VicInAqua

Integrated aquaculture based on sustainable water recirculating system for the Victoria Lake Basin

Deliverable 3.4
Handbook of the integrated VicInAqua system

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PU	Public	x
PP	Restricted to other program participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Contents

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1. Introduction

This handbook is a guideline for the operation and maintenance of the VicInAqua integrated pilot built for the VicInAqua H2020 project in Nyalenda, Kisumu, Kenya.

The project consortium developed innovative multipurpose self-cleaning water filtration solutions adapted for sanitation of different wastewater systems to be reused in Recirculation Aquaculture Systems (RAS) around Lake Victoria. The main goal of this project is to enable the supply of clean water to RAS and agriculture through a single solution for water treatment of different waste water streams. The system has a semi-autonomous power supply by renewable energy (PV, biogas, TEG) and is remotely monitored with sensor technologies. The technology development and demonstration at pilot scale is combined with capacity building of local and regional actors. Solutions offered by VicInAqua are focussed on robustness, energy efficiency and economic viability in order to be adapted to the local challenges and to achieve high acceptance in peri-urban areas, where the sanitation infrastructures are poor and the demand for water is high.

The VicInAqua system is primarily designed to use for fish cultivation as here high-quality water use is essential. For the pilot system, a Tilapia hatchery using RAS technology was designed and constructed in Kisumu, Kenya. RAS conserve water and reduce waste discharges. This hatchery will produce high quality fingerlings to supply pond aquaculture in the area. The RAS is tailored to the local conditions and the output of the self-cleaning membrane bioreactor. The pilot system will be used by the local partners as a training and demonstration facility to promote the aquaculture sector and increase awareness, knowledge and skills for fish farmers.

In this handbook, all the different components of the VicInAqua pilot system are described, as well as operational and maintenance considerations, protocols and procedures. The guidelines in this handbook can also be used by other stakeholders in the aquaculture sector in East-Africa.

Deviation from the work plan

This deliverable has been submitted with a one-month delay. This is due to the fact that the partners were all actively involved in finishing the pilot construction. The pilot has been almost achieved on 22nd of November 2018. The part on TEG and biogas has to finalised.

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2. Membrane Bioreactor

2.1. Description of the system

The membrane bioreactor (MBR) will be used for mechanical and biological wastewater treatment of the water taken from the intake of the Nyalenda ponds. The system is design to have a population equivalence of 20 which equates to 3 m3/d. A MBR system combines the biological wastewater treatment and membrane filtration. It consists of a mechanical pre-treatment, an anoxic tank, an aeration tank, a filtration tank for separating activated sludge and biological treated water. An upstream inlet holding tank equals fluctuations of daily inlet. The equalising tank the large 3000 L black tank located close to the biogas digestors. The filtrate water is stored in a 2000 L white tank directly outside the MBR room and is sterilised by a UV before being distributed to various applications (RAS or agriculture).

At first, the wastewater will be mechanically processed by a fine screen system with a 1 mm perforated strainer. The fine screen separates the wastewater from solid matters and pulp, for example toilet paper or hairs, which would entwine and blog the membrane filters. In the MBR room a cartridge bag filter with a mesh of 900 µm (0.9 mm) is included as a final solid separation step before the intake water enters the bioreactor.

The organic ingredients from the screenings will be washed out and used as carbon source in the biological cleaning stage and be catabolised. A submerged pump “P1” type “Jung U3KS” feeds the screenings into the anoxic tank of the MBR plant.

The anoxic tank is used for denitrification (elimination of nitrogen compounds) and is equipped with some sensors (Redox, pH) and a mixing system “M1” type “Jecod SW15”. From anoxic tank, wastewater / biomass mix flows back by a static overflow into the aeration (aerobic) tank. The surplus sludge from the aeration tank is pumped into the filtration tank and overflows into the anoxic tank. This avoids a concentration of biomass in the filtration tank.

In the sewage treatment system (in this case MBR system), especially in the aeration tank, the wastewater biological is treated by microorganism. They use some of the wastewater ingredients for their metabolism and transform them into carbon dioxide and water. Other ingredients will be used for microbiological cell-substance synthesis (excess sludge). There will build on crude protein in form of biomass based on carbohydrates and hydrocarbons by use from mineral nutriment, nitrogen, phosphatic compounds and oxygen.

The oxygen intake will be controlled by the integration of a dissolved oxygen sensor and the control cabinet. At the MBR plant, specifically in the aeration tank, a blower “V2” type “Nitto LAM120” frequently pumps air into the membrane tube diffusors, which are located on the button of the aeration tank and distributed the air equable. Therefore, the microorganism always will be provided with enough oxygen.

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In the filtration tank, membrane filters with a pore size of 35 nm (ultrafiltration) separate the treated wastewater from the biomass (sludge). A specific air flow along the membrane modules through the injected air controls the growth of the surface layer and cleans the membrane. All matter with a large diameter than the pore size will remain within the membrane tank. Filtration is carried out from outside to inside. The biological treated water is sucked through the membrane modules by two independent self-priming rotary pumps and a gently negative pressure. The system has a membrane surface area of 6.25 m^2.

The filtrate pumps transfer the effluent into filtrate holding tanks. The stored filtrate can be used as process water. Therefore, it is advisable to be sterilised by UV light and thus keep it permanent clean. If the filtrate isn't used as process water, it has to be discharged through the outfall surge tank to the drain or agricultural area. The filtration performance will be corrected automatically by the control cabinet. When the maximum pressure range has been reached, the filtration is stopped, and a service signal is generated.

For cleaning the membrane surface, air will be blown through the membrane tube diffusors which are located under the membrane modules. The diffusors dispense the air evenly on the membrane surface. The air generates a turbulent air / water mix, which streams up across whole the membrane surface in the modules. This flow carries the concentrated particles permanently away from the membrane surface and avoids filtration repressive cover layers. This procedure is called cross-flow-filtration. The intake air for cleaning the modules is also used for circulation of the activated sludge in the reactor and is therefore enough for biological treatment as well.

In addition to internal cleaning by the up-streaming air, the membrane must be chemical cleaned once or twice per year. The cleaning take place in the filter chamber (in-situ) without dismantling of the membrane filters. To clean the filters, the filtration tank will be drained and refilled with fresh water up to filters head. By addition of an oxidative and an acidic cleaner, the surface layer will be removed. The effectiveness of this procedure can be increased by up streaming air through the membrane tube diffusors. After the cleaning, the chemicals will automatically carry to the sludge treatment.

Outside view of the MBR unit (without air blowers)

To ensure the sustainable operation of the wastewater treatment plant the following tasks are required by the operator:

- Check the quality of the filtrate
- Documentation of the most important parameters (Daily) – Checklist provided
- Check of the sludge volume concentration (Mixed Liquer Suspended Solids)
- Calibration of the Redox and Dissolved Oxygen sensor
- Lubrication of pumps
- Cleaning of the fine screens (Daily)

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2.2. System specifications

2.2.1. Intake System

Component	Intake pump
Function	Transfer water from the Nyalenda pond intake to the feed tank within the pilot site
Number	1 unit
Model	Pedrollo VXCm15/45 1.1 kW pump, purchased from Davis & Shirtliff (Kisumu Branch)
Flow rate	30 m^3/hr at 6 m head
Power / current	1 x 240V, 1.1 kW, 8 A, Max particle size of 50 mm
Name	Intake pump

Component	Intake pipeline
Function	Transfer water from intake pump to the feed tank
Number	207 m
Pipe size	1.5 inch
Material	HDPE with compression fittings

Component	Feed tank
Function	Store intake wastewater
Number	1 unit
Volume	3000 L
Material	Polyethylene
Dimensions	H x diameter = 1700 x 1540 mm
Name	NA

Component	Feed pump P1
Function	Pump the waste water from feed tank into MBR plant
Number	1 unit
Model	Jung U3KS
Flowrate	6.5 to 1.5 m3/h at delivery head from 1.0 to 6.0 m
Power/current	0,32kW / 230 V / 50Hz (1-phase)
Name	P1

Component	Feed tank level sensor
Function	Measurement of fill level
Number	1 unit
Model	Vegawell, 52, 0.. 0.4 bar
Name	LISA/S1

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2.2.2. Mechanical Pre-treatment

Component	Pre-filter
Function	Separation of undissolved solid matters/concentration of large material
Number	1 unit
Filtration area	0.15 m^2
Mesh size	0.9 mm
Max operating pressure	6 bar
Bag length	460 mm

Component	Pre-filter pressure sensor
Function	Measuring upstream pressure of pre-filter to determine when filter requires cleaning
Number	1 unit
Model	Vegawell, 52, 0.. 0.4 bar
Name	PIA/S11

2.2.3. Anoxic Tank (Denitrification)

Component	Anoxic Tank
Function	denitrification of Nitrate and Nitrite from wastewater
Number	1 unit
Volume	Approx 0.44 m^3
Material	Polypropylene
Dimensions	L x W x H = 510 x 800 x 1070 mm

Component	Mixer Anoxic Tank
Function	Stirring the wastewater in the anoxic tank
Number	1 unit + 1 spare unit
Model	Jecod SW15
Flowrate	1200-13000 l/h
Power/current	0.04 kW, 230 V, 50 Hz

Component	Redox ORP sensor
Function	Measurement of Redox potential
Number	1 unit
Model	OxyGuard K04GNV20RP
Measurement range	-500 to +200mV
Name	QIRCA/S9

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2.2.4. Aeration Tank

Component	Aeration Tank
Function	construction for optimal activated sludge
Number	1 unit
Volume	approx. 0.7 m^3 (at Hmax.: 960 mm)
Material	Polypropylene
Dimensions	L x W x H = 900 x 800 x 1070 mm

Component	Aeration Tank Blower V2
Function	Oxygen intake and stirring the aeration tank
Number	1 unit
Model	Nitto LA120
Flowrate	7.2 m^3/h
Power/current	0.13 kW, 230 V, 50 Hz

Component	Membrane pipe aerator
Function	Produce fine bubbles of oxygen and stirring the aerobic zone
Number	2 unit
Model	OTT Flexil 500
Air flowrate	1,5 – 18 m^3 / h /m

Component	Aeration Tank DO sensor
Function	Measurement of oxygen level in the aeration tank
Number	1 unit
Model	OxyGuard D0243C (E002592C5342675E)
Current	4-20 mA
Name	QIRCA/S8

Component	Aeration Tank Level Sensor
Function	Measurement of fill level in the filtration tank
Number	1 unit
Model	Vegabar 14, 0 … 4 m
Name	LISA/S2

Component	Sludge Discharge Pump / Drain pump
Function	conveys the crushed sludge / rejects mix to drain
Number	1 unit
Model	Jecod DCP5000
Flowrate	5.5 m^3/h
Power/current	0.04 kW, 24 VDC
Name	P2

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Component	Aerobic Tank recirculation pump
Function	pumps sludge into the filtration tank
Number	1 unit
Model	Jecod DCP5000
Flowrate	5.5 m^3/h
Power/current	0.04 kW, 24 VDC
Name	P3

Component	Circulation pump flow sensor
Function	measurement of circulation flow rate
Number	1 unit
Model	IFM SM8000
Flowrate	0.01 … 6.0 m^3/h
Name	FIRCA/S13

2.2.5. Filtration Tank

Component	Filtration Tank
Function	tank with integrated filter membrane
Number	1 unit
Volume	approx. 0.56 m^3 (at H: 1170 mm))
Material	Polypropylene
Dimensions	L x B x H = 600 x 800 x 1170 mm

Component	Filtration tank filter pumps
Function	pumps filtrate out of the filtrate tank
Number	2 units
Model	Winter pumps MMS
Flowrate	7.0 m^3/h
Power/current	0.14 kW, 24 VDC
Name	P4 and P5

Component	Filtration Tank Blower V1
Function	Membrane aeration for air scour
Number	1 unit
Model	Nitto LAM200
Flowrate	12 m^3/h
Power/current	0.22 kW, 230 V, 50 Hz
Name	V1

Component	Filtration tank Air pressure sensor
Function	measurement of air pressure after blower

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Number	1 unit
Model	Vegabar 14, -1.0 … 1.0 bar
Name	PIA/S10

Component	**Filtration tank air flow measurement**
Function	measuring the downstream air pressure
Number	1 unit
Model	Krohne VA45 V/R, 1.7… 17.0 m3/h @ 200 mbar
Name	FI/S12

Component	**Membranes**
Function	separating biomass from treated water
Number	1 unit with two membrane modules
Model	CUBE® FM 621
Filtration area	3.125 m^2 each module
Material	Organic polymers

Component	**Filtration tank pressure sensors**
Function	measuring the downstream filtrate pressure
Number	2 units
Model	Vegabar 14, -1.0 … 1.0 bar
Name	PIA/S4 and PIA/S5

Component	**Filtration tank level sensors**
Function	measurement of fill level in the filtration tank
Number	1 unit
Model	Vegawell 52, 0 … 0,4 bar
Name	LICA7
Component	**Filtration tank flow sensors**
Function	measurement of filtrate flow rate
Number	2 units
Model	IFM SM4000
Flowrate	0.3 … 180 l/h
Name	FIRCA/S6 and FIRCA/S7

Component	**Filtration tank Solenoid Valve**
Function	degassing the filtrate pipe
Number	2 units
Model	W27MA
Name	M2

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2.3. Operation procedures

2.3.1. Operational checklist

Task number	Description of Task	Frequency
1	Visual inspection of effluent for turbidity, staining and odour	Daily – Once per day
2	Testing the operating and display panel for existing messages, errors and position of the switches	Daily – Twice per day, morning and afternoon before leaving
3	Sampling and analysis for the major water quality parameters • Ammonia-Nitrogen • Nitrate-Nitrogen • Nitrite-Nitrogen • pH Other parameters – Such as phosphate and selected heavy metals can be carried out once per week.	Weekly – Twice per week, or three times per week during start-up
4	Determination of sludge volume from the aeration tank, adjust settings for sludge discharge (as per instructions in the appendix)	Weekly – Once per week Or twice per week during start-up period
5	Document operating data	Weekly – Twice per week
6	Clean pre-filter and intake mesh	Daily or weekly – Check daily and clean as minimum twice per week
7	Control, clean and replace if required the filter cartridge of all blowers	Every three months
8	Chemical cleaning of membranes	Every six months or when required
9	Inspect the complete plant	Once per year

2.3.2. Feed tank

At first, the received water is stored in a collecting tank (feed tank) and then transferred to the mechanical pre-treatment unit by feed pump P1. The feed tank gets the raw wastewater by a previous pump P0. This pump (P0) works according to adjustable liquid levels in the feed tank (level sensor LISA/S1). The pump P0 starts normally at level L2 and stopped at L3. At level L3, P0 is out of operation and a message “Feed Tank full” can be generated. If level L4 is achieved, a High-Level Alarm is generated (reset at L4). The Feed Pump (P1) starts operation when L2 in Feed Tank is achieved. At L3 or L4, P1 should be still running. When the level L1

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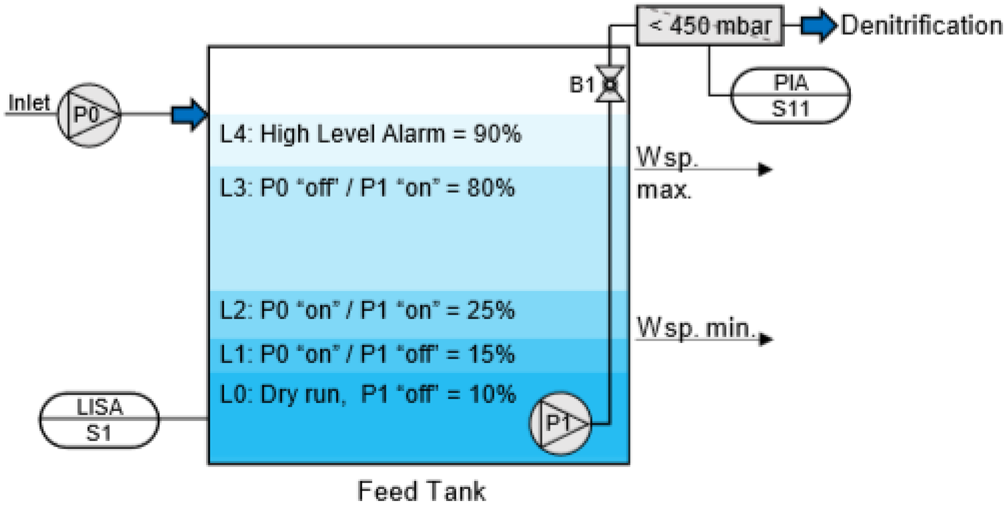
is achieved, P1 is stopped for protection as “dry run”. P1 can also be stopped when the pressure in the pre-filter (PIA/S11) exceeds the value of 450 mbar. P1 can be regulated by the ball valve B1.



When the maximum pressure at PIA/S11 is achieved, an alarm is shown: “Pre-filter cleaning required”.

Problem	Solution
Feed Pump “P0” does not start when level L1 or L2 in Feed Tank is achieved	• Check if button “Feed Pump” is in “A = Automatic in control cabinet • Check if in TP P0 is in Automatic • If P0 does not start, change to Manual (H = Hand) and check if P0 starts. If not, contact technical staff of MMS. P0 should be changed • If P0 does start, the problem is on the level indicator LISA/S1. Rinse the level indicator with tap water and contact technical staff of MMS
Feed Pump “P0” does not stop when Level L3 is achieved	• Change P0 to “0 = No operation” • Rinse with tap water the Level Indicator Sensor LISA/S1 • Put P0 back to “A = Automatic”. If problem persists, contact technical staff of MMS
Feed Pump “P1” does not stop when level L1 is achieved	• Change P1 to “0 = No operation” and put back to “A = automatic”. If problem persists, contact technical staff of MMS
Feed Pump “P1” does not start when level L2 is achieved	• Check if button “Feed Pump” is in “A = Automatic in control cabinet • Change button “Feed Pump” (P1) to “H = Hand” and check if P1 starts. If not, contact technical staff of MMS. P1 should be changed • Check the pressure value on PIA/S11 (Pre-Filter) • Clean the Pre-Filter and start again the process with button “Feed Pump” in “A = Automatic”

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2.3.3. Mechanical Pre-treatment unit

The received sewage water passes the Pre-filter unit (Filter Bag, 0.90 mm) which retains coarse particles and solids. This is necessary to protect the sewage plant for solid sedimentation, protect the membrane filters for damages and reduce the organic load.

The Pre-Filter is installed into a cartridge 460 mm long. The filter bags are made of polypropylene with holes of 0.90 mm diameter. The sewage arrives to the cartridge through a connection R 1 ½". The particles bigger than 0.90 mm are retained, while the light substances go through the filter. Afterwards, the sewage flows freely to the denitrification tank.

Bag filter housing

The Filter Bag should be "manually dismantled and by hand with tap water washed out". The PIA/S11 is a pressure sensor, which indicates the positive pressure on the filter bag. When the pressure achieves 450 mbar, an Alarm with message "Pre-filter cleaning required will be shown in TP.

2.3.4. Denitrification Tank

Denitrification Tank In the anoxic tank, microorganism use a part of the organic sewage ingredients for their metabolism and cell growth. Thereby, they transform nitrogen compounds (nitrate, nitrite) into molecular nitrogen. To prevent sedimentation of the biological sludge and mixing the tank, a small mixer (M1) is used. M1 works time-based with adjustable interval periods. Please only choose continuous mixing times. The mixer M1 starts at level L1 of the level sensor LISA/S2 located in the aeration tank. When level L0 (LISA/S2) is achieved, M1 stops and starts to work in a fixed cycle operation of 480 seconds "on" and 120 second "off".

The operation of M1 is also regulated by the REDOX sensor. If there is a disturbance or trouble in the REDOX sensor, M1 starts to work in a fixed cycle operation of 480 seconds "on" and 120 second "off".

2.3.5. Aeration Tank

After the anoxic tank, the pre-treated sewage flows by gravity into the aeration tank. In the aeration tank, air is supplied to the suspended microorganisms for their metabolism (the biological treatment of the wastewater). The air is injected via membrane tube diffusers that are installed at the tank button and an aeration blower (V2). The Biologic aeration blower works according to a dissolved oxygen (O2) monitoring (QIRCA/S8). When the oxygen value drops under the setpoint (i.e. 2 mg/l, minus hysteresis), blower V2 starts and at exceedance of the setpoint, blower V2 stops. In case of fault of QIRCA/S8 (O2 sensor), the blower V2 works timer based with adjustable interval periods (V2 "on" 480 s; V2 "off" 9 min").

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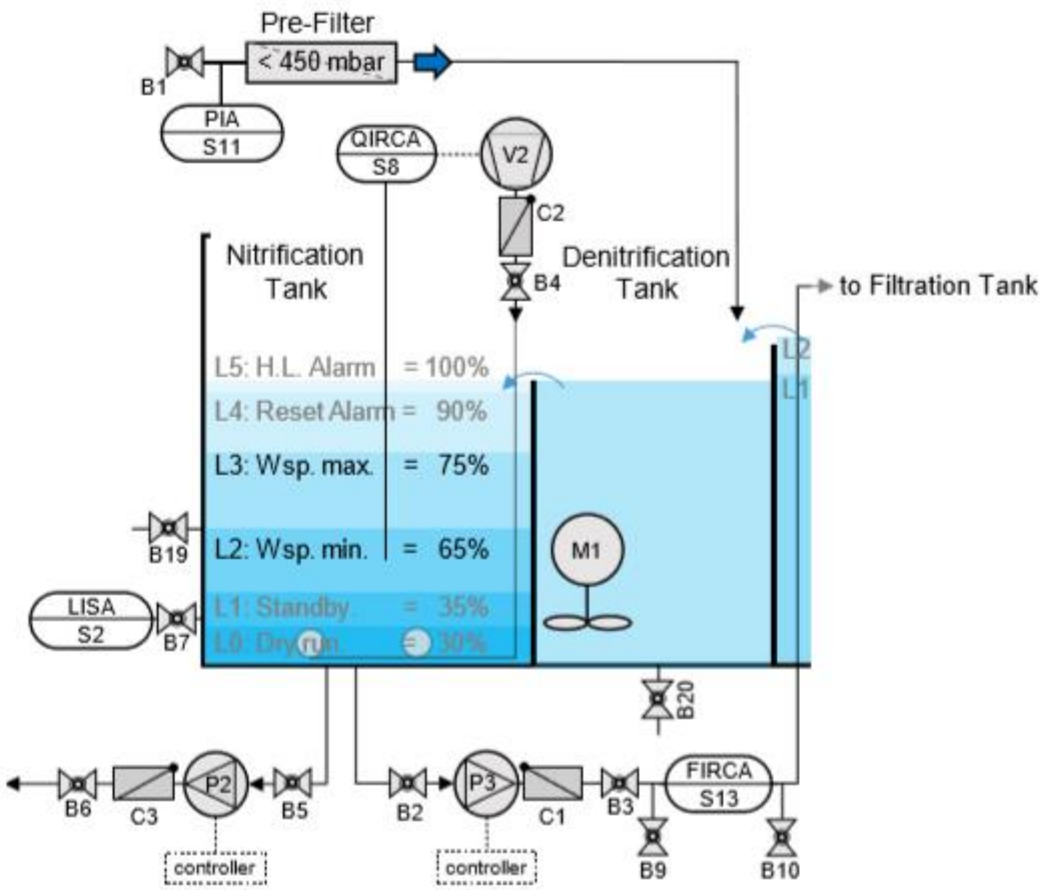
The water volume in the aeration tank is controlled by LISA/S2. The different levels can be set-up in the control panel (TP). As standard, the levels are as follows:

L5: High level Alarm	=	100 % of the tank volume
L4: Reset Alarm	=	90% of the tank volume
L3: Max. Water Level (Wsp. max)	=	75% of the tank volume
L2: Min. Water Level (Wsp. min)	=	65% of the tank volume
L1: Stand-by	=	35% of the tank volume
L0: Dry run protection	=	30% of the tank volume



The aerated wastewater is pumped to the filtration tank by Circulation Pump (P3). P3 can be manually regulated by the ball valve B3. In addition, P3 can be automatically regulated by a controller. P3 works always when water level is between L2 and L3. When water level achieves L1 in aeration tank, P3 works in a fixed cycle operation of 60 seconds “on” and 60 second “off”. If water level achieves L0 in aeration tank, P3 is out of operation. In addition, the water flow of P3 will be always monitored by FIRCA/S13, when FIRCA/S13 is lower than 3 time the complete amount of filtrate water (3 x [FIRCA/S6 + FIRCA/S7]), the following notification in TP is shown: “Circulation Pump Failure”.

The excess sludge will be removed from the aeration tank by the Sludge Pump “P2”. P2 is automatically started when the amount of filtrate water exceeds the water production per day. As standard, P2 will be started when an amount of 3 m3/d is achieved.

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Aeration tank showing air diffusers and air hose (connected to the air blower)

Possible Problems / Alarms in Denitrification and Aeration Tank

Problem	Solution
QIRCA/S9 does not work, or there is a disturbance on the measurement	• Check the instructions of the REDOX sensor • Change in the TP the Mixer (M1) to Manual • Contact technical staff of University of Karlsruhe (HSK). QIRCA/S9 should be repaired or changed
Nitrification Tank achieves L0 or L1	• Check if button of Feed Pump “P1” is in “A = Automatic”. Check if P1 is in Automatic in TP. • Check the pressure value of the Pre-Filter. If necessary, clean the filter bag before restarting P1 • Put P1 back to “A = Automatic”. If problem persists, contact technical staff of MMS
Nitrification Tank achieves L5	• Check if button of Sludge Pump “P2” is in “A = Automatic”. Check if P2 is in Automatic in TP • Check if button of Circulation Pump “P1” is in “A = Automatic”. Check if P1 is in Automatic in TP • Check if Filtrates Pumps “P4 and P5” are in “A = Automatic” • Check if water level sensor LISA/S2 works. Close ball valve B7 and then LISA/S2 can be dismantled and rinsed with tap water
Aeration blower V2 works only in a fixed cycle operation	• Maintenance of O2 sensor (QIRCA/S8)
Bubbles in aeration tank are not enough to mix the water	• Check ball valve B4 is completely open • Check the air filter of blower V2 • Change blower V2 for a new one

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2.3.6. Filtration Tank

Then, the biological treated wastewater flows through the filtration chamber, where submerged membrane modules separate the clean wastewater from the biologic sludge, back to the anoxic chamber. During the filtration operation purified wastewater is drawn from the outside inwards by means of a low-pressure vacuum created by self-priming pumps P4 and P5. Particulate matter greater than the membrane pore size of 0,1 µm (MWCO, nominal: 150 kDalton) will be captured on the outside face. This way the submerged membranes present a physical barrier to the activated sludge thus reducing the suspended solids in the effluent to effectively zero.

The filtration part comprises of 1 CUBE® FM 621 filter unit, which has two independent ultrafiltration modules FM06, compressor/air blower and two filtrate pumps (P4 and P5, for each FM06 module). The filtrate pumps have a variable speed drive to meet the variable flow conditions of the plant, independent of particle deposition on the membrane surface. The filter performance (flow and transmembrane pressure) is monitored by pressure gauges (PIA/S4 and PIA/S5) and electromagnetic flow meters (FIRCA/S6 and FIRCA/S7) and will be transmitted to the main control panel. According to adjustable transmembrane pressure set values, alarms and messages on TP will be generated.

Filtrate pumps P4 and P5 operate timer based (12 min “on” / 3 min “off” time, i.e. cycles). The timer-based operation of P4 and P5 (cycles of 12 min ”on” / 3 min “off” time) can be changed in the TP. P4 and P5 are off at level L1 (Standby) in Aeration Tank and/or at level L0 in Filtration Tank and at fault of Circulation Pump P3 or scouring blower V1.

	
Filtration tank showing two separate filtration modules	External view of the filtration tank showing the filtrate pumps (P4&5) which are connected to the two membrane modules

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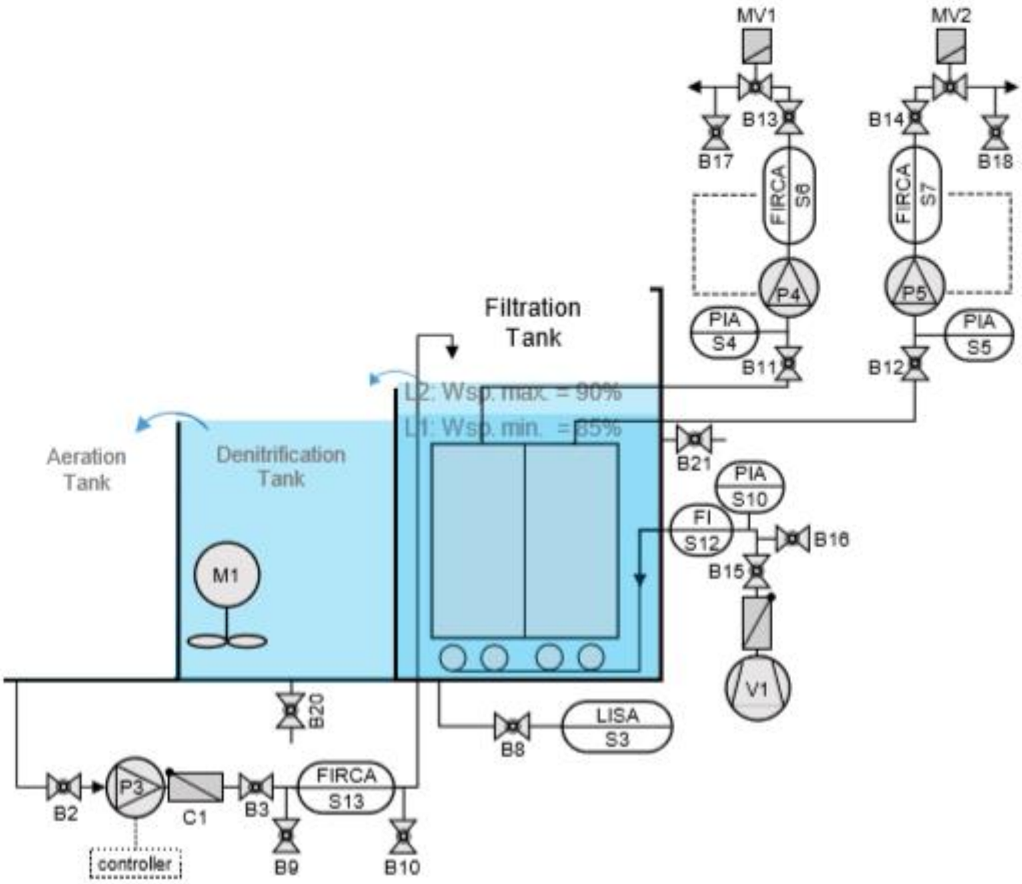

P4 and P5 can work by two options:

- Standard operation: P4 and P5 work at fixed flow-rate and the velocity of both filtrate pumps is controlled by the transmembrane pressure (TMP) and the level in the Filtration Tank as follows: ▪
  - **Normal Operation**: If level in Aeration Tank (LISA/S2) is between L2 (Wsp. min.) and L3 (Wsp. max.) and the TMP is below -200 mbar, P4 and P5 will work at a norm. fixed flow rate of 65 l/h. The norm. fixed flow rate (65 l/h) and the minimum TMP (-200 mbar) can changed in the TP
  - **Maximal Operation**: If level in Aeration Tank (LISA/S2) is higher than L3 and/or in Filtration Tank (LISA/S3) is higher than L2 and the TMP is below 200 mbar, P4 and P5 will work at a max. fixed flow rate of 95 l/h. The max. fixed flow rate (95 l/h) and the minimum TMP (-200 mbar) can changed in the TP
  - **Minimal Operation**: Each filtrate pump (P4 and P5) should achieve at least certain flow (default 50 l/h) when the TMP is below -200 mbar. If not, a message will be shown in TP

- **Ramp parameter operation**: P4 and P5 start at a normal operation as explained before and there will have an increase of the flow-rate (default 5 l/h) after each filtration cycle. After a fixed number of filtration cycles, the flow-rate will decrease again in ramp operation until the normal operation is achieved. The filtration cycle is understood as the "on" and "off" time of each filtrate pump, in this case 12 min "on" / 3 min "off". The

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increased flow-rate (in this case 5 l/h) and total of cycles that the flowrate will be increased can changed in TP. In addition, the repetition of the operation of increasing the flow-rate can be set up in TP

Each filtrate outlet has a solenoid valve (MV1 and MV2). They are used to equalise the filtrate-pipe pressure to the atmospheric pressure, so that air from membrane modules can go out. MV1 and MV2 are normally closed and they will be open for a few seconds when filtrate pumps P4 and P5 are “off”.

Possible Problems / Alarms in Denitrification and Aeration Tank

Problem	Solution
Aeration Tank achieves L0	• Check if Circulation Pump “P3” is in “A = Automatic”. Check if P3 is in Automatic in TP. Check if B3 is completely open • Check if FIRCA/S13 > 3 x (FIRCAS6 + FIRCA/S7). Check if ball valves B11, B12, B13 and B14 are adjusted so that P4 and P5 achieve the expected flow
Aeration Tank exceeds L2	• Control flow-rate in P3 by external controller or by slightly closing B3 • Check if P4 and P5 are in “A = Automatic” in both control cabinet and TP
Error by level sensor LISA/S3	• Check if water level sensor LISA/S2 works. Close ball valve B8 and then LISA/S3 can be dismantled and rinsed with tap water

2.3.7. Membrane scouring blower

Air flow is injected at the button of the membrane modules to create a turbulent liquid mixture cross flow that scrubs and cleans the membrane surface and prevents the polarisation or thickening of suspended solids within the membrane modules. The airflow is also used to reduce BOD, COD and Ammonia levels.

The membrane scouring blower V1 operates in cycle operation with adjustable “on” and “off” time to avoid unilateral stressing of the membrane and to safe energy. There is also a pressure monitoring (PIA/S10) for detecting faults of this very important blower. If pressure is below to minimum pressure (default + 80 mbar), alarm messages are in TP displayed. The minimum pressure of V1 can be changed in TP. In addition, the amount of air flow can be manually measured by a rotameter (FI/S12). The amount of air can be also regulated by the ball valve B15.

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2.3.8. Membrane cleaning

During the filtration operation, the membranes become covered by a dynamic layer of solids and the hydraulic resistance increases. To keep this resistance low, a short relaxation period (in this case filtrate pumps P4 and P5 have 3 min “off”) is automatically initiated. During this time the filtrate pumps stop drawing water through the membranes while the cross flow continues membrane scouring and the attached particles on the membrane surface become easier to remove via scrubbing action.

Over a period (for instance, every 6 months) some fouling, and scaling may occur on the membrane surface which cannot be removed by physical cross flow alone. As the transmembrane pressure (TMP) approaches the maximum allowable pressure (for instance, -200 mbar), chemical cleaning will be required (monitored). This will restore the initial transmembrane pressure and maintain the flow at the design levels.

It is expected that under normal operating conditions the cleaning cycle could be once or twice a year. The chemical cleaning will use sodium hypochlorite to remove fouling and citric acid to dislodge scaling.

For more details, see section 2.4.2.

2.3.9. Automatic sludge discharge

During operation, activated sludge grows by degradation of the wastewater ingredients. To avoid a too high biomass concentration into the MBR plant, excess sludge has to pump out of the system. Therefore, a sludge pump P2 is installed. The excess sludge is pumped out to the specific sludge treatment that the customer has installed. P2 is automatically started when the amount of filtrate water exceeds the water production per day. As standard, P2 will be started when an amount of 3 m^3/d is achieved.

2.3.10. Oxygen measurement

Controlling of aeration blower V2 is by oxygen measurement. If the oxygen measurement value is below to set value (default value, 2.0 mg/l), the blower V2 will start operation. At exceedance of the maximum set value (default value, 5.0 mg/l) V2 will be stopped. Additionally, there is an adjustable cycle with adjustable run – und break times. In case of oxygen sensor fault, the blower V2 works in adjustable cycles. A fault message is shown on TP. Cycle can be freely selectable in TP. If level L1 (LISA/S2) in Aeration Tank is achieved, V2 works in a Standby period in short adjustable cycles (60 seconds “on” and 540 second “off”).

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2.4. Maintenance procedures

2.4.1. Routine maintenance tasks

For detailed maintenance instructions please find the hard copy manual and all manuals for each of the separate equipment and sensors (exchange of impeller etc.). Furthermore, it is necessary to notice and follow the maintenance instructions of each single aggregate and sensor from the manufacturer!

The following notes refer only to basic remarks for maintenance. A good time for maintenance is when wastewater intake decreases. For maintenance, firstly switch off the equipment, you work on, at Touch panel (Auto to Off) and at repair switch. Please only work on aggregates, if they are switched off. Otherwise, you risk injuries.

The most important aggregates you must check at maintenance are:

- Pumps:
  - P1 (Jung U3K S)
  - P2, P3 (Jebao Jecod DCP 5000)
  - P4, P5 (Winter pump)
- Mixer:
  - M1 (Jecod SW15)
- Blowers:
  - Nitto LA 120 ▪
  - Nitto LAM 200
- Level sensors:
  - Vegawell 52
  - Vegabar 14
- OxyGuard sensors
  - O2 sensor (D0243C)
  - Redox sensor K04GNV20RP)

Maintenance includes checking, cleaning and maybe replacing parts or the complete equipment. Therefore, please look at the user manuals of this aggregates and sensors!

At maintenance you have also to check the tanks, all connection, pipe connections and seals for tightness. Please tighten up all screws and change old seals if necessary. If you look at the aeration tank you should drain it once per year and check also the diffusors inside.

2.4.2. Membrane cleaning

Over a period, some fouling and scaling may occur on the membrane surface which cannot be removed by physical cross flow alone. As the transmembrane pressure (TMP) approaches the maximum allowable pressure, chemical cleaning is necessary. It is expected that under normal operating conditions cleaning cycle could be once or twice a year. The chemical cleaning will use sodium hypochlorite to remove fouling and citric acid to eliminate scaling.

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For the cleaning of the membranes you need the following chemicals (per filtration tank):

- 3 litre Sodium hypochlorite (NaOCl) with 13% active chlorine
- approx. 4.25 litre Citric acid 50%ic
- approx. 1.5 litre Peroxide to inactivate residual chlorine
- Caustic soda (NaOH) to reach pH 11-11.5
- Potable water

Wear safety gear (goggles, gloves) and be careful with the chemicals! Read MSDS (material safety data sheet) from chemical supplier and follow these instructions!

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3. Recirculation Aquaculture Systems

3.1. Description of the systems

3.1.1. Introduction

Aquaculture is a growing sector becoming more important to provide the growing world population with protein. Traditional aquaculture in ponds requires a large quantity of water. Recirculating aquaculture systems (RAS) use only a fraction of the water required by ponds to produce the same quantities of fish. Up to 95 % of the water in a recirculating system can be reused. Because RAS usually use tanks, less land is required. The environment in tanks can be fully controlled through water treatment. Feeding and harvesting activities require less time and labour than in ponds. Although RAS is more costly than traditional aquaculture, high yields and year-round production at locations close to the market make it a viable technology.

The aquaculture systems for the VicInAqua pilot were designed to be used as a tilapia (*O. niloticus*) hatchery with a capacity of production of 25,000 tilapia fry per month. The design is appropriate for the local needs ensuring the long-term sustainability of the system both in terms of the availability of spare parts as well as operating costs. The hatchery will be used as a demonstration and training facility by the Ministry of Agriculture, Livestock and Fisheries of Kisumu County.
The hatchery consists of 3 RAS; one broodstock and egg incubation system, one system for larval rearing and one nursery system.

RAS A: Broodstock and egg incubation
This system includes 6 broodstock tanks of 3m^3 (2x3x0.6m) each. The egg incubation unit consists of a table with 5 Mac Donald jars and hatching trays. The input water for the egg incubation system is filtered through a UV steriliser. The filtration system for RAS A is designed for a maximum of 10 kg/m^3 feeding 2% of total biomass.

RAS B: Larval rearing
This system consists of 9 500 litre round plastic tanks. The filtration system for RAS B is designed for a maximum biomass of 2 kg/m^3 with a maximum feeding rate of 15% of total biomass.

RAS C: Nursery
This system consists of twelve 500 litre round plastic tanks. The filtration system for RAS B is designed for a maximum biomass of 4 kg/m^3 with a maximum feeding rate of 10% of total biomass.

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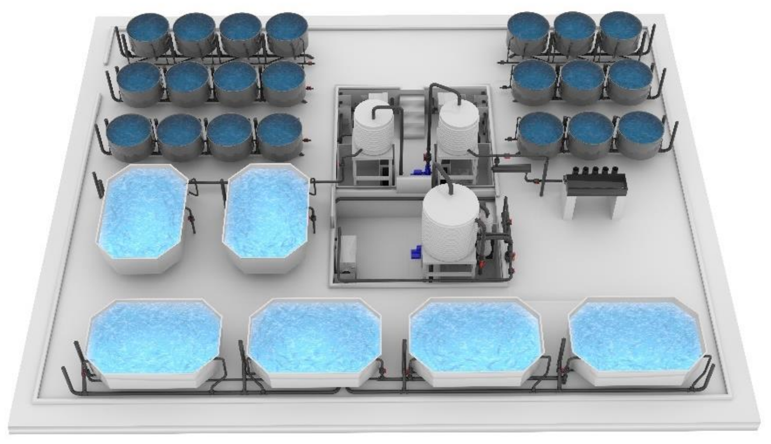	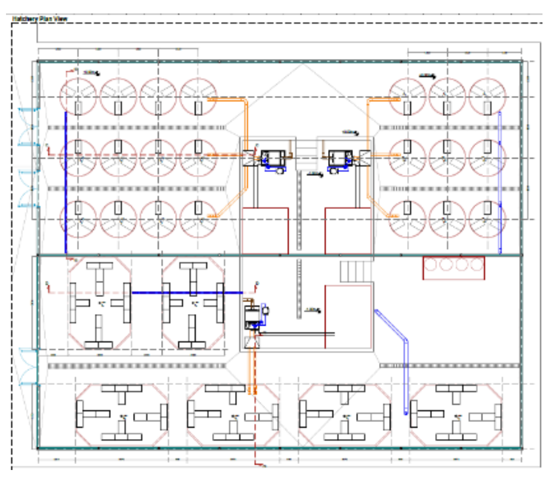
3D view of design of the aquaculture systems	Hatchery plan view

Filtration systems

The Recirculating Aquaculture Systems were designed in such a way to minimize energy use while facilitating ease of use. Water from the culture tanks flows by gravity from the main drain of the tank and the overflows into the drum filter collection box and then into the drum filter. The drum filter has a mesh of 20 and 40 micron and is backwashed periodically by a pump. From the drum filter water flows into the biofilter where bio-media is kept moving in the water by air flowing through an air-grid. Water is pumped from a clean partition in the biofiltration sump, up to the header tank. The header tank is positioned higher than the rest of the system components on a large table. Water from the header tank flows back by gravity to the culture tanks after being aerated using air diffusers connected to an air blower.
Emergency oxygen will be supplied to the fish tanks in case of power outage by compressed oxygen tanks connected to dosing cabinets which automatically dose oxygen if the dissolved oxygen concentration falls below a limit set by the operator.

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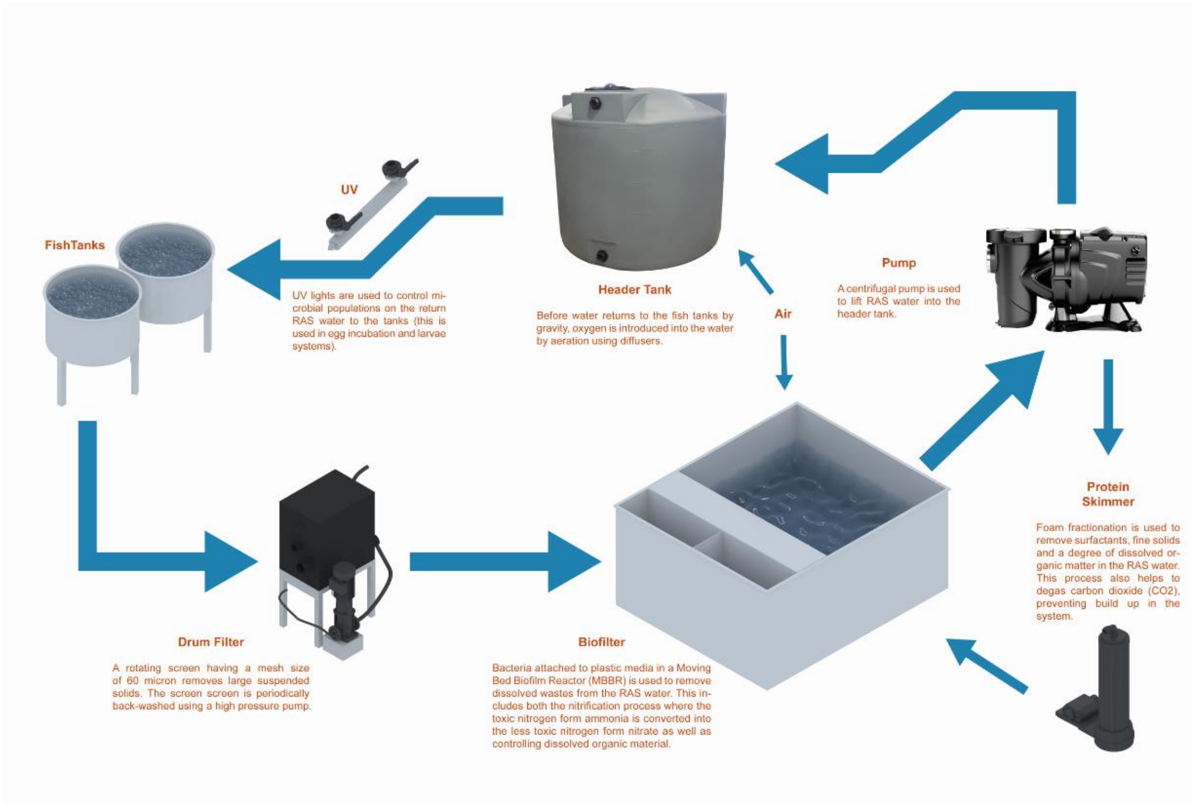

The VicInAqua Recirculation Aquaculture Systems- Progress flow

3.1.2. Tanks

The VicInAqua hatchery houses 27 tanks as following:

System	Type	Material	Dimensions	Water volume (L)	Number of tanks
Broodstock	Rectangular (octagonal)	Fiberglass	700mm (H) x 3058mm (L) x 2080mm (W)	3,000	6
Larvae rearing	Circular	Plastic	630mm (H) x 1180mm (Ø)	500	9
Nursery	Circular	Plastic	630mm (H) x 1180mm (Ø)	500	12

The broodstock tanks have a rectangular shape. The broodstock require a large surface area and the shape makes it easy to catch the fish for egg collection. The tanks have one inlet, one overflow outlet, and one bottom drain outlet. The water level should be approximately 500mm from the bottom of the tank and not be higher than the overflow outlet level. The water level

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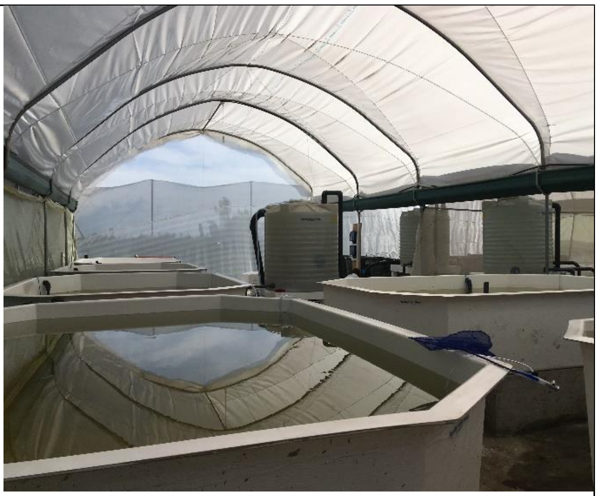
within a tank can be changed by either changing the length of the external standpipe or by increasing the inflow into the tanks by means of adjusting the tank inlet valve, or a combination of both. Broodstock tanks should be covered with nets to prevent fish from jumping out.

	
Circular tanks in larvae and nursery systems	Broodstock tanks

For the larvae and nursery systems circular tanks are used. Circular tanks have an inherent structure and good hydrodynamics. Walls are self-supporting and maintained in tension by water pressure. The tanks have one inlet, one overflow outlet, and solids are removed through the centre drain.

3.1.3. Main pump

The main pumps ensure recirculation of the water through the system. In the VicInAqua systems the main pump is located after the biofilter pumping water up to a header tank. The header tanks are 2,000L in RAS A and 900L in RAS B &C.

Electric centrifugal pumps are used with a built-in high capacity prefilter. These pumps operate from the thrust generated by the high-speed spinning of water in the pump head. The body of the pump is made from fibreglass reinforced technopolymer.

Main Circulation Pump connected to the biofilter and pumping into the header tank

3.1.4. Solids removal

Settable and suspended solids are removed using a drum filter with a fine mesh screen (20 µm for the larvae system and 40 µ for the broodstock and nursery systems). The drum rotates so the screen can be back-washed using high pressure water sprays to prevent clogging of the screen. This is done using a backwash pump connected to the drum filter. Water and solids are collected in a gutter in the drum filter and removed from the system to the main drain.

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Drum filter with backwash pump	Protein skimmer with timer

Fine and dissolved solids are removed using a protein skimmer. By removing these solids, water turbidity is reduced, and oxygen demand of the system reduced. RAS A has a protein skimmer with the capacity of 10,000 L/hr. RAS B&C have protein skimmer with a capacity of 3,000L/hr. In the protein skimmer, air bubbles flow from the bottom of a closed water column. As the bubbles rise through the column solid particles attached to the bubbles creating foam at the water surface at the top of the column. The foam is channelled into a waste collector. Flowmeters are located before the protein skimmer to measure the flow rate of the water entering the protein skimmer.

3.1.5. Biological filter

In the biofilter, dissolved waste is removed by using bacteria. Ammonia, which in its un-ionised form (NH_3) is very toxic to the fish, is utilised by nitrifying bacteria for growth and nitrite is produced as a by-product. The concentration of un-ionised ammonia can be controlled by maintaining an optimal pH of 7.0 (max. 8.75). Nitrite is less toxic than ammonia, but it is still harmful for fish. Nitrites are used by *Nitrobacter* bacteria to produce nitrate, which is only toxic to fish at very high concentrations. The bacteria grow on the surface of biofilter substrate (biomedia).

The biofilter consists of a sump tank divided in two partitions separated by a screen mesh, one part with biomedia chips and a clean sump. The surface of the biomedia chips used in the system is 700 m^2/m^3. The biofilter in RAS A contains 0.9m^3 of bio media chips, RAS B contains 0.3m and RAS C contains 0.6m^3.On the bottom of the sump, an air grid provides air for water movement in order to keep the biomedia moving and provide oxygen to the bacteria. A level sensor is installed in the sump that sends a signal to the controller when water level is low to alarm the technician to fill-up the tank.

3.1.6. Aeration

Aeration is provided to the biofilter sump and header tank using an air pump connected to an

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air grid and submerged air stones respectively. The flow of air bubbles increases contact with air and thus oxygen exchange between the air and water. This type of aeration also strips carbon dioxide from the water.

There are 7 air blowers in the system. Three blowers are installed in RAS A connected to one manifold. The blowers can be switches on independently depending on the air flow required. Two blowers supply air for RAS B and two blowers for RAS C. From the manifold, air stones in the header tanks are connected through air hoses. Air stones used are disc stones with a diameter of 5 and 20 cm.

Set of air blowers; 2 providing air to the biofilter and 1 providing air to the header tank (RAS A: broodstock system)

3.1.7. UV disinfection

Treatment using Ultra Violet light eliminates harmful micro-organism from the water. In the VicInAqua pilot system, 2 models of UVs are used, for RAS B a UV unit with a capacity of 6,000 l/hr is used while for the egg incubation system in RAS A the capacity of the UV is 3,600 l/hr. The UV units include a separate microprocessor that features a LCD display with lamp working hours, operating status and faults, countdown hour meter, alarm indicator and relay for remote monitoring, remote on/off relay and timer. Lamps must be changed after 9000 hrs of operation (every year).

Emergency oxygen dosing cabinet

UV unit in the egg incubation system

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3.1.8. Emergency oxygen

Emergency oxygen is provided when there is a power outage (when no power is supplied by the main electricity net as well as the renewable system). Pure oxygen will be inserted into the fish tanks from compressed oxygen cylinders that are connected to a dosing cabinet. The valves in the dosing cabinet are normally closed and when the system is not fed with power the valves will open and oxygen will flow through air hoses to the tanks. Oxygen is dispersed in the water using air stones.

3.1.9. Egg incubation

The egg incubation system consists of 5 Mac Donald Jars. Mac Donald jars are made from transparent plastic with a cylindrical form. Water enters the jars through a vertical tube causing upwelling to keep the eggs suspended. Each jar overflows in a fiberglass tray, where swim-up larvae are housed until stocking in the larvae system. The jars have a height of 46 cm and a diameter of 16cm with a 6-litre capacity for up to 60,000 eggs.

	
MacDonald jars for egg incubation	Trays for swim up fry

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3.2. System specifications

3.2.1. Design specifications

	System A: Broodstock and egg incubation		System B: Larval rearing		System C: Nursery	
Design parameters:						
Water turnover rate	1 tank turnover per hour		0.5 m3/hour		0.5 m3/hour	
Flow Rate	28,000 L/h		8,000 l/h max		9,000 l/h max	
Water temperature	25°C - 30°C		28°C - 30°C		27°C - 30°C	
Tanks:	**Volume**	**Number**	**Volume**	**Number**	**Volume**	**Number**
Fish Tank	3,000 L	6	500 l	9	500 l	2
Sump / biofilter	2,000 l	1	1,650 l	1	1,650 l	1
Pumps:	**Flow**	**Number**	**Flow**	**Number**	**Flow**	**Number**
Main pump	30,000 l/h @ 9m head	1	18,000 l/h @ 5m	1	18,000 l/h @ 5m	1
DF backwash pump	1,000 L/h, 5.5 bar	1	3,100 l/h, 10 bar	1	3,100 l/h, 10 bar	1
Disinfection:	**Watt**	**Number**	**Watt**	**Number**		
UV	40W	1	80W Max. Flow 6,000 l/h	1		
Filtration:	**Flow**	**Number**	**Flow**	**Number**	**Flow**	**Number**
Drum filter	Rated 30 m^3/h at 40µm	1	15 m^3/h at 20µm	1	15 m^3/h at 40µm	1
Protein skimmer	10m^3/h	1	3m^3/h	1	3m^3/h	1
	Surface	**Volume**	**Surface**	**Volume**	**Surface**	**Volume**
Biofilter media	700m^2/m^3	900 l	700m^2/m^3	300 l	700m^2/m^3	600 l
Aeration:	**Flow**	**Number**	**Flow**	**Number**	**Flow**	**Number**
Air pump	160 l/min at 2 meters	3	47 l/min at 2 meters	1	47 l/min at 2 meters	1

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3.2.2. Biological specifications

System Design	Unit	A. Broodstock	B. Larvae	C. Nursery
Number of tanks	#	6	9	12
Volume / tank	m^3	3	0.5	0.5
Volume total	m^3	18	4.5	6
Total RAS volume (fish + water treatment)	m^3	20	5.5	7
Max density	kg/m^3	10	2	4
Stocking size	g	100-150	0.01	0.2
Max fish weight	g	450	0.2	1-2
Time in system per batch	days	-	21	21
Max biomass per tank	kg	30	1	2
Average feeding rate	%	2	15	10
Expected survival	%	-	75	80
Expected number of transferred fish / batch	#	-	23,500	18,750

	Unit	Values
No. of batches per year	#	17
Max number of fry per year	#	300,000
Max Harvest per batch (3 weeks)	#	18,750
FCR (average)		1.5
Feeding /year	Kg	1600
Feeding average systems	kg / day	4.5

3.2.3. Water quality limits

Tank turnover: The tank should have a water turnover of 100% per hour (corresponding water of 3 (A) and 0.5 (B&C) m^3/h respectively).

Description		Criteria
Optimal Average temperature	°C	28-30
Optimal Average Salinity	‰	0
Optimal DO	mg/l	5-7.5
Optimal DO	%	70-100
Optimal Average pH		6.8-8
Maximum Ammonia NH_3	mg/l	0.1
Maximum TAN -NH3/NH4+ (pH dependent)	mg/l	2
Maximum NO_3- -N	mg/l	300
Maximum NO2-	mg/l	0.1
Maximum CO2	mg/l	40
Calcium hardness	mg/l	50-100
Chloride	mg/l	100-300
Alkalinity	mg/l	100-250

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3.2.4. Technical information equipment

For technical information for each of the components consult the technical passports. The technical passports include a function description, specifications on power, connections, dimensions and materials. They also provide information on installation, operation and maintenance.

3.2.5. Energy requirements

System	Equipment	Voltage (V)	Power (kW)	Amperage (A)	Duty time @24h (% estimated)	Energy consumption (kWh)
System A: Broodstock Development & Egg Incubation			3.12			
	Drum filter	220	0.15	0.7	1	3.6
	Centrifugal pump	220	1.50	6.8	1	36
	Ultraviolet Disinfection	220	0.04	0.2	1	1.0
	Solenoid valves	220	0.01	0.1	1	0.2
	Backwash pump	220	0.70	3.2	0.3	5.5
	Air blower	220	0.16	0.7	1	3.8
	Air blower	220	0.16	0.7	1	3.8
	Air blower	220	0.16	0.7	1	3.8
	Control system	220	0.12	0.5	1	2.9
	Control system	220	0.12	0.5	1	2.9
System B: Larvae & Weaning System			**1.67**			
	Drum filter	220	0.15	0.7	1	3.6
	Centrifugal pump	220	0.33	1.5	1	7.9
	Ultraviolet Disinfection	220	0.08	0.4	1	1.9
	Solenoid valves	220	0.01	0.1	1	0.2
	Backwash pump	220	0.70	3.2	0.3	5.5
	Air blower	220	0.16	0.7	1	3.8
	Control system	220	0.12	0.5	1	2.9
	Control system	220	0.12	0.5	1	2.9
System C: Nursery			**1.75**			
	Drum filter	220	0.15	0.7	1	3.6
	Centrifugal pump	220	0.33	1.5	1	7.9
	Backwash pump	220	0.70	3.2	0.3	5.5
	Solenoid valves	220	0.01	0.1	1	0.2
	Air blower	220	0.16	0.7	1	3.8
	Air blower	220	0.16	0.7	1	3.8
	Control system	220	0.12	0.5	1	2.9
	Control system	220	0.12	0.5	1	2.9

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3.3. Production plan

Assumptions

Biological parameters	Value
Sex ratio (♀:♂)	3:1
Broodstock weight minimum (g)	100-150
Broodstock weight maximum (g)	450
Number of eggs/female per spawning	500
Eggs required per 7 days	18,500
Number of days egg incubation	7
Number of days in larvae system per batch	21
Number of days in nursery system per batch	21

Broodstock management and egg incubation

In order to produce 25,000 fry per month the following broodstock management protocol can be followed. Note that this is an example and other options are possible.

Sex	Tank 1 Spawning tank	Tank 2 Spawning tank	Tank 3 Spawning tank	Tank 4 Spawning tank	Tank 5 Resting tank	Tank 6 Resting tank	Total
Females #	28	28	28	28	45		**157**
Males #	9	9	9	9		15	**52**
Total #	37	37	37	37	45	15	**209**
Total max biomass (kg)	16.5	16.5	16.5	16.5	20	7	**93**
# fish/m2	6.2	6.2	6.2	6.2	7.5	2.5	
Egg production per week	4,620	4,620	4,620	4,620			**18,480**
Fry production per week (2 gram)							**6,100**
Fry production annual							**300,000**

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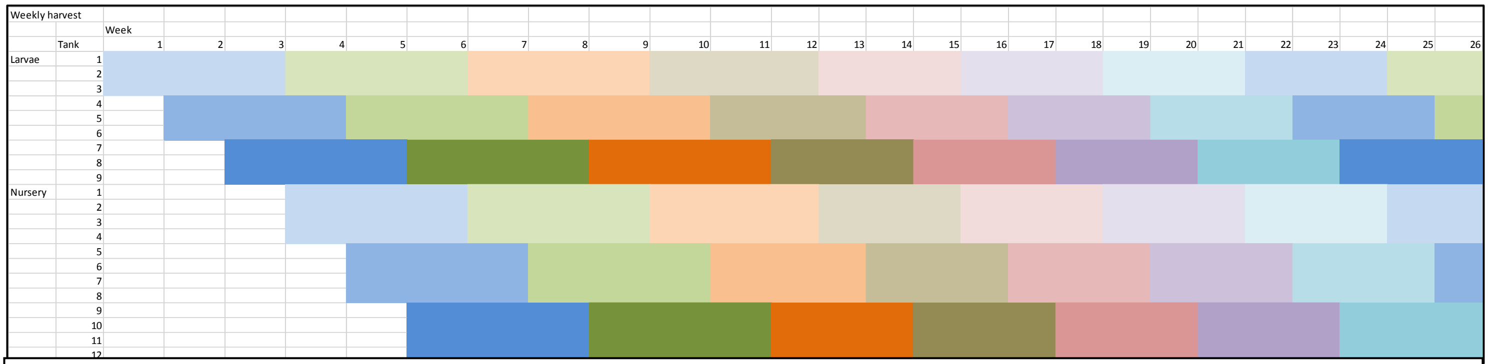
Example of batch production plan



Production plan showing batches in different colours for 26 weeks for larval rearing and nursery with optimal tank use stocking eggs and harvesting fry every week

3.4. Hatchery Operation procedures

3.4.1. Broodstock management

Only high quality broodstock free from diseases are being used in the hatchery. Broodstock are kept at a temperature of between 24 and 30 °C.

Tilapia spawn naturally in captivity. Nutrition for broodstock is essential in producing high quality fry. Broodstock is fed twice a day with 1-1.5% of their body weight per feeding. Feed should contain high quality and quantities of proteins (35-45%) and lipids. *O. niloticus* is a mouth breeding species, and females stop eating during oral rearing. Each female produces around 500-1000 eggs per spawning and spawns once a month. A sex ratio of 3 females to 1 male should be used. Stocking for active breeders is kept between 4-8/m^2. If higher densities are used, crowding effects like increase in male aggression, decrease in courtship and reduction in the proportion of active females, can occur. Active broodstock is kept in hapa nets for easy egg collection.

3.4.2. Egg collection and incubation

Collection

Eggs are collected at 7-day intervals. Eggs are collected by passing a PVC pipe/stick float underneath the netting material from one end of the hapa to the other end to concentrate the brood fish in one end. The brood fish are captured individually with two small scoop nets—a large-mesh inner net and a fine-mesh outer net. The nets are held in one hand while the fish is held with the other hand, which is gloved to prevent injury from the dorsal fin. Using a finger to open the fish's mouth, the fish is moved quickly up and down in the water with the nets underneath to wash out any eggs the fish may be incubating in its mouth. Occasionally, a fish will expel its eggs as it is being captured. With a double-net scoop net system, the eggs fall through the large mesh net and are retained by the small mesh net. The large mesh net prevents the fish from crushing the eggs. After each fish is inspected, it can be returned to the other end of the hapa net. Before returning fish, the empty side of the hapa net can be cleaned

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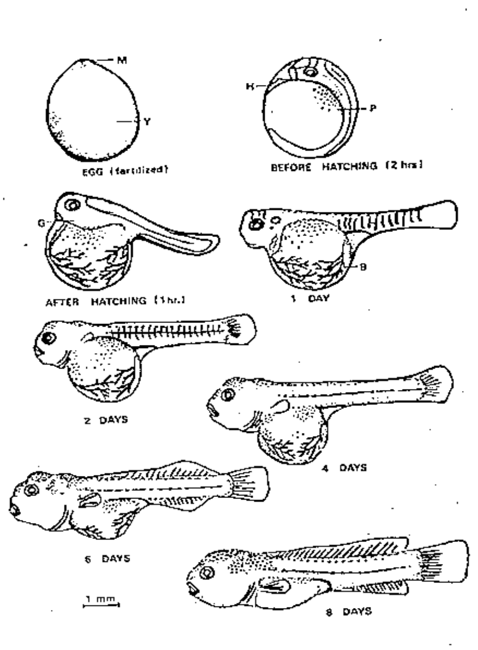
or a new clean net can be used to return the fish to.

Eggs are transferred from the scoop net to a bowl with water. Stage 1-2 eggs are separated from stage 3-4 eggs. After every 3-4 females or after few minutes the eggs are transferred to the egg incubation jars. At least 3 people are needed to harvest eggs from one tank.

Incubation

Eggs are washed in water and large fry (if applicable) will be sieved out using a strainer. Eggs are transferred from the bowls to the hatching jars using a small funnel. Stage 1 and 2 eggs are transferred all together in one jar and the stage 3 and 4 eggs in another jar. Eggs in the jars are kept in gentle motion. Bad eggs float and can be siphoned out of the jars. The eggs hatch between 3-6 days. They swim out in the flow to the small trays where they will stay 24-48 hours. The free-swimming fry (swim up fry) are then moved to the larvae system.



Development stages:

1) Just fertilised, no spots

2) With eye spots

3) Darker in colour with small tail and protruding eyes

4) With longer tail and head

5) Swim up fry

Development stages of tilapia from eggs to fry

Eggs hatch on different days, stage 3 and 4 eggs will take 2-4 days to hatch while stage 1 and 2 eggs will hatch in 5-6 days. In the system there are 5 sets of jars and trays. Each tray will contain the eggs hatched on a different day as following:

Tray 5: Egg that hatched on day 2

Tray 4: Eggs that hatched on day 3

Tray 3: Eggs that hatched on day 4

Tray 2: Eggs that hatched on day 5

Tray 1: Eggs that hatched on day 6

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Since only 2 jars will be stocked with eggs, the trays need to be moved at the end of the day and replayed by an empty tray to catch the hatched eggs for the following day.

The different batches will be stocked in different larvae tanks. It is up to the hatchery manager to decided which batches to combine (depending on quantities of batches). Before the fry are stocked in the tanks a sample weight is done to estimate the average body weight of the fish in the batch. The fish are then removed from the tray with a scoop net and put into a small bowl without water. The entire batch is then weighed (sample weight and total batch), and a record is made. The fish are then put into a bucket with water and transferred to the larvae tank.

3.4.3. Larval hormone treatment

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

There are three methods for all-male fry production:

- Mechanical or hand grading
- Sex reversal using hormonal treatment
- Use YY males

In this hatchery sex reversal is used. However, the use of YY males is recommended for future use. Sex reversal of fry is achieved by using a synthetic male androgen (17-alpha methyltes-tosterone) administered in feed for 21 days post-hatch.

Hormone powder is mixed with 98% ethanol and mixed with the feed. The feed is then dried and stored in water tight containers. 0.765 gr of hormones is needed for every 10 kg feed. 1 gram of hormones is first dissolved in 3.7L ethanol and then mixed into the feed. It is suggested to prepare feeds (around 15 kg) for every batch of 3 weeks.

3.4.4. Feed management

Guaranteeing 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 labelled 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

Feeding practices

Feeding practices also play an important role in optimizing the growth rate and health of your fish and therefore:

- Feeding practices should minimize the risk for biological, chemical and physical contamination of feed and farmed fish

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- 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

Pellet feeds are used to feed tilapia from first feeding. Fish are fed manually in order to observe feeding behaviour. The first feed is fine powder that floats on the water surface. Small fry eat between 15-20% of their body weight. As the fry grows larger feeds should be offered. The feed size should be based on the smallest fish in the tank, feed the largest size of pellets they can eat so they spend less energy on feeding. Broodstock fish are fed 2% of their biomass per day with 3-5 mm pellets.

Average fish weight (grams)	**Feed size (mm)**	**Range of feeding rate (% biomass/day)**
Post-hatch- 0.05	0.2-0.3	15-20
0.05-0.5	0.25-0.75	15-20
0.5-3	0.75-2	10-15
>100	3-5	2-3

When feeding ensure that all fish can eat. Provide feed in different place of the tank to ensure that fish that were crowded out also eat. When feeding slows, feeding application should be stopped or decreased to reduce the amount of uneaten feed. If feeding behaviour is not normal, stop feeding, check the water quality and fish health.

Feeding should be spread over the day in five different feeding sessions for fish up to 2 grams, and then reduced to four sessions for fish above 2 grams.

Feed storage

Proper storage of feeds is important to maintain the quality of the feeds and it is recommended that:

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

3.4.5. Sorting and grading

Grading of fry is very important after the initial development stages to minimise mortality caused by cannibalism and dominance. By grading the fish uniformity in the tanks is maintained. The first grading is done after the larval stage and the second grading when the fry is harvested from the nursery. During the grading activity, accurate sample weighing can be done. Grading is done using hand graders.

The grading procedure is as following:

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- Fill up the nursery tanks with clean water
- Put a hapa net in the first nursery tank that will serve to keep the "small fish"
- Choose the grader to use according with the fish size desired and place it onto the hapa net
- Scoop the fish from their original tank onto the grader and shake it gently with up and down movements, letting the smaller fish (called "small group") pass through the grids.
- Collect the fish remaining above the grids (called "big group") using a scoop net and weigh them.
- Record the weight and transfer the fish into another tank.
- Stock the first nursery tank up to maximum stocking biomass and then start stocking the next nursery tank
- Repeat until the larvae tanks are empty.
- The last batch ("small group") can be weighed by grouping the fish on one side of the net (split the net with a stick), weigh them and transfer them on the other side of the net. Once all fish are weighed the net can be removed and the fish can be stoked in the tank.
- Dip the nets into a bleach bucket, rinse them with tap water and leave them in their corresponding place.

3.4.6. Water quality management

The following water quality parameters should be monitored:

Temperature — Optimum growth for tilapia fry is achieved at 28 to 30 °C. Temperature is measured by the monitoring system.

Dissolved oxygen — Operating levels of between 5.0 and 7.5 milligrams per litre (mg/L) are recommended. Growth and feed conversion will be affected by chronically low DO concentrations below 3.5 mg/L. Dissolved oxygen is measured by the monitoring system.

pH — Tilapia can survive a wide range of pH, from 5 to 10, but are said to grow best at pH 6 to 8. In tank systems, dissolved carbon dioxide causes pH to decline because of the formation of carbonic acid (H_2CO_3) in solution. A minimum pH of 6.8 is suggested as the lower limit of tolerance for the nitrifying bacteria of the biofilter. Due to the presence of dissolved carbon dioxide, high pH is generally not a problem in tank systems. pH is measured by the monitoring system.

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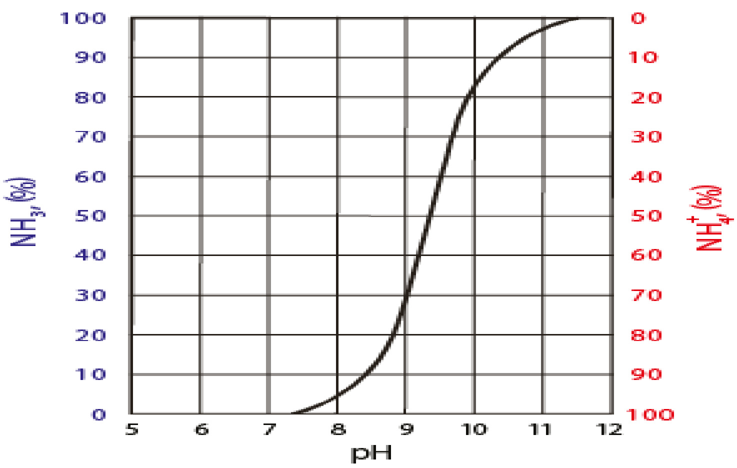
Ammonia (NH3) — Ammonia exists in two forms in the tank environment, un-ionized NH_3 (highly toxic) and ionized NH_4+ (less toxic). Avoid concentrations of un-ionized ammonia greater than 0.1 mg/L. Consult other sources to understand the relationship between pH and the toxicity of Total Ammonia Nitrogen (TAN), un-ionized ammonia and ionized ammonia.



Test equipment is available in the laboratory.

Nitrite (NO2-) — Avoid concentrations greater than 0.1 mg/L nitrite-nitrogen if chloride (Cl^-) is low (less than 10 mg/L). Maintain chloride concentration of 150 to 200 mg/L under normal operating conditions, and increase chloride concentration when nitrite is elevated. The chloride ion alleviates nitrite toxicity and can be added as sodium chloride (NaCl) or calcium chloride ($CaCl_2$). This can be measured with test-kits.

Nitrate (NO3-) — Nitrate toxicity can occur if levels in water reuse systems exceed 300 mg/L nitrate-nitrogen. Normal water exchanges during filter backwashing or solids removal generally control nitrate concentrations. Water exchange or a denitrification process may be required. Test equipment is available in the laboratory.

Carbon dioxide (CO2) — Maintain at less than 40 mg/L. Elevated carbon dioxide levels cause lethargic behaviour or slow feeding response in fish. While tilapia can tolerate a wide range of pH, dissolved carbon dioxide gas stripping is required in water reuse systems to keep pH above 6.8 and promote conditions favourable to nitrifying bacteria in the biofilter. This can be measured with test-kits or probe.

Calcium hardness — Maintain between 50 and 100 mg/L. Dissolved calcium in the water aids in osmoregulation and relieves stress in fish. It is usually added as calcium chloride ($CaCl_2$), which dissolves readily and also increases chloride (Cl^-).

Chloride (Cl^-) — Maintain between 100 and 300 mg/L. See description under Nitrite. Also see the Harvesting and Marketing section. This can be measured with test-kits.

Alkalinity — This is the measure of the pH buffering capacity of water, and should be maintained at 100 to 250 mg/L by adding a soluble carbonate or bicarbonate source. Sodium bicarbonate is commonly used because it is readily available, highly soluble, and safe to handle. Dissolved carbon dioxide reduces pH, so higher alkalinities must be maintained if CO_2 stripping is poor. Choosing a water source with higher alkalinity reduces operating expenses because less supplemental alkalinity will be needed. This can be measured with test-kits.

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Parameter	Unit	Equipment	SOP #
Temperature	[°C]	Monitoring system, available temperature probes	OxyGuard
Oxygen (O_2)	[mg/L]	Monitoring system, OxyGuard Handy Polaris dissolved oxygen probe	OxyGuard
pH		Monitoring system, OxyGuard Handy pH probe	OxyGuard
Ammonia, as total ammonia (NH_3+NH_4^+)	[mg/L]	Test kit	See kit instructions
Nitrite (NO_2^-)	[mg/L]	Test kit	See kit instructions
Nitrate	[mg/L]	Test kit	See kit instructions
Carbon dioxide (CO_2)	[mg/L]	OxyGuard portable CO_2 analyser	OxyGuard
Carbonate hardness/alkalinity	[mg/L]	KH/ALK test kit	See kit instructions

When a parameter is out of its optimal range the following measurements can be taken:

Observation	Possible measures
Low dissolved oxygen	• Increase aeration • Stop feeding until corrected • Watch for symptoms of parasites/disease
High carbon dioxide	• Increase aeration • Watch for symptoms of parasites/disease
Low pH	• Add alkaline buffer (sodium bicarbonate) • Reduce feeding rate • Check ammonia and nitrite concentration
High ammonia (un-ionized)	• Exchange system water • Reduce feeding rate • Check biofilter: pH, alkalinity and DO • Watch for symptoms of parasites/disease
High nitrite	• Exchange system water • Reduce feeding rate • Add 5 ppm chloride per 1 ppm nitrite • Check biofilter: pH, alkalinity and DO • Watch for symptoms of parasites/disease
Low alkalinity	• Add alkaline buffer (sodium bicarbonate)
Low hardness	• Add calcium carbonate or calcium chloride

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3.4.7. 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 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)
- Contact with the systems, system water or material in the systems must be kept to only the necessary minimum.
- 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

Personal hygiene

- Clean T-shirts should be worn at the facility with the staff exchanging clothes and footwear before entering.
- Hands should be disinfected when entering the facilities and moving between systems. Ethanol should be sprayed on the hands and distributed evenly so that hands and wrists are completely wetted. Watches and rings can hamper effective disinfection, and must be taken off before entering the facilities.
- Disinfect the boots (foot bath) when moving between systems.
- No material should be brought into a system without being thoroughly sterilized.
- No material should be moved between systems. If this cannot be avoided, each item must be disinfected before it can be moved.
- It is not allowed to store material on the floors. Any material, which was in contact with the floor must be considered contaminated, and needs to be disinfected immediately. The floors must be kept dry whenever possible.

Pest control

Most farms have issues with pest animals like mice, rats, cockroaches and flies. One of the most important reasons why it is important to control these animals on a farm is because of health and food safety issues associated with these animals. Pest animals can bring microbes and diseases, have an impact on production and resources and cause damage to facilities and equipment. By implementing a pest control system, farmers ensure that the risks of contamination of feed, equipment and farming systems are minimized. A pest control system typically includes the following steps:

• Correct pest identification as different pest animals require different control strategies
• Planning of preventive strategies like proper cleaning and sanitation, a good waste disposal system and very importantly by storing all feeds indoors in a sealed room
• Selection of optimal pest control tactics, like mouse and rat traps and electric fly killers
• Proper monitoring and recording of the pest control activities
• Regular evaluation to see if your pest control system is still working well

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Handling of mortalities

Any mortalities collected shall be recorded and sampled according to protocol (date, system, tank, etc), and should be disposed of immediately in a sanitary manner.

- Observe bottom of tanks for dead animals.
- Tare bucket on scale if mortality needs to be weighted.
- Place net into the tank and remove the mortalities taking special attention not to disturb other fish.
- Count mortalities from net into bucket.
- Once all mortalities removed, record on sheet.
- If the mortality appeared to be the result of disease or infection report immediately to manager or a veterinarian and take appropriate actions.

3.4.8. Disease control

Aquaculture has been the fastest growing animal production sector for the last 20 years, but diseases are increasingly limiting production. This is especially a problem in tropical countries as 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 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 through proper disease management. It is very important to understand that a successful approach to disease management requires the implementation of general hygiene procedures, feed management, veterinary drug management, post-harvest management and good record keeping. These are all of vital importance to keep your fish healthy and to prevent diseases from spreading.

Disease prevention

The best way to prevent diseases is to follow appropriate culture procedures to minimize the potential for microbiological and chemical contamination during aquaculture production. A farmer does this by implementing all procedures that are discussed in this handbook. Additionally, it is recommended to:

• Monitor fish stocks and water quality regularly to identify potential disease outbreaks

• Design and construct equipment such as cages and nets in a way that ensures minimum physical damage of the fish during the growing stage

Disease diagnosis and monitoring

Movement of fish to the hatchery should be controlled. Sanitary measures should be taken, such as disinfection of the system and followed before re-stocking. When irregularities or symptoms of disease are observed by staff, the hatchery manager should be notified. If the cause cannot be identified by the manager, a fish health specialist should be contacted, and a sample of fish should be sent to the laboratory for checking. In case a disease is diagnosed, treatment should be carried out by an authorised person.

- It is advisable to keep diseased fish in a separated quarantine area
- In case fish cannot be moved to a separate quarantine area, seal off the area with diseased fish
- Inform all staff of the disease outbreak and place the tank under quarantine

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- Dead fish should be disposed of immediately in a sanitary manner that will discourage the spread of disease

Guidelines for disease treatments

- Only use chemicals and veterinary drugs from suppliers that are registered with the authorised authority.
- Veterinary drugs, medicated feeds and other chemicals should be labelled in an adequate language, with clear information on: name, active substances, target animal species, storage conditions, prescribed dosage, route of administration, expire date and withdrawal period.
- Veterinary drugs, medicated feeds, chemical and biological substances should be used according to the instructions of the manufacturer and as specified on label.
- Substances requiring prescription should be used under adequate supervision by a qualified expert.
- Veterinary drugs need to be stored in a separate room from standard feeds.
- Veterinary drugs, medicated feeds and other chemicals should be stored according to manufacturer's instructions.

3.4.9. Power failure procedure

In the event of a long power cut (15 minutes and longer), project staff must follow the instructions below:

Note: During the duration of the power cut, feeding of fish must stop.

- Makes sure all the main oxygen supply lines are closed in all the systems.
- For every system, check that the oxygen diffusers in all tanks are dosing oxygen.
- Check that oxygen levels are between 6.0-10.0 mg/L via the monitoring system. If more oxygen is needed in a tank, increase flow using the oxygen valve. If a tank has no fish close the oxygen valve to that tank.

IMPORTANT: If the power cut is longer than 2 hours or the monitoring system loses power, repeat the steps above using a handheld DO meter.

3.4.10. Trouble shooting low oxygen

The first step is to make sure that the fish are safe, that the emergency oxygenation system is ready and that oxygen levels are closely monitored. Act without panicking, use good judgement in assessing the situation and reacting to it. Clear communication between staff members is essential, inform other staff member and the facility manager as soon as possible.

When the fish are safe, and the situation is stable, the system can be checked according to the flow diagram below to try and resolve the issue.

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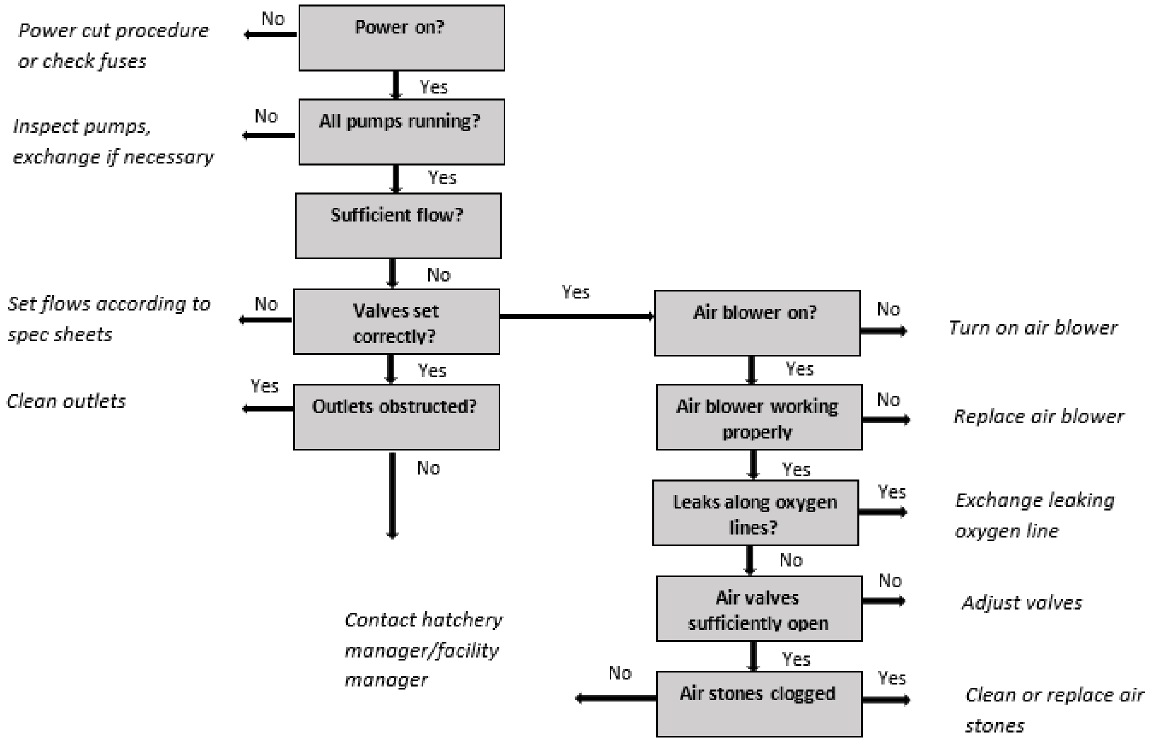

3.4.11. Harvesting and transportation

Handling

To minimize the damage of fish during harvesting and post-harvest handling farmers should:

• Use equipment that has been designed for rapid and efficient handling of aquaculture products without causing mechanical damage. Any scratches on the fish should be avoided

• Use harvesting areas and equipment for harvesting, catching, sorting, grading, conveying and transporting of products that are smooth and easy to clean.

Harvesting procedures

Harvesting activities should be planned in advance and should be organized timely in order to avoid that fish are exposed to high temperatures for longer periods. Additionally, technicians should ensure that:

- The fish should not be fed one day prior to harvest to reduce their gut contents
- Only healthy fish that show no clinical sign of disease should be harvested
- Detailed records need to be maintained during harvesting to tallow for proper traceability
- Do not subject the fish to extremes of heat or cold or sudden variations in DO
- Slowly cool down the fish using ice when sorting and packing to avoid stress during transport
- Minimize physical damage and stress during packing and transport by fast and efficient handling

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Fry will be harvested, graded and weighed before packing. The grading and weighing procedures described in 3.4.5 should be followed. Basins will be used for harvesting, grading and weighing. Fish will be transported life in containers (plastic bags are not available in Kenya due to the plastic ban) and supplied with oxygen (medical grade).

3.4.12. Record keeping

Water quality monitoring

All quality parameters discussed in section 3.4.6 should be measured and recorded.

Feed management

- Origin of feeds and feed ingredients (e.g. raw material details, supplier details)
- Feeding records (e.g. quantities of feed used, bag numbers)
- Storage and control records (e.g. checking expiry dates, verifying the First In, First Out system)

Quality control

- Clean and sanitation records (e.g. cleaning and sanitation checklists and forms)
- Workers hygiene records (e.g. worker hygiene checklist)

Management of chemicals and veterinary drugs

- Origin of the chemicals and veterinary drugs used in the farm (records should proof the legality of the product and verify proper labelling of the product)
- Required records for every application of drugs and other chemicals should include the treatment start date, treatment stop date, compound used, diagnosis and symptoms, dosage, withdrawal period, MRL, identity of ponds or cages where the drug was applied, and harvest date for the treated ponds or cages

Post-harvest management

Records of harvesting and packing of fish should be properly maintained to ensure product traceability including:

- Species (scientific name)
- Harvest date and slaughter date
- Origin (tank number)
- Treatment history

Records for the transport of fish should be properly maintained to ensure product traceability including:

- Departure time
- Arrival time
- Net and Gross weight
- Source (tank number)
- Transportation method (including vessel registration number and/or license plate number)
- Origin
- Destination

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3.5. System Operation and Maintenance procedures

3.5.1. Daily checklist

Every day each system is checked on the following for about 6 times per day:

- **Water quality measurements**: see section 3.4.6
- **Check drum filter-nozzles**: Technicians should check drum filter spray nozzle function once per day. If blocked, the drum filter spray nozzles can be cleaned with a brush to remove debris. If after cleaning persistent pollution of the same nozzle occurs the nozzle can be placed in diluted acetic acid for 1-2 hrs to remove blockages; wash in clean water before fitting back into nozzle holder.
- **Tank sump and levels:** Check the water level of all tanks and sumps. Water levels are marked on the inside of the tanks.
- **Check for leaks:** Check the whole system for leaks in tanks, fittings, pipes and equipment.
- **Check flow meters:** Check the flow on the flow meters and if it is corresponding with the required flow going to the protein skimmers.
- **Purge and syphon:** In case a lot of debris can be found on the tank bottom, some water needs to be purged from the tank removing the waste or the tank should be siphoned. For purging open the outlet valve for a few seconds until the waste has drained. For siphoning a small hose if used attached to a stick and debris can be removed accurately.
- **Add buffer for pH if necessary:** As fish grow, they produce metabolic wastes and carbon dioxide. The accumulation of CO_2 and the consumption of alkalinity in the biofilter will reduce pH and the water will become increasingly acidic. To maintain pH within optimal levels of between 7 and 8, this drop in pH needs to be controlled by the dosing of Sodium Bicarbonate to control the buffering capacity of the water. Sodium Bicarbonate will be added daily into the systems during system checks. Sodium Bicarbonate will be added into the system by dissolving a set amount into a 10 L bucket and mixing it thoroughly until it is completely dissolved into the water. The solution will then be added into the clean sump (and not into the biofilter).

    a. Sodium Bicarbonate amounts should be weighed out for each system at a level of 40% (0.4) of the feed amount the night before. After checking the pH and Alkalinity of the water, this value could be reduced to a minimum of 20% (0.2) if the pH and Alkalinity are above the set points (Alkalinity 150 – 250 mg/L as CaCO3 or 3 – 5 mEq/L and pH between 7.3 and 7.5). **A minimum value of 20% of the feed should be added per day.**

    b. At every daily check from 7 am to 7 pm 1/5 - 1/6 of the amount must be mixed with 10 L of FRESHWATER from the tower supply to each system and added

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to the clean sump at the point where the system pump draws water. This must never exceed 500g of bicarbonate mixed with 10 L of water.

c. During the daily checks, if the pH is below 7.2:
   Sodium bicarbonate at 10% (of the feed amount) must be added in case the pH is below 7.2.

d. If pH is above 8.6 a water exchange must be performed in the system in order to bring the pH back to the optimal range

- **Clean buckets and probes:** Clean the cleaning materials, buckets and brushes with clean water as well as the probes.
- **Change rubbish, alcohol bottles:** Change the rubbish bags in the bin and dispose of garbage properly. Check if alcohol bottles still have sufficient content and replace if necessary.

The checklist is used to record the system checks (note that this is an example, checklists are tailored to each system):

Tank	O_2 (ppm)	
	AM	11 PM
1		
2		
3		
4		
5		
6		
Initials		

Tank	Mortalities		
	AM	Noon	5 PM
1			
2			
3			
4			
5			
6			
Initials			

Tank	Feed (g)		
	In	Out	Total
1			
2			
3			
4			
5			
6			
Initials			

Date	/ /20	
	AM	5 PM
T (°C)		
pH		
P1 (rpm)		
P2 (rpm)		

DAILY FEEDING & SYMCHECKS (Tick)							
Time	07:30	08:30	10:00	12.30	14:30	17:30	19:00
Feeding		X					
Fish health		X					
DF - Check net & nozzles are working	X		X	X	X	X	X
O_2 and pH within parameters							
Check flowmeters (m^3/h) (airlocks?)	X		X	X	X		X
Tanks and sump levels		X					
Check for leaks	X		X	X	X		X
Purge and syphon if needed	X		X	X	X		X
WQ scheduled	X		X	X	X	X	X
Check there is still NaOH in the bottle *		X	X	X	X	X	X
Add 1/5 of the total initial amount of NaHCO3 in 10l of water			X		X		
Dry biosecurity area if needed	X	X	X	X	X	X	X
INITIALS							

OXYGEN	AM	5 PM	11 PM
			Emergency
O_2 emergency working			

COMMENTS / OBSERVATIONS / ABNORMALITIES / MORTALITIES

Checked by supervisor/s			
AM		PM	

* Switch on if pH < 7.1 [time:____]; Switch off if pH > 7.1 [time:____]

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3.5.2. Cleaning & sanitation

Equipment cleaning

Cleaning and sanitation of facilities and equipment for harvesting and sorting is a very important part in preventing the occurrence and spread of diseases in a hatchery. Proper cleaning and sanitation can be achieved by strictly implementing the following procedure:

- Put on appropriate protective clothing before starting any cleaning and sanitation activity (apron, gloves and boots)
- Prepare cleaning tools (brooms, scrubbing brushes, shovels, water hoses, cleaning cloth, buckets, detergents, sanitizers, etc.)
- Dismantle any equipment (like fish sorters) to clean it well
- Remove all visible rubbish and place in appropriate disposal bins
- Wipe surfaces to remove loose surface dirt
- Rinse all surfaces materials and equipment with clean water
- Apply detergent to break down grease and remove any stains and scrub all surfaces from the top down to remove all dirt
- Rinse off the detergent from the top down with plenty of clean water
- Apply sanitizer to kill and reduce bacteria to a safe level
- Rinse off sanitizer with plenty of clean water
- Dry the materials and equipment by removing excess water that may remain behind and allow bacteria to grow
- Properly store all clean materials and equipment

System cleaning

While carrying out cleaning of a system or part of a system, record activities in the System Cleaning Checklist.

- Clean tank walls inside: Brush slowly and carefully in order to stress the fish as little as possible.
- Clean tank walls outside: Clean the external surface of the tanks using a brush with tap water, if needed use alcohol to remove stubborn dirt.
- Brush Standpipes: Isolate the tank by closing both drain and inlet valve and then remove the dirty standpipe from the tank with one hand and immediately replace it with a clean spare standpipe held next to it on the other hand. Special care should be taken while replacing standpipes to minimize the risk of small fish being trapped in the outlet. Open the drain valve and the inlet valve and then repeat all the operation in all the tanks. Brush all the standpipe`s surface especially the perforated and internal part and rinse them with tap water.
- Brush overflow pipes: Remove the dirty overflow pipe from the tank with one hand and immediately replace it with the clean spare standpipe held next to it on the other hand. Special care should be taken while replacing overflow pipes to minimize the risk of small fish being trapped in the outlet. Brush all the pipe`s surface especially the perforated and internal part and rinse them with tap water.
- Brush inlet pipes: Remove all the inlet pipes from the tanks. Using a brush clean all the surface of the pipe with particular care to the perforated part. Clean the inside of the

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inlet pipe with a pressured water jet of tap water, shake it well and rinse it twice. Put back all the inlet pipes in place and make sure that the correct water flow direction is followed.

- Clean Sump: Clean the wall of the sump using the tank broom.
- Brush outlet pipe Drum Filter: Clean the drum filter outlet mesh by using the brush or the tank broom if the pipe is not easy to reach.
- Clean lids: Clean the mesh of the lids by using a brush and rinse the brush in a bucket with tap water, flip the lids and do the same operation on the other side.
- Clean air stones: Take the air stone out from the tank, brush it and spray it with alcohol. Dry the air stone and place it back in the tank.
- Clean skimmer foam outlet: Use the alcohol sprayer for breaking the foam inside the outlet pipe, clean inside with blue paper or with a brush, if it is possible to disassemble the pipes for a deeper cleaning, rinse all the pipes with tap water and put the outlet back in place.
- Clean skimmer foam trap: Remove the lids from the foam trap, spray with alcohol to brake the foam and remove all the dirt from the surface.
- Clean O_2 probes: Clean all the O_2 probes with a soft brush and then use paper to gently clean the membrane, never use a brush or other aggressive methods for clean this part so as not to break the membrane.
- Clean the floor: Use the floor broom and tap water for cleaning the floor and underneath the tanks and other equipment.
- Remove dust\dirt from equipment: Remove all the dust\dirt from all the equipment in the system like protein skimmer, drum filter, air blower, electrical box, flowmeter and UV unit. Use paper and an alcohol sprayer.
- Tidy Up: Tidy up all the System and check that all the equipment is clean and in the right place.
- Clean and fill footbath: Empty the footbath, rinse it with tap water and use the brush if needed. Then fill the footbath with approximately 10 litres of tap water and add 50 mL of Bleach.
- Clean all the cleaning equipment: Clean with tap water all the cleaning equipment used and disinfect. Put back all the cleaning equipment in the designated place.

System disinfection

System disinfection is only carried out when the whole system is emptied and cleaned, not during continuous operations. For system disinfection follow the following procedure:

- Switch off the UVs
- Remove pH and O2 sensors from the water. Spray and clean probes with a 15% bleach solution. Leave the solution on the probe for 10 minutes and then rinse with clean water. Leave the pH probe inside a clean feed container filled with enough tap water to cover the electrode (it is important that the electrode does not dry).
- Throw out rubbish and replace the bin bag for a new one.
- Wear appropriate Personal Protection Equipment to handle bleach including impermeable protective clothing and arm length gloves and apply the volume of concentrated sodium hypochlorite (bleach) solution given in table below distributed into the system sump and tanks.

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System	Bleach volume (L)-15% solution
RAS A	13
RAS B	4
RAS C	5

- Leave all husbandry equipment (empty spray bottles included) within the tanks so that all equipment is in contact with the bleach solution.
- Leave the system running overnight with sodium hypochlorite (bleach) solution.
- Drain the system
- Scrub down the tanks, pipes, buckets, lids etc.
- Disassemble and clean inside the protein skimmer
- Siphon and brush the back of the drum filter
- Snake the system and drain all water
- Wipe down all the pipes, equipment, lights, lids and table.
- Rinse all tank surfaces and anything which was in contact with the Bleach solution (including standpipes, buckets, nets etc.) with fresh water and drain and place equipment in the designated area. (For systems which cannot drain remove all rinse water by alternative means)
- Remove biomedia and place it in the bleaching vessel. For large systems remove only half of the total biomedia.
- Clean the flowmeters
- Fill the system with fresh water and run through the whole system for 2 hours, check for chlorine
- Disconnect tanks, UV, drum filter pump, and system pump. and completely drain all the components
- Leave system to air dry
- Carry out a system check.
- If any leaks were detected or notice damaged equipment, inform maintenance staff if required. Inform maintenance team to carry out their checks, including UV sleeve cleaning.
- Throw out any other remaining rubbish
- Fill a footbath with 33% bleach solution and dip the challenge boots inside.
- Take all documentation and hand it over to the person in charge

Preparation of system for new batch

- Fill up all the system, tidy up equipment.
- Switch UV system on
- Before the system is operated: Switch on the air blowers.
- Before transferring fish into the system, check that the system is equipped with: nets, buckets (clean, water and bleach), spray containers (alcohol and bleach) and each tank is equipped with: standpipe, overflow pipe and inlet pipe.
- On the day fish are actually going to be placed into the system, the technician in charge of the operation has to check again for free chlorine
- After transferring fish into the system add the biomedia

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3.5.3. Biofilter start-up and maintenance

Starting up the biofilter is to manage and control the seeding of nitrifying bacteria cells in the biological filter. When starting up the biofilter in a natural way with fish in the tank, high water exchanges are necessary to keep the ammonia within limits. Feed rates must be reduced until biofilter activation occurs.

When starting up the biofilter without fish in tanks following steps have to be taken:

- Prepare water of the system. System should be free of chlorine. Temperature, pH, alkalinity and hardness should match the requirements of the incoming stock.
- Provide alkalinity (carbon source). Sodium bicarbonate or baking soda can be added to the water to increase alkalinity to 150 mg/l for *Nitrosomonas* to grow. In order to establish the *Nitrobacter* an alkalinity of 200-250 mg/l is optimal. Add 53 g of sodium bicarbonate to increase by 10 mg/l for every 3.8 litres (1 gallon). Also adjust the pH if necessary.
- Provide ammonia and nitrate. Add ammonium hydroxide, ammonium chloride, ammonium nitrite or unscented household ammonia until the level is between 3-5 mg/l. 60ml per gallon of clear household ammonia (10% aqueous ammonia) will raise ammonia levels with 1.6 mg/l. Use ammonia test to check the concentration when the water is mixed.
- Once one biofilter is running, this can be used as a starter for the biofilters in the other systems.
- Monitor water quality parameters. Check culture tanks (at the same time and place) every day for ammonia, nitrite, pH, temperature and alkalinity. When both *Nitrosomonas* and *Nitrobacter* are established, ammonia and nitrite concentrations stabilise to acceptable levels.
- Stocking of fish can now occur. If stock was present in the tanks, feeding can start with a low rate.
- Start the biofilter with a low aeration and increase as more bacteria cells become established on media surfaces.

3.5.4. Water exchange

The procedure involves draining a portion of the system water and replacing it with new water. To do this, follow these steps:

- Fit the drain line so that system water can be removed and sent directly to the floor drain or open the drain line valve
- At the same time open the water line located at the system sump
- Try to balance the outflow with the inflow to prevent draining or overflowing the system sump.
- Always add new water to the system sump to allow for sterilization before reaching the rearing tanks.

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- When doing large water exchanges make sure the sludge pump is the waste sump can cope with the flow and does not overflow
- When finished, close the inflow valve and the drain line valve
- Check the system after 30 minutes to see if there is any problem with the water level in tanks or sump.

3.5.5. Equipment maintenance

Proper cleaning and maintenance for all tanks, equipment, pipes and fittings is very important for functioning of the system and to avoid break down of equipment and thus reparation costs. Equipment should be serviced regularly according to the applicable Standard Operation Procedures, Technical Information and user manuals.

System attention checks

System attention checks are carried out once a week. The following functions are checked, and the record form filled up:

DATE			
SYSTEM	RAS A	RAS B	RAS C
UV			
Lamps working			
DRUM FILTER			
Clean water level sensor			
Check nozzles flow			
Check completely drum filter net for holes			
Check Water pump (Working/Leaks)			
Check net cleaning-manually			
WATER CIRCULATION			
Check for leaks			
Check flowmeters			
Check/Regulate water inlet in tanks			
MONITORING SYSTEM CLEANING			
Cleaning pH, Redox and CO_2 probes			
EMERGENCY OXYGEN LINE			
Check emergency oxygen volume			
INITIALS			
COMMENTS			

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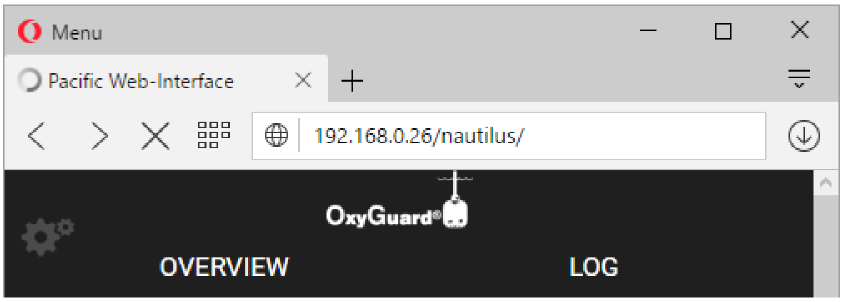
4. Monitoring and control system

4.1. Description of the system

Nautilus is a supplement to OxyGuard Pacific software developed for use in the VicInAqua project. It is designed to permit easy access to the Commander Pacific systems used in the project by means of wireless connection, and it will also function with a wired connection. It can be used on a smartphone and tablet as well as on a PC. The wireless connection uses a standard wireless IP connection, i.e. Wi-Fi, and a wireless access point must be connected to the main Pacific or Commander Pacific system in order to obtain wireless connection. It provides an excellent and easy-to-use system for normal, everyday operation of the systems. It is set up with the algorithms necessary for such normal, everyday operation and does not present the user with functions and possibilities that are not needed. For several reasons, security being the most important, Nautilus only works with a local area network using a fixed IP address for the system.

Nautilus operates using a web browser, for example Google Chrome, and has two main display types, "Overview" or "Log". Both these are set up as needed. It is started by entering the IP address of the "Host" Pacific of the main system into the browser followed by /nautilus/.

Water Treatment:	http://192.168.81.41/nautilus/
MBR:	http://192.168.81.45/nautilus/



4.1.1. Functions

- **System overview**
  The system overview shows actual measurements as well as the most important logged data, and displays actual warnings and alarms. If the user has the necessary access permission such warnings and alarms can be acknowledged.
- **Configuration overview**
  Basic configuration data for probes, inputs, outputs and systems is shown. This includes serial numbers, set points, node addresses, channel numbers etc.
- **Log of measured values**
  Nautilus gives access to the data that is stored in all the Pacific units of the system. Data can be shown as graphs for easy and immediate inspection, and can be downloaded for use or as a security backup.

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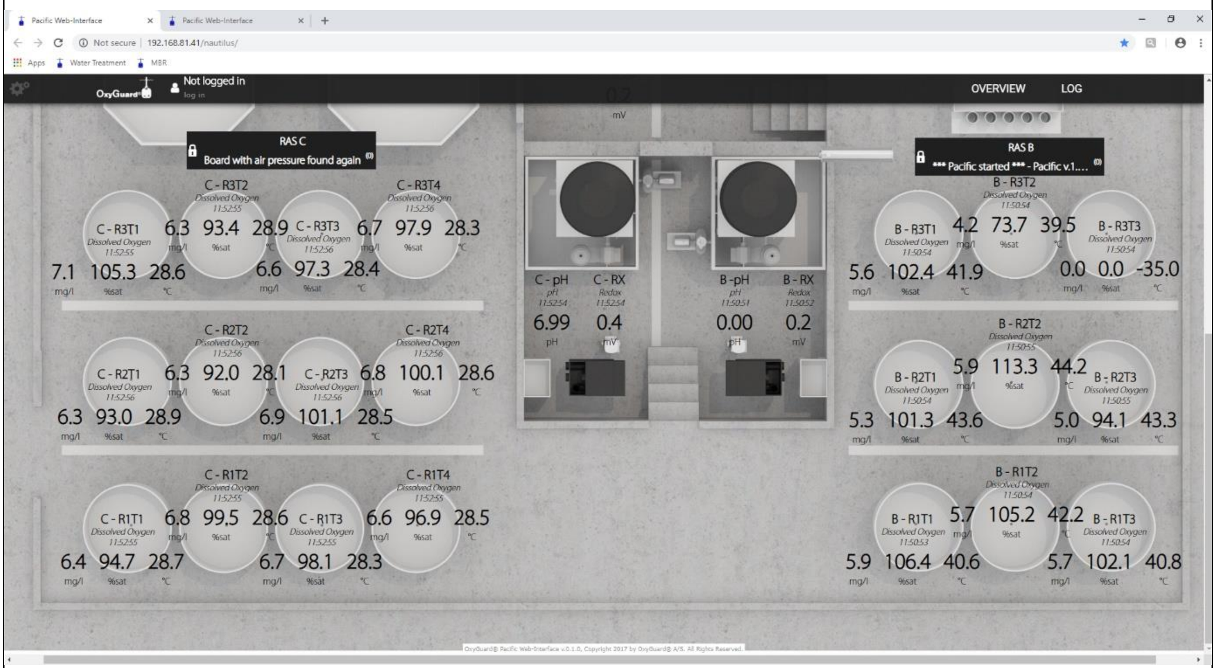
- **System log**
  The system log shows the most important events such as warnings and alarms. The data can be sorted according to type to make it easy to see what is happening and what has happened.
- **Comments log**
  Comments can be added to all the Pacific parts. The Comments panel is very easy to use, and comments can be titled and sorted according to titles so that they can be arranged according to function, for example feeding, health, treatment etc.

4.2. Operation procedures

Nautilus has two main parts, Overview and Log. There are also several panels, partly for an event log and also for system configuration information, as well as a set-up menu.

4.2.1. Overview



The overview showing here-and-now measurements and the actual state of I/O's and relays

The overview shows here-and-now measurements and the actual state of I/O's and relays. Please note that there is an update interval of a few seconds. For detailed information click on the item of interest.
At the right-hand-side of the top bar of each column the latest event log is shown, together with the number of such messages for the last 12 hours.

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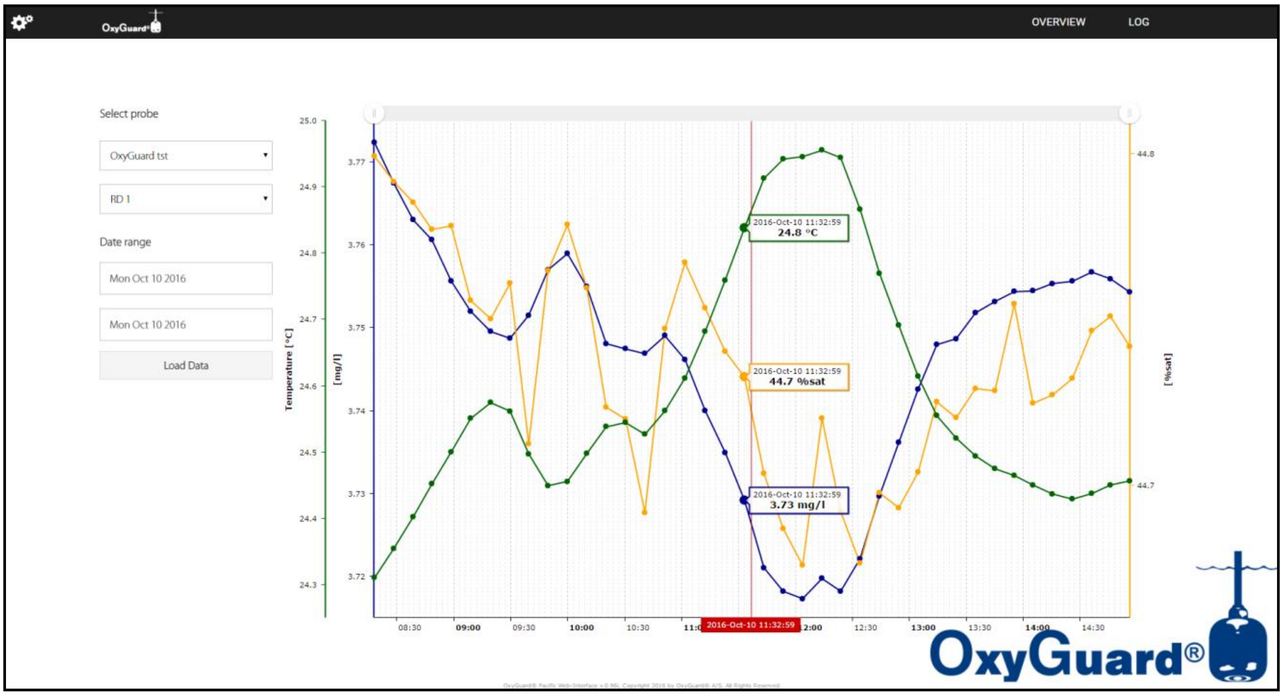
Warnings and alarms
If there is a warning or alarm the associated measurement value will blink yellow or red accordingly, and a message is shown allowing the warning or alarm to be acknowledged, if the operator has appropriate access permission.

4.2.2. Log

The Data log gives access to measurement values stored on the Pacific. To store the log on a PC it must be downloaded, either by using the web interface or by taking a backup of the Pacific. A standard Pacific has capacity to store between 1 and 6 months of values.

View graph
To view a graph, you must choose the system, choose the probe, choose the start and stop dates and then choose "Load Data". When the data has loaded you can inspect it.



Export data
To export data, click on "LOG" at the top right of the graph, and then choose "Export" from the resulting menu. To obtain a .CSV file choose the system, then the probe or probes concerned, then "comment labels", then start and stop times, and then click on "Compile Data". When the data has been collected click on "Download" to save each result.

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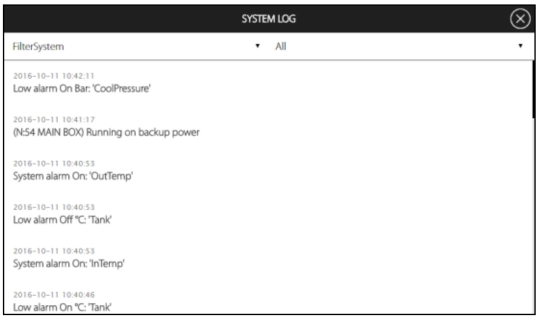
The following example shows three results ready for download:

4.2.3. Event Log

These are obtained using menus from the ”LOG” button

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>System event log panel</td><td>System Comment log panel</td></tr>
</table>

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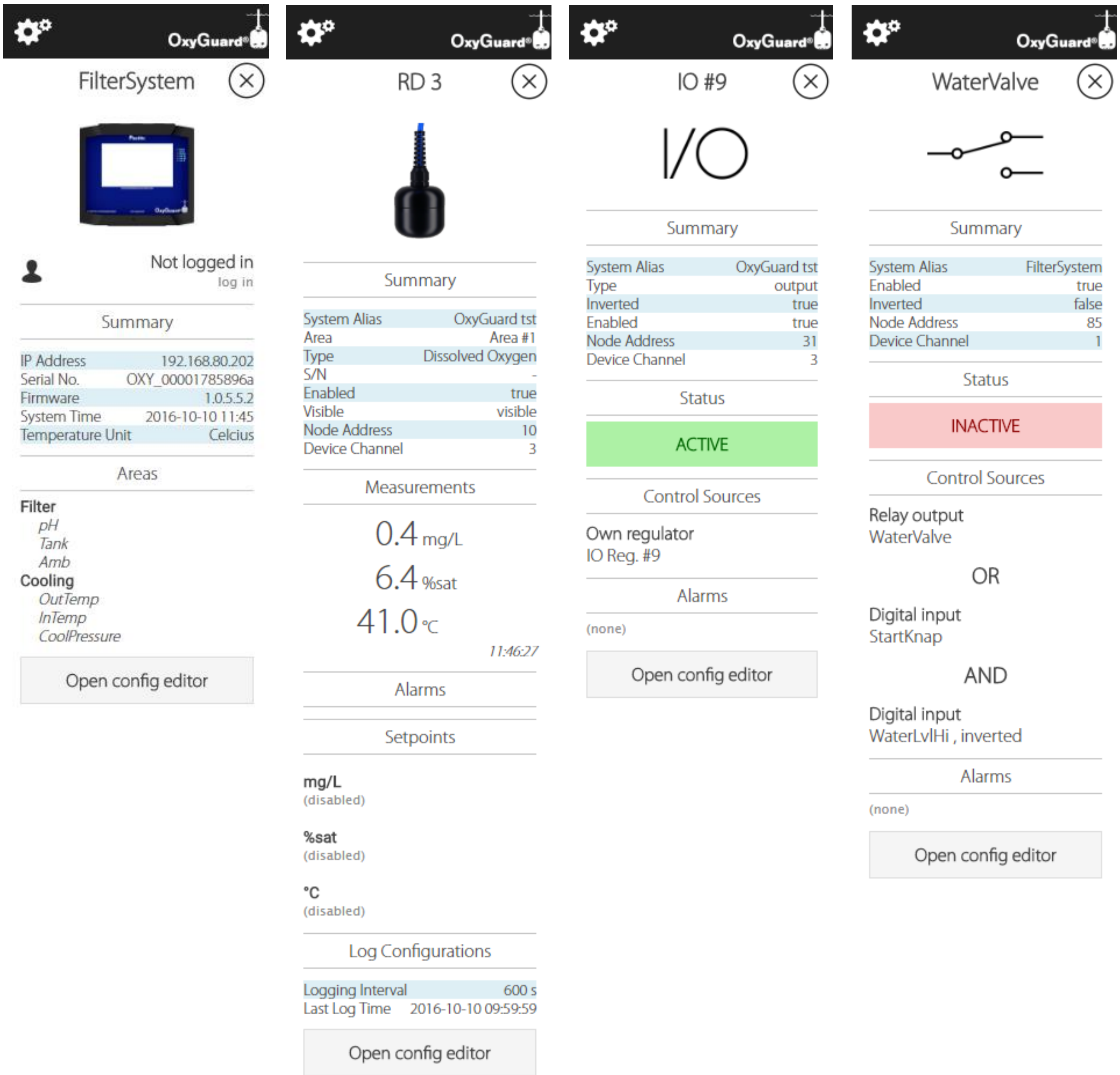
4.2.4. Configuration panels

The detailed configuration information obtained by clicking on a part in the Overview display depends on what type of part is concerned:



If changes are needed, click on ”Open config editor” at the bottom of the panel.

4.2.5. Login

You must be logged in to acknowledge warnings and alarms, or to make changes to the configuration.

To log in click on the system that you will connect to or the Overview, and then click ”log in”.

A padlock icon shows whether or not you are logged in.

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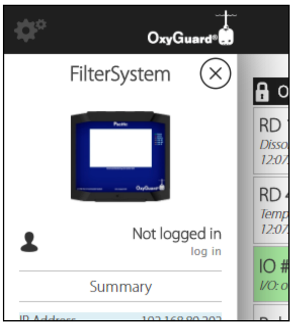
<table>
<tr>
<td>
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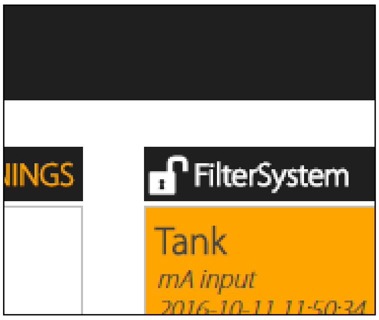
<td>
</td>
</tr>
<tr>
<td>In this example click on ”log in” to log in</td>
<td>In this example you are logged in</td>
</tr>
</table>

4.3. DO probe- Directions for use

The DO probe does not need regular service or renovation – just keep the membrane reasonably clean. Renovation intervals are typically between 3 and 5 years. Please see the maintenance instructions.

The probe does NOT need frequent calibration. The actual calibration frequency depends on the actual conditions and on the accuracy wanted. It is recommended that a calibration check, that also will ensure that connected equipment is working, is performed at suitable intervals.

4.3.1. Calibration check

You can check calibration by wiping the membrane clean and placing the probe in the air, protected from sunlight and direct heat. Check the measurement after a few minutes. If it is close (e.g. +/- 3%) to the calibration value of 100.5% saturation, then calibration is probably not needed. Any deviation is probably because the probe has not attained the same temperature as the air. The temperature should be stable. If, after 30 minutes, there is still a deviation then calibration is indicated. The probe must have the same temperature as the water or air it is calibrated in and must be allowed to attain this temperature before being calibrated.

4.3.2. Calibration

If a calibration check indicates that calibration is needed the automatic calibration process can be started. Please see the instructions for the system concerned.

4.4. DO probe- Maintenance

4.4.1. Regular care

The frequency with which care is needed varies according to the actual conditions. You can start with frequent cleaning and control and increase intervals as needed to maintain the measurement accuracy that you want.

Once a month

Wipe the membrane. There is biological activity that deposits a film on all surfaces in all healthy waters, and thick deposits can give errors. You can check measurements before and after

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wiping the probes. If the measurements, when steady, are the same before and after you can probably choose longer intervals for wiping the probes.

Check the measurement. Take the probe up, wipe the membrane and hang it in the air. After a couple of minutes, it should give a measurement of between 98 and 103% saturation. This is a good, quick check that both probe and electronics are working. A deviation from 100 or 100.5% is because the probe does not have the same temperature as the air.

If the measurement is not between 98 and 103 you should wait. If conditions are unstable, i.e. if the temperature is changing, it might not be possible for the probe to stabilize because temperature equalisation happens slowly in the air. If calibration is indicated, follow the calibration instructions.

After many years

Renovate the probe with a new anode, membrane and electrolyte. Renovation is only indicated if the probe has been used for several years and you cannot calibrate it, or if the membrane should be damaged. If the probe is opened it must be renovated.

4.4.2. Fault-finding

Unstable measurements

The most probable cause of unstable measurements in a new installation is that the probe is placed over a diffuser! If the probe has worked well for a long time renovate it. Instability can also be caused by the probe being not completely filed with electrolyte, in which case renovation is indicated.

To check cables and connections start by checking visually. Check the cables, open any junction boxes and check that they are completely dry. You can switch the probe under investigation, with one that you know is in order, at the junction box nearest the probe. If the measurement is now OK renovate the probe under investigation. If there is still a fault, connect the good probe directly to the equipment terminals. The fault will probably now disappear, indicating a fault in the wiring.

If the dissolved oxygen value in a tank with oxygen dosing oscillates, i.e. swings between two values at regular intervals, the dosing settings probably need adjusting. This can also be caused by poor mixing of water in the tank or by unfortunate placing of the probe.

4.4.3. Check of probe

When the probe is open for membrane replacement/renovation a simple check can be performed, as described below in step 5. Do not open the probe if it can be calibrated correctly and is completely filled with electrolyte.

4.4.4. Membrane replacement

The probe's membrane should be wiped clean from time to time.

Membrane replacement should only be performed if:

- The membrane is damaged
- After long use (years), you cannot calibrate up to the correct value
- The probe is not completely full.

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The procedure, described below, will completely renovate the probe:

1) Remove the probe, rinse it and unscrew the cap. If it sticks, tap the side of the probe gently with a hammer then try again. Discard the electrolyte, rinse the cap and top part, clean off any brown or black oxide deposits. Note that the used electrolyte will be very dark.

2) Inspect the anode. If the probe was filled correctly when it was last renovated it will be easy to clean the dark deposits from the anode using a nail brush or similar. If the probe was not filled completely the anode will be very corroded and must be replaced. Check that the nut under the anode is tight before fitting a new anode. Wash the new anode in soapy water before use to remove any protective oil.

Clean and check

3) Check the cathode and remove any deposits using the plastic abrasive pad supplied with the probe or a little wet or dry emery paper, grade 600. The cathode MUST NOT BE POLISHED.

4) Rinse and dry the top part.

Clean cathanode

Plastic scouring pad

5) You can now perform the following easy "Dry Probe Check" on the probe. Dry the probe completely, especially the cathode and area around it, and observe the measurement or output signal. The probe should have zero output, i.e. 0.0 mV when measuring between the brown and blue leads.

You can also disconnect the yellow and black leads for the temperature sensor and check that there is between 10 and 25 kilohm between them. Contact OxyGuard or your distributor if this is not the case.

Brown
0.0 mV=OK
1.0 Blue

Completely dry

6) Fill a new (or renovated) cap to the brim with electrolyte. The excess electrolyte helps remove any air bubbles. Use type 3 electrolyte. The cap is renovated by fitting a new membrane and O-ring, see below.

New or
Renovated
Cap

7) Locate the flat machined from the thread. Lower the upper part into the cap and turn the cap half a turn to engage the thread.

Flat

1/2 turn

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8) Tilt the probe 15° so that the flat is uppermost and screw the cap onto the top part. Excess electrolyte and air should dribble out at the flat.

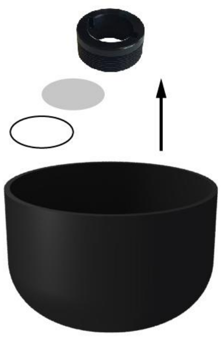
It is important that the probe is filled completely.
When you are certain that the probe is filled completely tighten the cap **hard.**

Important: After renovation the probe can be regarded as new. It should be hung up in air to stabilize for at least an hour before calibration. It is advisable to re-calibrate after a day or two.

A new membrane can easily be fitted to the cap, as shown in the drawing. The membrane must be flat, if it wrinkles remove it and try again with a new one. It is important that all parts are clean and dry. A cap must not be re-used without replacing the membrane, as the membrane stretches to fit the cathode, and will not fit perfectly a second time. Make sure you use the membrane and not the coloured backing paper. The Commander Probe uses membranes with grey backing paper, order number D10MC.

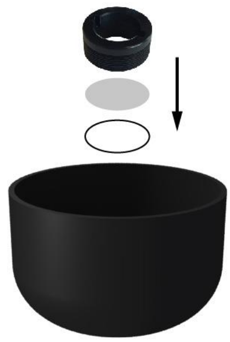
1. Unscrew ring, discard used membrane and O-ring

2. Clean and dry cap and ring **thoroughly**



3. Assemble as shown THE O-RING GOES UNDER MEMBRANE

4. Tighten the ring. If the membrane wrinkles, try again with new membrane.



When probes are delivered “dry” (without electrolyte), please remember to scratch the anode with a screwdriver before you fill in electrolyte.

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5. Energy supply system-Photo Voltaic

5.1. Description of the system

The solar system integrates different energy production technologies. The main objective of the solar system is to guarantee an uninterrupted electricity supply around the clock. Another objective is to reduce energy costs by minimizing electricity consumed from the grid. It is configured as a hybrid solar system for own consumption with zero feed-in. The system includes 52 PV modules, a biogas generator, a diesel generator and two thermo-electric-generator modules (TEG) as electricity sources. 12 Li-Ion batteries with a total capacity of 30 kWh store energy for the event of a power cut or for use during night time.

The 14.3 kWp solar photovoltaic array consists of 52 PV modules which produce electricity from the sun during daytime. According to the current electricity consumption on site one share of the electricity produced from the sun is directly supplied to consumers. The other share exceeding the current electricity consumption is stored in the batteries for the use during power cuts or during nighttime. The biogas generator is integrated into the solar system. It is automatically switched on if sufficient biogas is available and feeds the electricity produced to the inverter. The solar system is also connected to the grid and uses the national grid as an alternative power source. If the PV modules and the biogas generator are not producing sufficient power to supply all the consumers additional power is consumed from the grid. For the event that the PV modules and the biogas generator are not producing enough power, the national grid has an outage and the batteries are empty a diesel generator serves as backup. The diesel generator starts automatically and feeds its power to the inverter. The power generated by the PV TEG module as well as the biogas TEG module are directly fed to the consumers as AC power. Sepearte energy meters monitor the energy production of the TEG modules for reasearch purposes.

The electricity consumers on site are seperated in emergency consumers and normal consumers. The consumers which are crucial for operations are connected as emergency consumers and are always powered. The more flexible consumers which are not crucial for operations and can be switched off for some time are connected as normal consumers. The normal consumers are switched off in the event of energy scarcity to extend battery runtime. This happens in the event of grid outage and if the battery state of charge falls below a predefined limit.

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The power sources integrated into the energy system have the following priorities:

1. **Solar PV**

   The solar PV modules produce always as much power as possible or as much as can be fed to the consumers and the batteries.

2. **Biogas generator**

   The biogas generator is the generator with the first priority and always produces electricity if enough biogas is available.

3. **Batteries**

   If Solar PV and biogas production is reduced and the battery state of charge high enough, consumers are supplied from batteries.

4. **National grid**

   Power is consumed from the grid if solar PV and biogas generation is not sufficient and if the battery state of charge is below a certain limit.

5. **Diesel generator**

   The diesel generator serves as backup. If there is no solar PV and biogas generation, if the battery state of charge is low and if the national grid has an outage the diesel generator supplies emergency power to the system.

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5.2. System specifications

In the table below a list of the main system components is provided.

	Type	No.	Specification
1	Solar module	52	Axitec 275 Wp, AC-275P/156-60S
2	Solar Module TEG	1	Axitec 275 Wp, AC-275P/156-60S, with TEG elements
3	Solar roof substructure	-	Schletter Aluminium, SingleFix-V
4	Battery housing	3	BYD, B-Box 10.0
5	Battery	12	BYD $LiFePO_4$, B-Plus 2.5
6	Inverter	1	Victron charge-inverter, Quattro 48/15000/200-100/100
7, 8	Charge controller	2	Victron charge controller, SmartSolar MPPT 250/100-MC4
9	Charge controller	1	Victron charge controller, SmartSolar MPPT 250/70-MC4
10	Charge controller	1	Victron charge controller, SmartSolar MPPT 150/60-MC4
11	Charge controller	1	Victron charge controller, SmartSolar MPPT 150/35
12	Inverter	1	Aeconversion Micro-Inverter, INV350-60EU
13	AC connection box	1	1-phase grid connection, fuse 100 A
14	DC connection box	1	DC connection with circuit breakers of charge controllers, batteries and inverter
14	TEG-biogas connection box	1	AC connection of TEG-biogas elements with circuit breaker and energy meter (Victron ET112)
15	TEG-PV connection box	1	AC connection of TEG-PV elements with circuit breaker and energy meter (Victron ET112)
16	Transfer switch	1	AC connection of biogas and diesel generator with energy meter (Victron ET112)
17	System control	1	Victron Venus GX

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Main system components : Number refer to table with list of components

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Power electronics

5.3. Operation procedures

The solar system is fully automated and doesn´t require manual interventions during normal operations. The different power sources as well as normal and emergency consumers are controlled automatically by the Venus GX system control unit.
The solar system has an online monitoring system which allows remote monitoring and system control through the internet. System parameters like solar production, power consumption, battery state of charge and many others can be reviewed in the online monitoring system. With the personal login data, the online monitoring system can be accessed with the following link: https://vrm.victronenergy.com/login

Soiling or other pollution of solar modules can significantly reduce the power output of the solar system. Therefore, the solar modules have to be cleaned at least every three months. If the PV modules are visibly dirty or power output reduces even more frequent cleaning can be necessary. For cleaning clear water and a wet mop, cleaning rag or similar have to be used. It must be ensured that the panels are not getting scratched and that sufficient water is used.

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In the course of system failures or for maintenance works it can be required to switch off or to restart the solar system. To restart the system the following switch off and switch on procedures have to be used:

Switch off

1. Set all the circuit breakers in the DC connection box to off.
2. Switch off all the batteries. Every battery has to be switched off separately. Press the on/off button of every battery for about 3 seconds until the LEDs turn off.
3. Check if all batteries are switched off. If all batteries are off the LED of the Venus GX also has to be off.
4. Set the Victron inverter to off.

Switch on

1. Switch on the batteries. The batteries have to be switched on separately. Press the on/off button of every battery for about 3 seconds until the LEDs turn on.
2. Check if all batteries are switched on. After switching on the batteries, the LED of the Venus GX also has to be on.
3. Set the battery circuit breakers in the DC connection box to on.
4. Set the inverter circuit breakers in the DC connection box to on.
5. Set the Victron inverter to on.
6. Set the charge controller circuit breakers to on.

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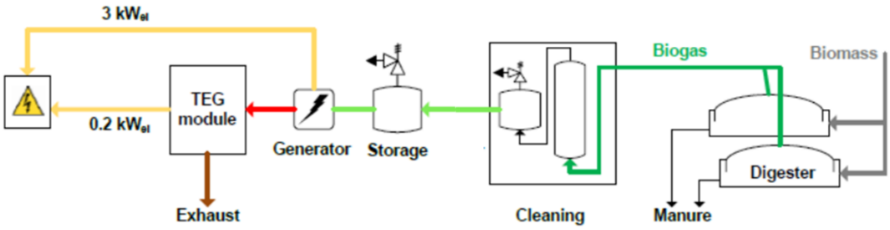
6. Energy supply system-Biogas and TEG

6.1. Description of the system

The biogas plant consists of two digesters. Each one has a slope on one end of the digester. Cow dung or sludge from the wastewater treatment plant is deposited in the influent box on one side of the digesters and leaves the digesters on the opposite side with the sludge flowing down by gravity due to the slope. The digestors are made of a PVC material and are supported by brick structure to maintain the shape and position of the digestors. Biogas is tapped from the centre of the digestors as shown in the figure below by a polypropylene pipe which takes the gas underground to the brick house were the gas is cleaned and stored before going to the biogas generator.

			
Biogas digester (front) for cow-dung fermentation	Biogas cleaning and storage (empty balloon)	Volume meter and gas pump	Biogas compressor and electric generator

The generator is modified with an electric starter, so it can be automatically controlled (On/ Off) by the VicInAqua controlling system. After harvesting the biogas from the digesters with a gas pump, the raw gas is cleaned inside the biogas cleaning stage containing CO2-scrubber (lime-stone), desulphurizer (iron wool) and dehumidifier (desiccant) and the treated, high quality gas stored inside a gas balloon. If desired, the electric generator is actuated which also starts the biogas compressor. The generator incinerates the biogas and feeds the electricity inside the VicInAqua system. The exhaust gases will be connected to the biogas-Sirio TEG module to further use the waste heat by thermoelectric generators, which convert the heat into electricity. The Sirio TEG module consists of a thermoelectric generator canopy, an electric panel and a DC/AC inverter. Hot gas flow enters the thermoelectric generator, is cooled down by thermoelectric modules in aluminium heat exchangers and leaves the generator at a lower temperature. The thermoelectric modules convert about 5% of the heat received by the gas flow into DC electrical power. The remaining heat is transferred to cold plates, which are cooled by a water-glycol mixture flowing in a closed circuit thanks to a pump.



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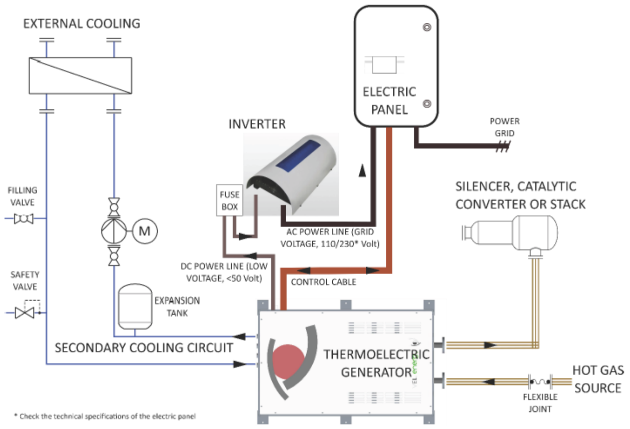
Thermoelectric generator canopy



TEG functional scheme

The electrical power produced by the thermoelectric modules is converted into AC power (typically 230 V– 50 Hz) through an inverter connected to the grid via the electric panel. The thermoelectric generator operation is supervised by a control automatic system embedded in the electric panel. The control system is able to monitor the thermoelectric power generation and stop the hot gas source operation in case of modules overheating.

6.2. System specifications

Sirio TEG must operate in well-ventilated interior spaces, and must be sheltered from direct sunlight, dust and moisture. Please consider that the generator canopy may become very hot during the operation. Consequently, surrounding parts/devices should be located at an adequate distance from the generator canopy and protected against heat irradiation, if necessary.

Operating temperature: 5-40 °C
Minimum distance between the canopy lateral panels and surrounding parts/devices: 0.5 m
Minimum distance between the canopy top panel and surrounding parts/devices: 1 m
Indoor use is the only one allowed.

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6.3. Operation procedures

6.3.1. Biogas quality

The following tables present Biogas purification data. Biogas composition can vary depending on the quality characteristics of the feedstock used. The Biogas cleaning and upgrading systems also vary with contaminant removal efficiencies. The results presented below are the minimum results that the wet scrubbing system can achieve. Higher purity can be achieved depending level of maintenance. If the biogas quality is not achieved within this range, the biogas cleaning system needs to be maintained accordingly. For the CO_2 scrubber, the water has to be refilled with fresh and clean tap water, the iron wool within the de-sulphurizer has to be checked for its corrosive state and replaced if necessary. For the dehumidifier, the desiccant could be saturated and if so has to be replaced.

	Percentage composition in %	
	Raw biogas	Cleaned biogas
Nitrogen (N_2)	21.3 – 24.0	21.3 – 24.0
Methane (CH_4)	48 - 54	70 - 73
Carbon dioxide (CO_2)	25.8 – 28.0	5.8 – 9.5
Oxygen (O_2)	0.9 – 1.5	0.9 – 1.5
Hydrogen Sulphide (H_2S)	Traces	Traces
Siloxanes	Traces	Traces
Ammonia (NH_3)	Traces	Traces

6.3.2. Running the digester

Initial feeding of the digester is accomplished by filling the two digesters with 400L of slurry each and waiting for about 10 days in the Kisumu temperature to allow the slurry to undergo anaerobic digestion. To produce enough gas constantly, the digesters must be fed with at least 40litres of slurry each every day or 80litres every two days.

6.3.3. Preparing the slurry

Make the best slurry by mixing 3 parts of water with 1 part of cow dung. The mixture is stirred in a suitable container for about 3 minutes to obtain a consistent slurry without lumps. This is then poured slowly with a funnel through the inlet pipe of the digester. Dry or old cow dung should not be used as it may already be exhausted.
Precaution: The water used to make the slurry must be free from antibiotics, soap or detergents as these will inhibit bacterial growth and reduce gas production.

6.3.4. Gas usage

The gas from the digester can be used for cooking, heating or running the biogas generator. Before releasing the gas for any application, ensure that there is enough gas in the digester or storage vessel at a pressure of at least 3kPa.

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6.3.5. Health and Safety Precautions

1. Do not light a fire or use a naked flame near the digester as this may cause an explosion if there is a leak.
2. Any area where the gas is being utilized should be well ventilated to avoid accumulation of the gas in case of a leak.
3. Biogas slurry should not be handled with bare hands as it could contain parasitic, bacterial or viral contamination. Always wear PVC hand gloves when handling slurry.
4. Care should be taken not to prick the digester cover with a sharp object as this may cause leaks.
5. Do not grow large plants next to the digester as the roots of these plants may crack the masonry and damage the digester
6. Children should not be allowed to play with the taps or fittings as this may loosen the fittings and cause leaks

6.3.6. Biogas Generator

BIOGAS ENGINE & GENERATOR SPECIFICATIONS FOR MODEL QH3600BG

Type of engine	Single cylinder air-cooled, 4-stroke
Oil Volume (engine capacity)	1.1 Liters
Recommended Oil type	SAE 10W-30
Noise Level at 7m	74 db
Ignition system	CTI (Contact-temperature ignition)
Starting method	Recoil start/electric start
Inlet air pressure	2.8±0.5 kPa
Min. Fuel consumption	3.5 m^3/hour
Rated voltage	220V a.c
Rated frequency	50Hz
Rated output power	2.8kW
Maximum output	3.0kW
Power factor	1.0
Inbuilt d.c. battery charging system	12V, 8.3A

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Maintenance

To have generator in good condition, reduce parts depreciation and prolong its working life, technical maintenance of the system must be strictly enforced. Please stop the engine before maintenance.

Item	Specific operation	Check before running	Every month or the first 20 hours operation	Every 3 months or every 50 hours	Every 6 months or every 100 hours	Every year or every 300 hours
Spark plug	Check ignition system, adjust the electrode gap to 0.7…0.8 mm, clean the carbon deposit or change the spark plug				√	
Lubricant	Check the engine oil level, oil leakage, air leakage.	√				
	Change the lubricant		√			
Air filter	Clean and replace if necessary			√		
Valve Lash	Check and adjust after the engine cooling					√
All cleaning	Remove the cylinder head, cylinder body and piston rings, then clean all the carbon deposit					√

Change the lubricant

1) Put the generator on the flat floor, start for a few minutes to raise the temperature of the oil, then stop, unscrew the filler plug.

2) Put a box under the engine, unscrew the oil drain plug, then the oil will discharge from the crankcase.

3) Check the oil drain plug, seal and screw down.

4) Fill enough lubricant to the prescribed maximum of the oil filler.

5) Fit with oil drain plug and packing washer (change if it was broken), don't fall off foreign body into the crankshaft box

Clean the airfilter

Don't start the generator without air filter, or it would lead to cylinder damage, don't twist the foam filer, it will make damage.

1) Unscrew the nut, and remove the shell of the air filter.

2) Take out foam filter from the shell of the air filter.

3) Clean the foam filter by uninflammable wash buffer and squeeze dry.

4) Use air filter oil or SAE#20 lubricant to soak the foam filter, then nipping out a folded excess

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oil, remain the foam filter slightly oily state.

5) Put the foam filter back into the shell of the air filter and make sure the foam filter at the right position without spare room.

6) Install the shell of the air filter then fix the clips

Safety Precautions

To ensure safe and reliable, please comply with the following precautions when using the generator. Otherwise it may lead to the invalidity of the generator guarantee commitment, also may damage the generator or injury people.

1) To prevent from being poisoned, never use the machine indoor or anywhere with air blocked.

2) Do not use in rain, snow and other wet environment.

3) Do not connect with the public power supply line.

4) Please keep the generator from the combustible at least 1 m.

5) Please operate the machine on the flat floor.

6) Do not leave children or pets near the machine when using the generator.

7) This is air-cooled generator. To ensure normal engine cooling, you should remove the dirt on the heat sink, fan cover, fan, etc.

8) Operator should be familiar with operation principle and generator structure, know how to emergency stop and control the operation of all components. Not allow untrained personnel to operate the machine, insist on periodic maintenance, and fix up the machine on time when there is a problem. Prohibit working when out of work.

9) Gas inlet should be sealed tightly, prohibit gas leakage.

10) To avoid scalding, don't touch the muffler and related hot parts during operation or when just finished using the generator.

6.3.7. TEG operation management

Standard operation

Sirio TEG is supervised by a control system able to automatically manage Sirio TEG in every operating condition. So, once the control system was loaded, Sirio TEG operation does not require any action by the operator, except the alarm reset (if the alarm reset requires a manual intervention). The thermoelectric generation automatically starts when the hot gas flows throughout the system and cold plates within the thermoelectric package are adequately cooled. The system will operate until the hot gas source is active and the hot plates in contact with thermoelectric modules are sufficiently hot. So, to start and stop the thermoelectric generation does not require any action by the operator. The thermoelectric generator can operate in safe conditions only when the control system is on.

For these reasons, Sirio TEG control system should be always active, also when the hot gas source is off. Switches "F1.2" (general switch) and "F1.10" (inverter switch) can be turned off

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only in case of maintenance, emergency and permanent deactivation of the plant (hot gas source and Sirio TEG).

Alarm mode

Sirio TEG status turns into ALARM mode when:

- Thermoelectric modules are overheating. This could be caused by an excessive power heat transferred
- by the hot gas flow to the modules or by a poor cooling of cold plates due to a fault occurred in the
- primary or in the secondary cooling circuit.
- Primary coolant temperature is close to 0°C or 100 °C.
- Primary coolant pressure decreases below 0.5 bar.
- The temperature of the hot gas flow exceeds 700 °C.
- The pump in the primary cooling circuit does not start because of a relay fault.
- The hot gas source power signal is not correctly acquired by Sirio TEG control system
- One of the two PT100 probes, or one of the three thermocouples aimed at controlling the temperature within key components of the thermoelectric generator are damaged or not properly connected.

When Sirio TEG is under ALARM, the key next to the control system display blinks (Figure 14a) and the PLC buzzer activates. The ALARM mode causes the opening of the status relays within the electric panel and the consequently interruption of the gas source operation. For instruction to turn the TEG status back to Stand-by or running mode consult the Sirio TEG manual.

6.4. Maintenance procedures

6.4.1. Taking care of the digester and fittings

The following steps should be taken to ensure that the digester runs smoothly and operates trouble free:

1. Pressure checks: Check the digester pressure occasionally to ensure that the release valve is functioning. High pressure in the digester will lead to a rupture of the digester cover. Pressure should not exceed 4kPa.
2. Weekly PH measurements: Check the PH of the slurry weekly (at the outlet). The PH should be 7±0.5. Higher or lower PH results to low gas production. The reserve slurry in the digester should be partially exhausted (flushed) through accelerated feeding of the digester (100kg of cow dung mixed with water in the ratio of 1portion of cow dung to 3 portions of water by volume) if the PH is greater than 7. If the PH is less than 7, it could mean that you have just fed the digester and you need to wait for a few more days.

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6.4.2. Maintenance of thermoelectric generator

Cleaning

Clean the panels of thermoelectric canopy using a soft, damp and lint-free cloth. Do not use solvents, aggressive cleaning agents or abrasive cleaners. The penetration of moisture within the canopy should not damage the device.
Make sure that the generator louvers are not obstructed, and kept free of dirt and loose objects. In case top and rear louvers are significantly obstructed by dirt and dust, panels can be removed from the canopy to make the cleaning operation easier. Lateral panels can be removed as well to clean the generator inside. Use a jet of compressed air for a safe cleaning of the system.

Coolant pressure

Pressure of coolant within the primary cooling circuit must be checked monthly. In case the coolant pressure is below 0.7 bar, refill the primary circuit following the instructions in the Sirio TEG manual.

Clamping force

Thermoelectric modules achieve best performance only if properly clamped. So, clamping force should be periodically checked (three/four times a year).

Follow the procedure below to check and regulate the clamping force;
1. Make sure that the thermoelectric generator is completely cooled down (i.e., at ambient temperature).
2. Remove the top panel of the thermoelectric generator from the canopy.
3. Remove the thermal insulation cover releasing the fixing springs.
4. Check the mobility of central washers using fingers. If washers are free to slightly move, there is no need to regulate the clamping force. If one (or more than one) washer cannot be moved or shows too much play, clamping force should be regulated. Force regulation can be performed acting on the lateral nuts that fix each beam (see white arrows in Figure below).

Central nuts must not be never screwed or unscrewed!

5. Use a wrench to screw or unscrew the two lateral nuts until the corresponding washer at the beam centre can slightly be moved using fingers. Screw the nuts to increase the washer play and unscrew the nuts to decrease the washer play. Make sure to screw or unscrewed both the nuts acting on the same beam to assure a uniform clamping force (the use of a level may make the regulation easier).
6. Make sure that all washes show a similar play at the end of clamping force regulation.

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7. Replace the thermal insulation cover and reinstall the top panel on the generator canopy

7. Agriculture

7.1. Description of the system

The vegetable garden is around $80m^2$ and is maintained using a drip irrigation system. The system is constructed using the following components:

a. Drip tank
b. Main pipe
c. Drip lines
d. Connectors
e. Sieve

The seedbeds are raised, and the drip irrigation lines run along the seed beds. Several species are grown in the vegetable garden; tomato, spider flower, spinach, collards (Sukuma wiki) and black nightshade. Diammonium phosphate (DAP) and calcium ammonium nitrate are used as fertilisers.

	
Installation of drip irrigation system	Vegetable garden

7.2. Operation procedures

7.2.1. Land preparation

Land preparation comprises of the following activities;
a. Clearing of any vegetation around the pegged area.
b. Ploughing of the land.
c. Levelling of the ploughed land.
d. Making of the raised seedbed.

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7.2.2. Planting of the seedlings

Seedlings from the nursery are planted in the raised seedbed. Spacing of the seedlings should be as follows;

Tomato	-60cm by 60cm
Spider plant	-45cm by Drill
Spinach	-60cm by 30cm
Collards	-60cm by 60cm
Black nightshade	-45cm by Drill

Multi-storage bags are also used, which are composed of the following;

a. Planting bag-0.7m in height and 1m in diameter
b. Sieved soil-A mixture of cow dung and soil.
c. Empty Bucket-5L
d. Ballast-To be put inside the bucket and placed right at the centre of the planting bag for uniform distribution of water.

	
Preparation of planting bags	Vegetables growing in the planting bags

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