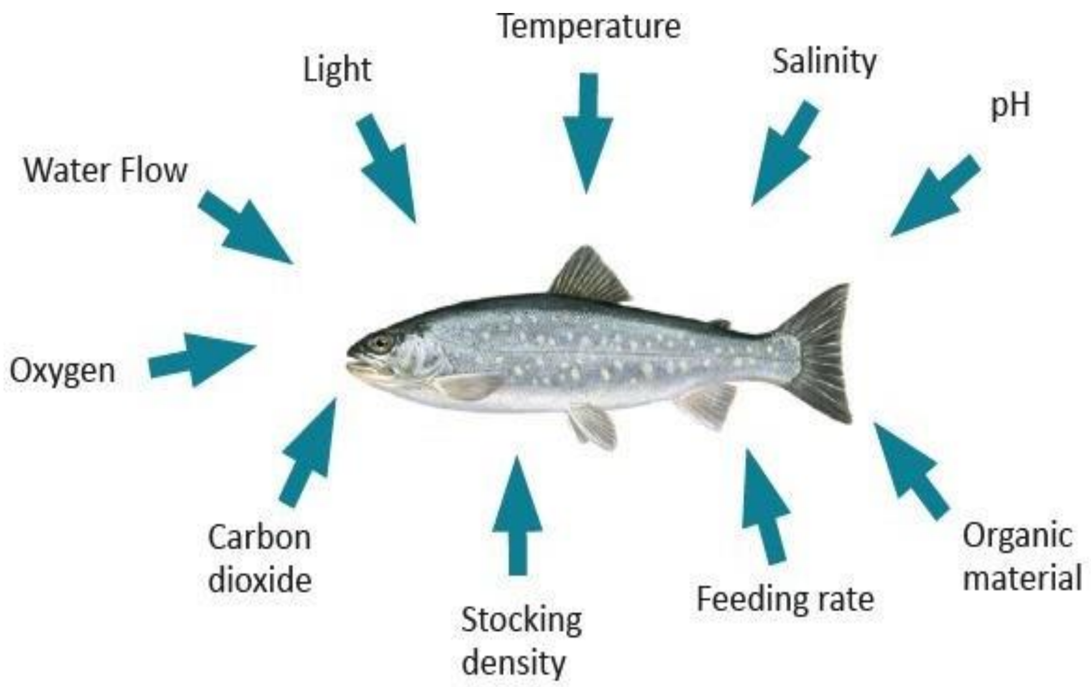

Source: FAO 2015

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Type of System

Type of system	Consumption of new water per kg fish produced per year	Consumption of new water per cubic meter per hour	Consumption of new water per day of total system water volume	Degree of recirculation at system vol. recycled one time per hour
Flow-through	30 m^3	1 712 m^3/h	1 028 %	0 %
RAS low level	3 m^3	171 m^3/h	103 %	95.9 %
RAS intensive	1 m^3	57 m^3/h	34 %	98.6 %
RAS super intensive	0.3 m^3	17 m^3/h	6 %	99.6 %

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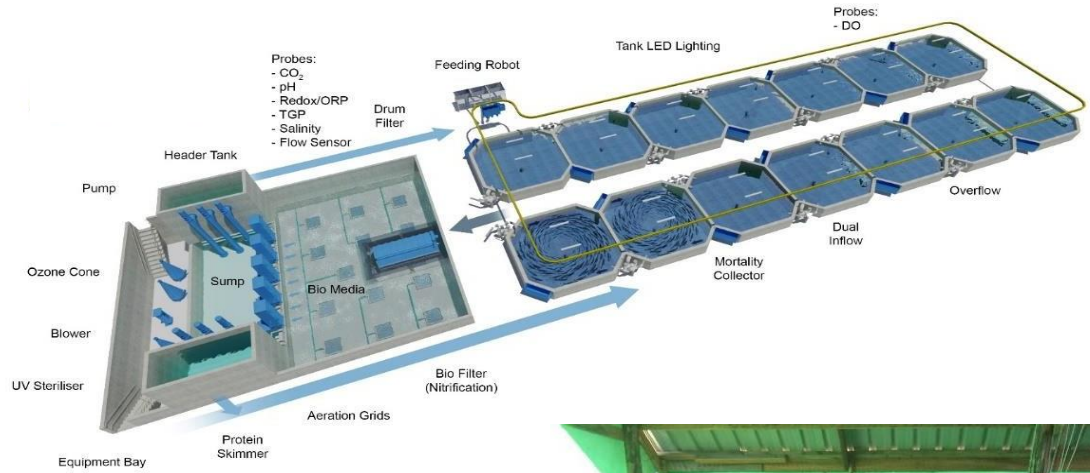

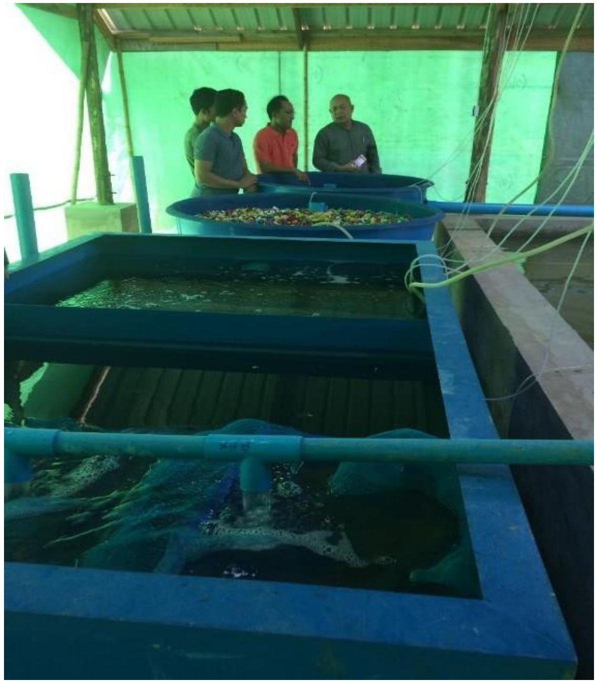

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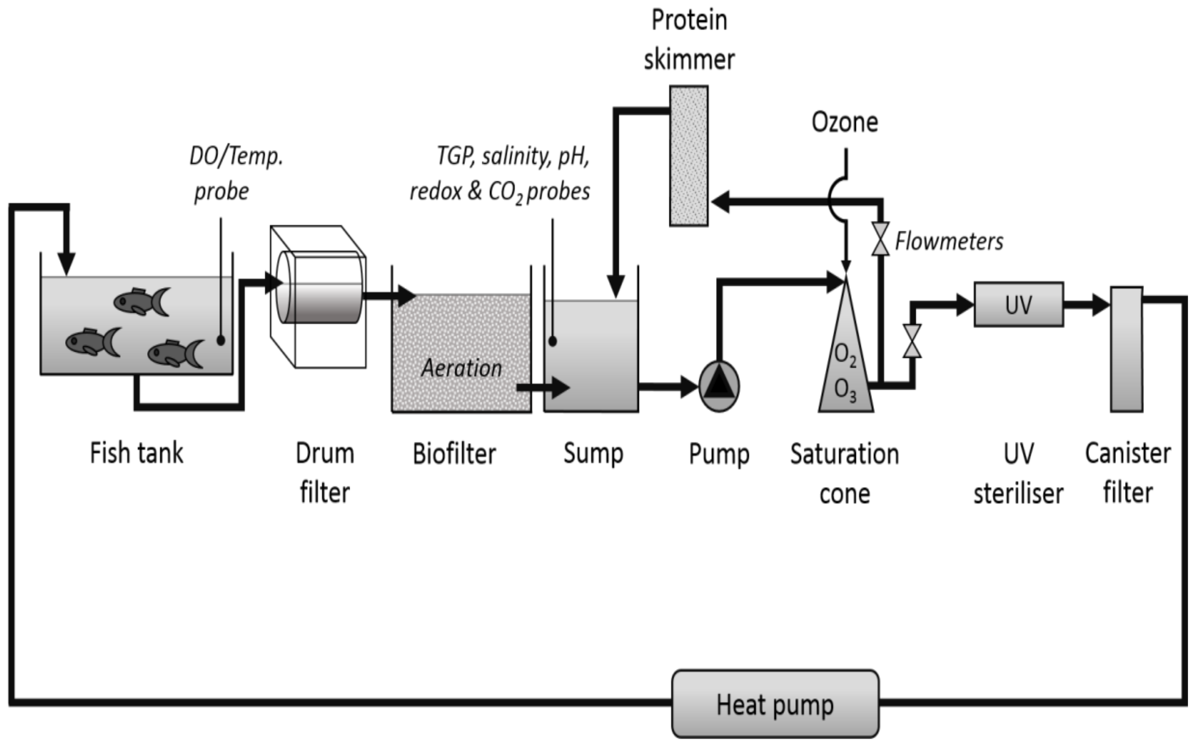
Components of RAS



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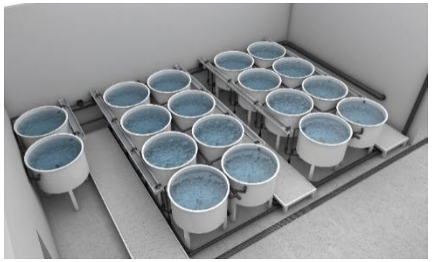
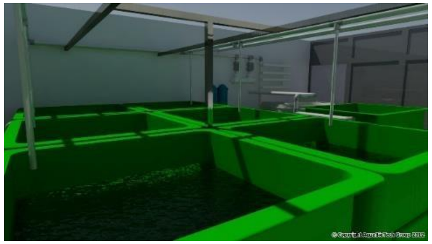
Components of RAS - Tanks

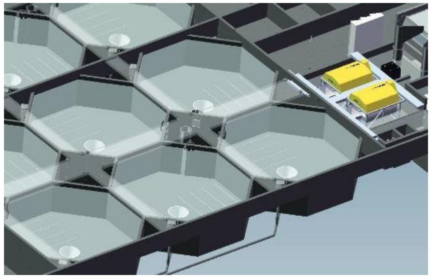


Circular Tanks
- Inherent structure and hydrodynamic nature
- Rapid removal of suspended solids using a center-drain and a sloping bottom



Rectangular tanks
- Prone to poor solids movement
- Efficient in floor space utilisation
- Easy to harvest

Raceway tanks
- Combines the advantages of circular and rectangular tanks and are mostly used in marine culture
- Rounded ends and a wall in the centre to facilitate controlled circulation of water
- Extra costs for the middle wall
- Harvesting can be more difficult



Octagonal tanks
- Optimal space use
- Hydrodynamic advantages of circular tanks

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Components of RAS – Main pumps

- Energy efficiency – pump 24 hr operation
- Minimise lifting heights – design of system and specifying pump
- Cost effective and reliable – materials and efficiency
- Only lift water once
- Place after mechanical filtration – remove solids before pumping
- When using oxygen cones: centrifugal pump
- Low lifting heights: low pressure pump
- Airlift pumps for single tank reuse system
- Back-up pump
- Header tank

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Components of RAS – Solids removal

Settleable solids (>100 micron)

- Generally settle within an hour under still conditions
- Can be removed as they accumulate on the tank bottom through proper placement of the drains
- Can be removed using a sedimentation tank, a mechanical filter or swirl separator

Suspended solids (30-100 micron)

- Do not settle to the bottom of the tank and cannot be removed using settling basins.
- Can significantly limit the amount of fish stocked in the tanks and can irritate the gills of the fish.
- Usually removed by screen filters or media (sand or pellets) filtration.

Fine & dissolved solids (0.1-30 micron)

- Contribute to more than 50% of the total suspended solids in a system.
- Increase the demand for oxygen and can cause irritation to the gills and damage to the fish.
- Dissolved solids are removed using foam fractionation.

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Components of RAS – Biological filtration

In the biofilter dissolved nitrogen compounds are broken down into less toxic nitrate using biological processes performed by bacteria.

Ammonia → Nitrite → Nitrate

Unionized ammonia	Nitrite	Nitrate
NH_3	NO_{2-}	NO_{3-}
<0.05 mg/l	<1 mg/l	<200 mg/l

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Components of RAS – Biological filtration

Fluid Bed / Moving Bed Biofilm Reactor (MBBR)

Biofilters use plastic media to provide a large surface area per m^3 of filter.
The bacteria grow as a thin film on the surface.
Because of the constant moving of the media, it can be more packed reaching a higher turnover rate per m^3 compared to a fixed media filter.

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Components of RAS – Oxygenation/Aeration

Air pump/Blower

- Blows air through submerged air stones, diffuser hoses or airlifts that delivers air in small bubbles, enhancing oxygen transfer rates.
- Has the ability to strip CO_2.

Oxygen cones

- The highest rate of oxygen transfer can be achieved by using pure oxygen.
- Oxygen is delivered using pressurised cones.
- Refrigerated liquid oxygen in insulated tanks is converted in to gas when warming up. The gas creates pressure assuring delivery without power. As an alternative compressed oxygen tanks can be used.

Column aerator

- Water flows through a tall column loosely filled with large porous media and is aerated when slowing downwards.

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Components of RAS – Degassing

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- Accumulated gasses need to be removed
- Result from fish respiration and nitrification
- Have an effect on fish welfare and growth
- Aeration of the water (stripping)
- Carbon Dioxide (CO_2) and nitrogen (N_2)

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Components of RAS – Disinfection

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UV lights

- Disinfects the water by applying light in wavelengths that destroy DNA of biological organisms
- Only effective with relatively clear water
- Targets pathogens and one-celled organisms
- Quartz sleeve needs to be cleaned frequently.
- Bulb should be routinely replaced

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Components of RAS – Temperature control

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Heat/ventilate building

- Consider the building isolation/ventilation when designing a system
- RAS can also be placed in greenhouses, which are known to gather and hold solar energy reducing heating requirement

Heat exchanger and/or heat pump

- Maintaining optimal temperature in the system
- If cooling with intake water is not sufficient a heat exchanger and/or a heat pump/chiller can be used
- In cold climates heating of the water may be necessary

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RAS projects - Netherlands

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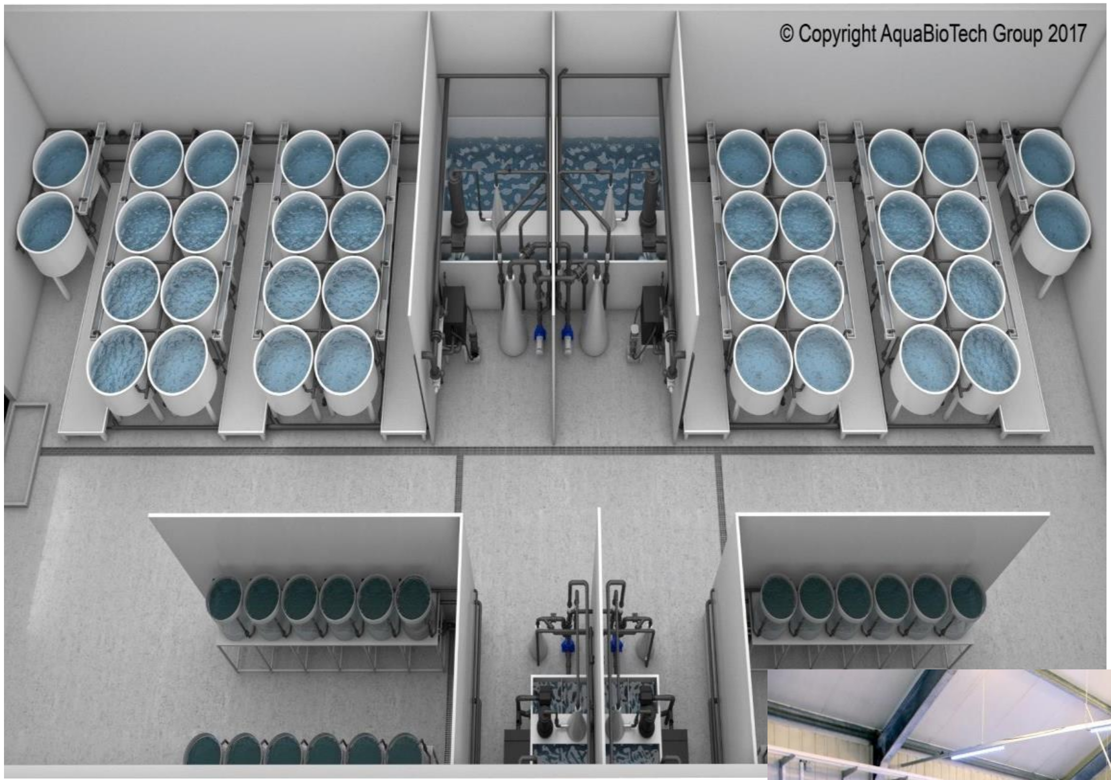

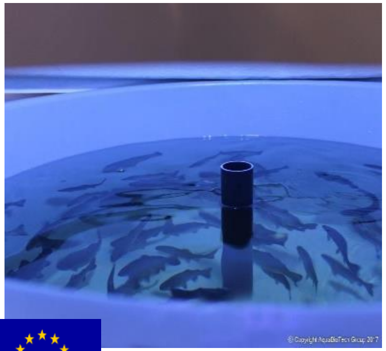

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Site selection

For aquaculture operators is it important to consider:

- Good climatic conditions
- Availability of clear, good quality fresh water throughout the year
- The availability of a power supply
- Good communication and transportation network
- Proper waste disposal facilities (on farm and local infrastructure)

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Broodstock management

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Tilapia (*Oreochromis niloticus*)

- High quality broodstock free from diseases
- Fish of 200-400 grams
- Tilapia spawn naturally in captivity
- Mouthbrooding
- Sex ratio 3/2:1 (♀:♂)
- 4-7 fish/m²
- Tilapia can spawn every 4 weeks
- Harvest every 7-10 days
- Temperature 24-30°C
- Feed twice per day (1,5% of body weight)

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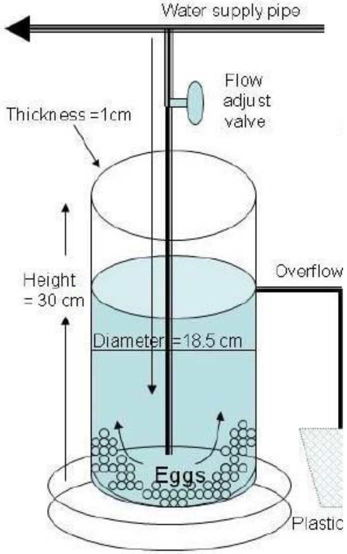
Egg incubation



Tilapia (*Oreochromis niloticus*)

- Eggs should be kept in gentle motion
- Aeration (oxygen level 4-5 mg/l)
- High water quality
- Round bottom down-dwelling containers
- Bad eggs are flushed out
- Eggs hatch between 3-5 days
- Reared in incubators till free-swimming

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Larval rearing

- RAS provides a controlled environment
- Survival up to 90%
- 21 days
- Up to 0.2 grams

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All male seed production

All-male populations have better growth rates than mixed-sex population, and it stops breeding in grow-out systems

All-male fry production:

- Mechanical or hand grading
- Sex reversal using a male hormone
- Use YY males

Sex reversal:

- Hormone (17ἀ-methyl-testosterone) is mixed with feeds
- Consequences for environment and fish are not well studied

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Nursery

Tilapia (*Oreochromis niloticus*)

- 21- 30 days
- Up to 1-2 gram
- Uniform in size
- Strong and disease free
- Ready for stocking in ponds
- Weaned on pellet feeds

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Feed management

Feed quality

- Water stable feeds
- Feeding regimes that reduce feed waste
- Highly digestible
- Nutritionally balanced

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Feed management

Feed quality

To guarantee optimal growth rate, survival and health of the farmed species, it is important to ensure and maintain feed quality and therefore:

- Packages should be properly labeled with description of composition, storage conditions, expiry date, feeding rate and other necessary guidance in adequate language.
- The content of the feed must fit the declaration on the label and the products should be hygienically acceptable.
- Content of additives and veterinary drugs should comply with National regulations

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Feed management

Feed intake

Feed intake of fish is influenced by a range of factors:

- Food availability (quantity, distribution)
- Feed characteristics (size, smell, taste, etc.)
- Environmental factors (water quality, competitors, contaminants)
- Intrinsic factors (species, stage, body size, etc.)

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Feed management

Basic Feed Practices

- Feeding practices should minimize the risk for biological, chemical and physical contamination of feed and farmed fish
- Feeding practices should ensure the maintenance of water quality
- Farmers should follow the instructions of the manufacturer when using the feeds
- Feed and fresh stocks should be purchased and used prior to the expiry of their shelf-life (First In–First Out)
- Traceability of all feeds and feeding activities should be assured by proper record-keeping

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Feed management

Feed storage

- Dry fish feeds should be stored in a cool and dry area to prevent spoilage, mold growth and contamination
- Transportation conditions should be conform to the specifications on the label
- Medicated feeds should be clearly marked on the package and stored separately, in order to avoid errors

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Water quality

Two types of water quality criteria in RAS:

- Fish requirements (e.g. oxygen)
- System requirements (e.g. alkalinity)

Water quality impacts on fish:

- Survival
- Health and welfare
- Efficient use of feed
- Quality (flavours)

Optimal water quality parameters vary with species and also depend on temperature and pH.

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Water quality parameters

Dissolved oxygen

- DO is the most critical parameter in aquaculture production systems
- DO should be above 5ppm/ close to 100% saturation
- Behaviour of the fish should also be observed. Fish show signs of oxygen stress by gathering at the surface and swimming into the current produced by the aeration device. If this occurs, aeration should be increased

Nitrogen

- Fish excretes a mixture of un-ionised ammonia (NH_3) and ammonium (NH_4^+) (together TAN). The ammonia (which is toxic) in the water depends on the pH. There is no ammonia if the pH is below 7 but rises quickly as the pH is increased.
- In general ammonia is toxic to fish above 0.02 mg/l. The pH for the biofilter should not be lower than 7 so the TAN concentration should be kept low.

pH

- Change in pH by 2 units is harmful for fish and bacteria

For bio-filter: pH 7-8 (below 6 bacteria do not remove waste)

For fish: pH6-9.5

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Water quality parameters

Alkalinity

- Alkalinity is defined as a measure of the pH buffering capacity or the acid neutralizing capacity of water (quantity of base present in water)
- Should be 100-400mg/l

Temperature

- Temperature affects the physiological processes of fish.
- Temperature also has an effect on other parameters in the system (TAN, DO, biofilter)
- Temperature must be maintained within the range for optimal growth of thecultured species: For the main species culture around Lake Victoria, Tilapia and African Catfish the optimal temperatures are between 27-30°C.

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Suggested levels

Parameter	Formula	Unit	Normal	Unfavourable level
Temperature		°C	Depending on species	
Oxygen	O_2	%	70-100	< 40 and > 250
Nitrogen	N_2	% saturation	80-100	> 101
Carbon dioxide	CO_2	mg/L	10-15	> 15
Ammonium	NH_4^+	mg/L	0-2.5 (pH influence)	> 2.5
Ammonia	NH_3	mg/L	< 0.01 (pH influence)	> 0.025
Nitrite	NO_2^-	mg/L	0-0.5	> 0.5
Nitrate	NO_3^-	mg/L	100-200	>300
pH			6.5-7.5	< 6.2 and > 8.0
Alkalinity		mmol/L	1-5	< 1
Phosphorus	PO_4^{3-}	mg/L	1-20	
Suspended solids	SS	mg/L	25	> 100
COD	COD	mg/L	25-100	
BOD	BOD	mg/L	5-20	> 20
Humus			98-100	
Calcium	Ca^{++}	mg/L	5-50	

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Water quality management

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Water quality parameter measurement	Possible solutions
Low dissolved oxygen (<5ppm)	• Increase aeration • Stop feeding • Check for symptoms of parasites and disease
High CO_2	• Increase aeration • Check for symptoms of parasites and disease
Low pH (<6.5)	• Add alkaline buffer (sodium bicarbonate) • Reduce feeding rate • Check ammonia and nitrate concentrations
High ammonia (>0.5 ppm)	• Exchange water • Reduce feeding rate • Check biofilter (pH, alkalinity, hardness and DO) • Check for symptoms of parasites and disease
High nitrate (>0.5 ppm)	• Exchange water • Reduce feeding rate • Check biofilter (pH, alkalinity, hardness and DO) • Check for symptoms of parasites and disease • Add 5 ppm chloride per 1 ppm nitrite
Low alkalinity	• Add alkaline buffer (sodium bicarbonate)
Discolored/clumped feed	• Purchase new feeds • Check for symptoms of parasites and disease

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Water quality monitoring

Parameter	Method(s)
Temperature	Thermometer or probe
DO	DO meter or probe
pH	pH meter, probe or test kit
Ammonia, nitrite, nitrate	Test kits
Total Gas Pressure (TGP)	Probe
Alkalinity	Test kit
Total Suspended Solids (TSS)	Gravimetric test or probe

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Stress and disease control

- Aquaculture has been the fastest growing animal production sector for the last 20 years, but diseases are increasingly limiting production especially in tropical countries
- Microbes and other disease-causing organisms prefer warmer water, resulting in a higher variety of diseases and the increased outbreak of diseases in tropical countries
- The excessive use of antibiotics in aquaculture can cause severe antibiotic resistance
- The aquaculture sector needs to continue to expand as a means of food production and therefore it is crucial to ensure that aquaculture operators are protected from the impact of diseases trough proper disease management
- In RAS generally low risk of diseases and no antibiotics are used

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Biosecurity

- To prevent diseases it is important that the facilities are bio-secure
- Using RAS it is expected that risk of pathogen introduction/spreading is reduced
- The most important is that the fish or eggs stocked are disease free and preferable from a disease free strain
- Broodstock fish are usually kept in a quarantine system with an isolated water supply
- The water going into the system should be disease free and sterilized (using UV f.e.)
- People entering the farm should follow strict bio security measures (use disinfection footbaths, wash hand thoroughly use alcohol, do not touch anything for visitors etc)
- Between batches the systems should be thoroughly disinfected. Different systems should be strictly separated in terms of use of equipment and staff/visitor bio-security measures

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Sorting and grading

- Grading of fry is very important after the initial development stages to minimize mortality caused by cannibalism and dominance
- Maintain uniformity in tanks
- First grading is done after the larval stage
- In the nursery fry are graded regularly
- Grading allows accurate sample counting
- Grading by hand graders

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Harvesting and transportation

- Fish should be purged to reduce their gut contents
- Live fish should not be subjected to extremes of heat or cold or sudden variations in DO (and salinity)
- Appropriate harvesting techniques should be applied to minimize physical damage and stress
- Fish should be slowly cooled down using ice to avoid stress during transport
- Appropriate packing techniques should be applied to minimize physical damage and stress

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Harvesting and transportation

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Cleaning and maintenance

- Cleaning and sanitation procedures
- Personal hygiene
- Water quality management
- Pest control
- Record keeping
- Staff training

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Personal hygiene

- Wear clean work clothing such as overall, gumboots, apron and gloves. Remember to remove watches and jewelry
- Use footbath to disinfect boots
- Wash work-tools when they are dirty
- No eating in the work area
- **MOST IMPORTANT:** Wash your hands properly!

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Cleaning and maintenance

Daily activities RAS

- Water quality measurements
- Check drum filter-nozzles
- Check heater (if applicable)
- Tank sump and levels
- Check for leaks
- Check flow meters
- Purge and syphon
- Add buffer for pH if necessary
- Bleach and empty sludge tank
- Clean buckets and probes
- Change rubbish, alcohol bottles

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Record keeping

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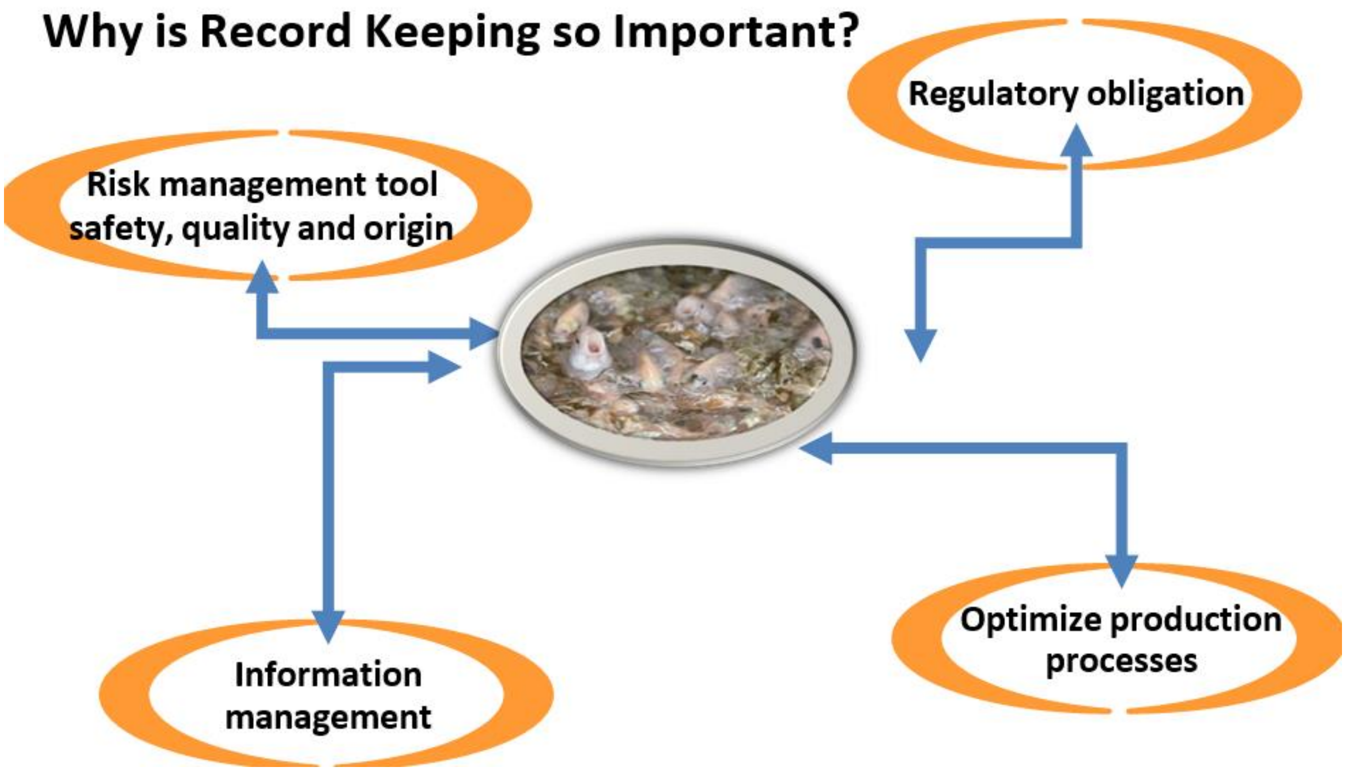

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Record keeping

Records to keep

- General hygiene practices (e.g. cleaning and sanitation, staff health, pest control)
- Water quality
- Feed management
- Fish health
- Management of chemicals and veterinary drugs
- Post harvest management
- Traceability
- Staff training
- Maintenance

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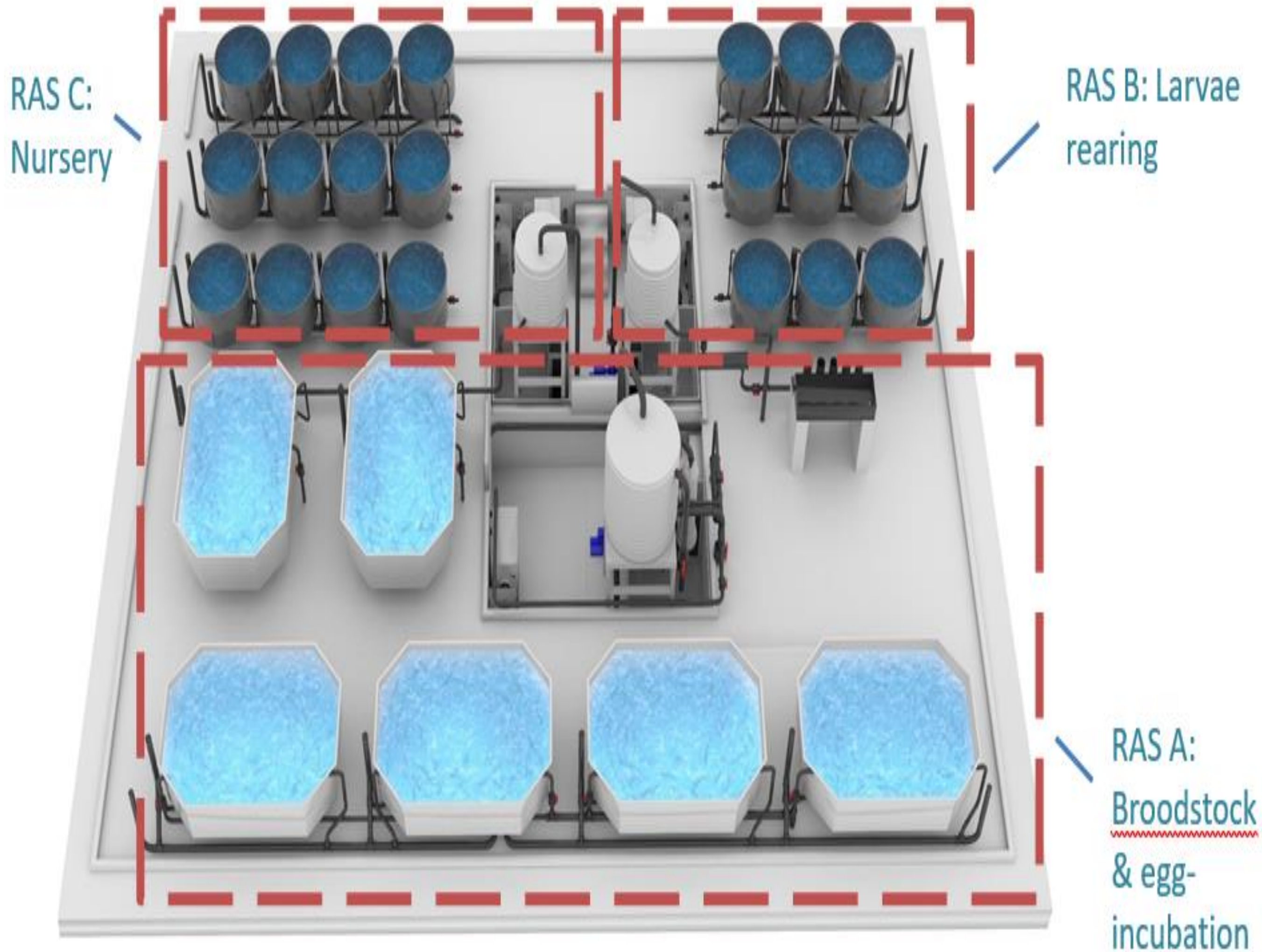
RAS in VicInAqua

VicInAqua Pilot with RAS tilapia hatchery at Nyalenda wastewater plant in Kisumu, Kenya



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RAS in VicInAqua

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- Training and demonstration facility
- Capacity: 30,000 fingerlings / month (1-2 g)
- RAS A: Broodstock & Egg incubation
- RAS B: Larval rearing
- RAS C: Nursery
- Input water from MBR
- Exchanged water to MBR (denitrification) + blend to agriculture
- Solids to bio-digestor
- Testing involving heavy metals & pathogens in fish after grow-out in cages or ponds

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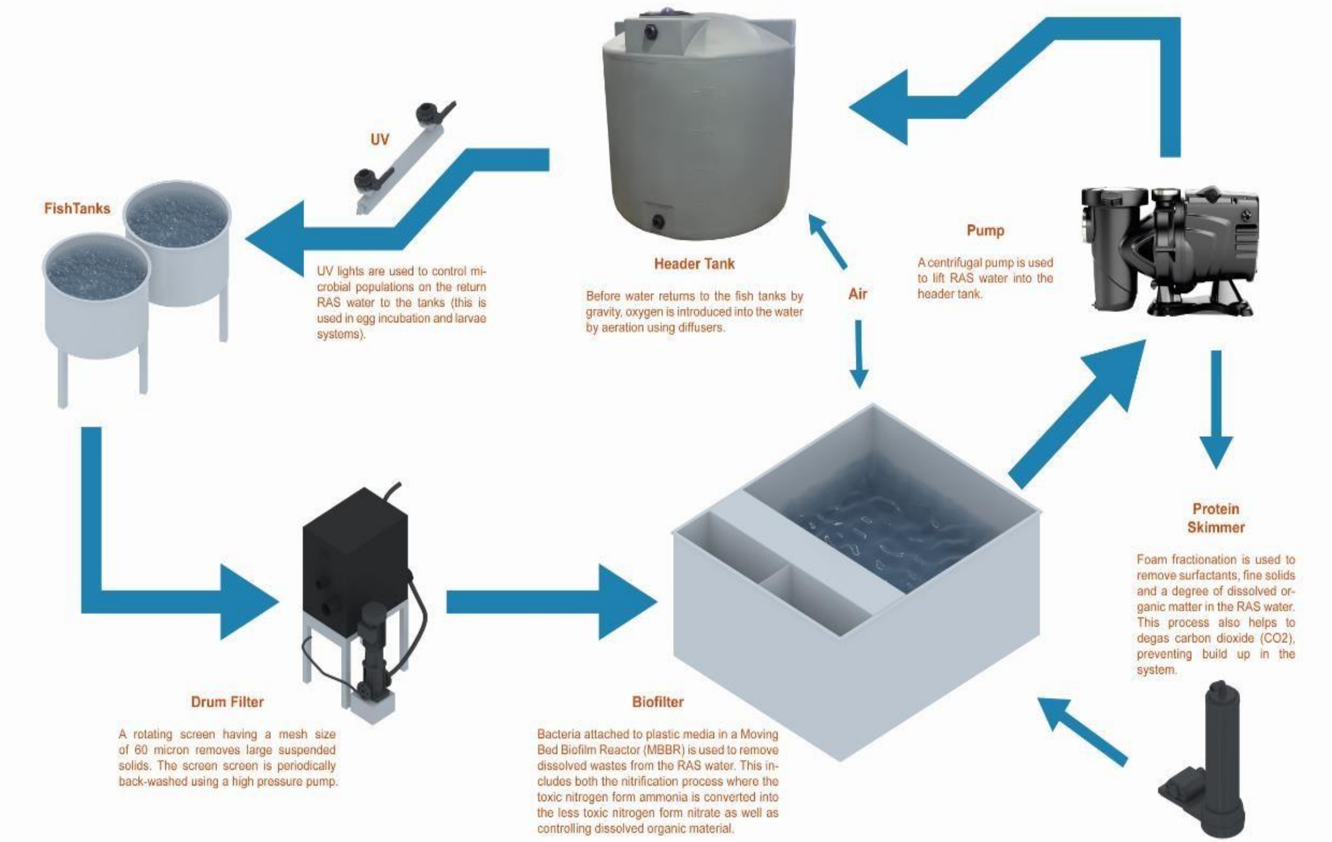
RAS in VicInAqua

RAS Process Flow Diagram



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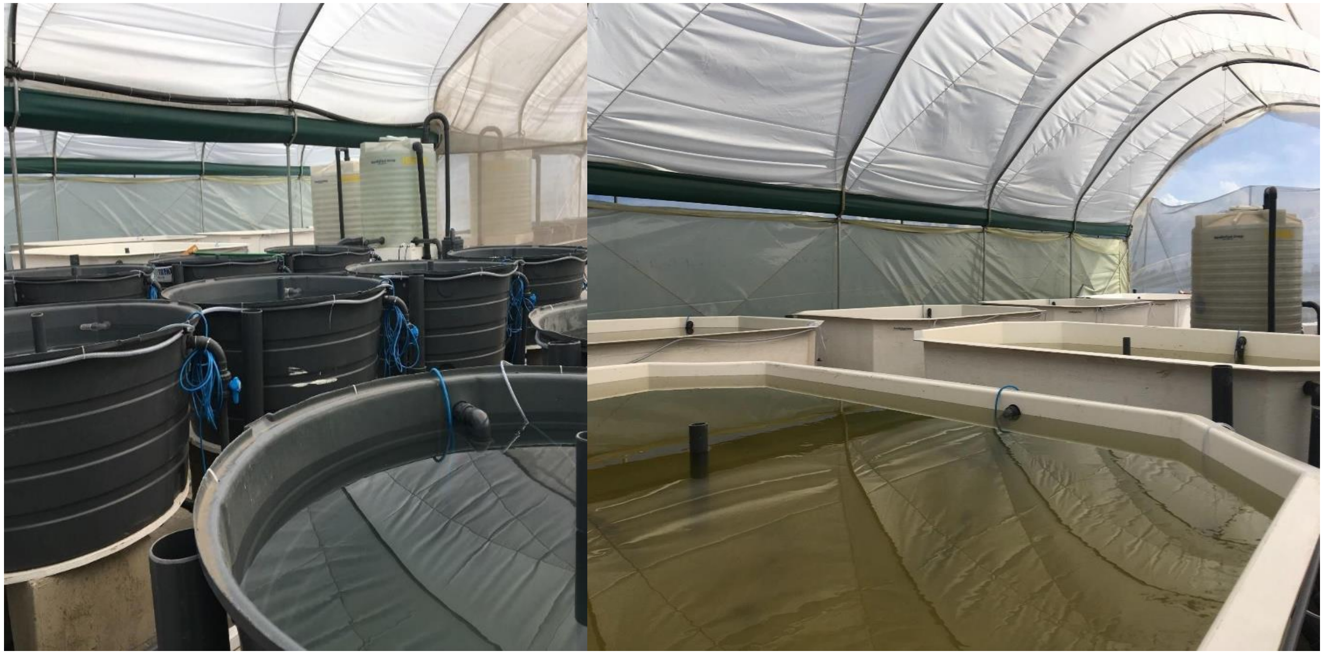
RAS in VicInAqua

RAS installation



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RAS in VicInAqua

Broodstock stocking

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