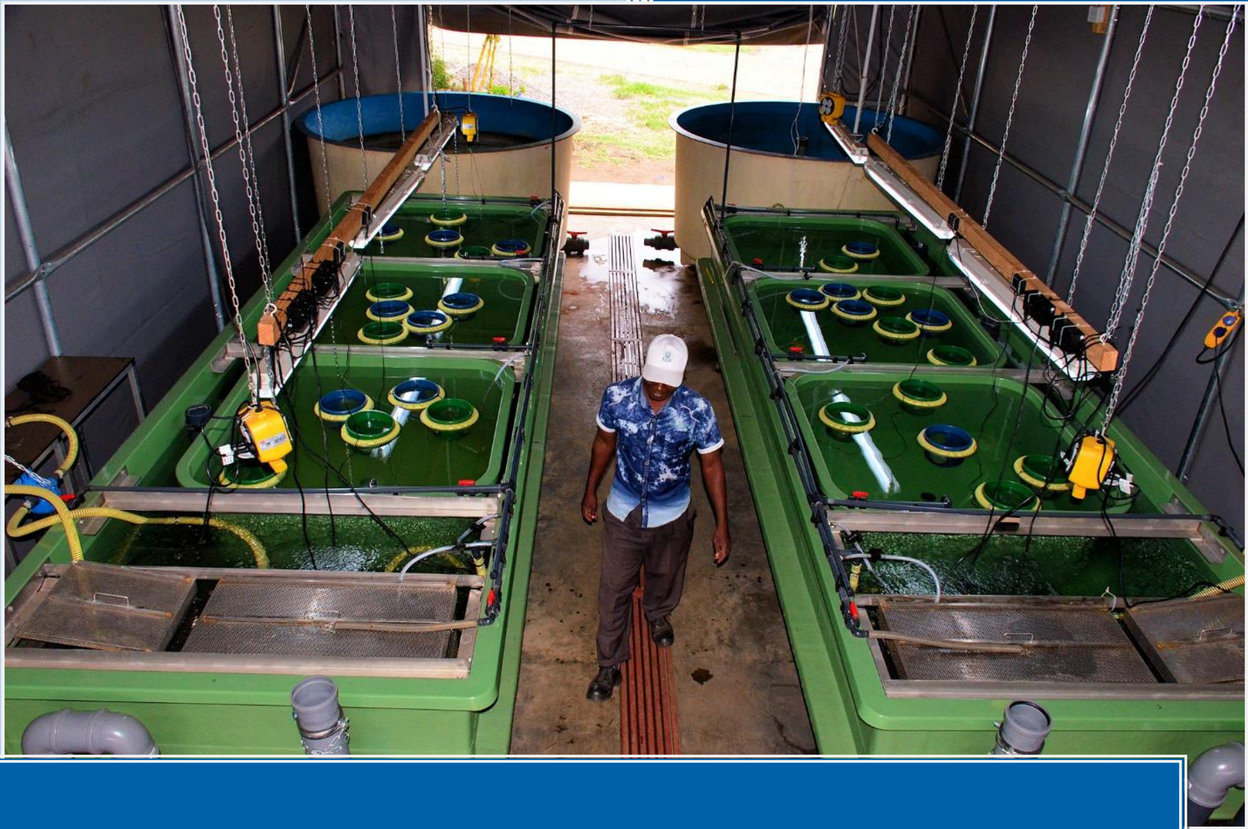
Introduction to the Operation of the Solar Powered hatchery at the Bunda College Farm

Version 1.0, May 2019



Hatchery Operation Manual

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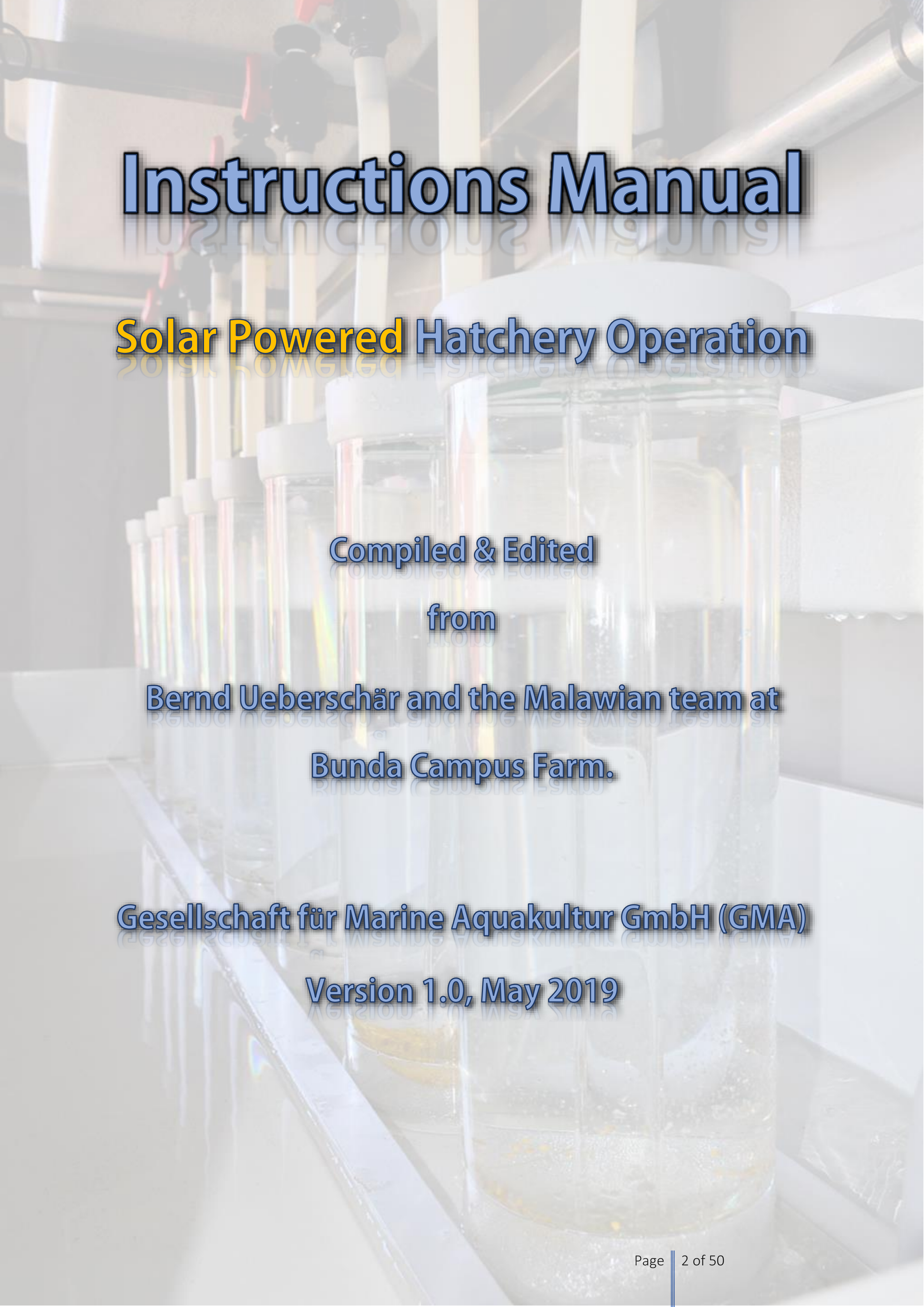
Gesellschaft für Marine Aquakultur GmbH (GMA)



Instructions Manual

Solar Powered Hatchery Operation

Compiled & Edited

from

Bernd Ueberschär and the Malawian team at

Bunda Campus Farm.

Gesellschaft für Marine Aquakultur GmbH (GMA)

Version 1.0, May 2019

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<u>Please note:</u> *This instruction manual is the 2nd Version and will be updated according to changes in the set-up, management & technologies which may occur in the future.*

Introduction

Implementation of New Hatchery Technologies to Improve the Supply of Tilapia fingerlings for Rural Farmer in Malawi.

A contribution of the R&D project "Improving Community Health-Nutrition Linkages through Solar Energy Based Fish and Crop Integrated Value Chains (Acronym "ICH LIEBE FISCH"), a cooperation between Germany and Malawi.

Background

The project is being accomplished under the umbrella of the German research cooperation for global food security and diversified agriculture for a balanced nutrition in Sub-Saharan Africa. The project is financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Office for Agriculture and Food (BLE). The project has mainly two German partner (Fraunhofer Research Institution for Marine Biotechnology and Cell Technology, EMB and the Association for Marine Aquaculture, GMA) and five Malawian partner and NGOs with the Lilongwe University of Agriculture & Natural Resources, Aquaculture and Fisheries Science Department (LUANAR-AQF) being the Malawian coordinator in the project.

Innovative hatchery technology for Malawi

Propagation and production of fingerlings in Malawi is usually conducted in ponds with all species and generations of tilapia. This implies, however, an unfavourable environment for fingerling production, including predation (predatory tadpoles from frogs are a huge problem in open ponds), cannibalism, feed competition and environmental impact. Thus, the number of offsprings which can be expected from the farmer in a breeding season is unknown.

Thus, one of the major goals of the project ¨Ich liebe Fisch "was to establish technologies which improve significantly the stable supply of viable fingerlings to farmers which want to grow fish for food and for the market. To achieve this goal, the project has provided a solar powered indoor hatchery which is designed to support intensive production of tilapia fingerlings, specifically for *Oreochromis karongae* (the "real" Chambo).

The design of the hatchery is based on a design which has proven it´s usefulness in fish larval rearing since more than 25 years. The design was adapted to the specific needs under the conditions in Malawian and the kind of species which will be reared in this facility. The main elements of the hatchery are two large fiberglass tanks with smaller tanks hanging inside of the big tanks (Figure 1). The advantage of this compact design is obvious. The water conditioning can be managed in the big tank (heating, aeration, filtering etc.) without having any mechanical impact on the larvae inside the small tanks. On the other hand, the larvae inside of the small tanks are practically swimming in about 12 cbm of water. The water in the big tank keeps the water temperature constant for all smaller tanks, which is a huge advantage if research trials will be conducted in this facility.

The equipment used and the water flow is depicted and annotated in Figure 2. Each unit has a two-way circulation and can be operated in a batch mode, which means that a certain volume of water, based on the current water condition, is being exchanged or the system can be operated in a flow-through mode. The second option might be difficult to apply under the conditions in Malawi, since constant water pumping often fails because of frequent failure in grid electricity.

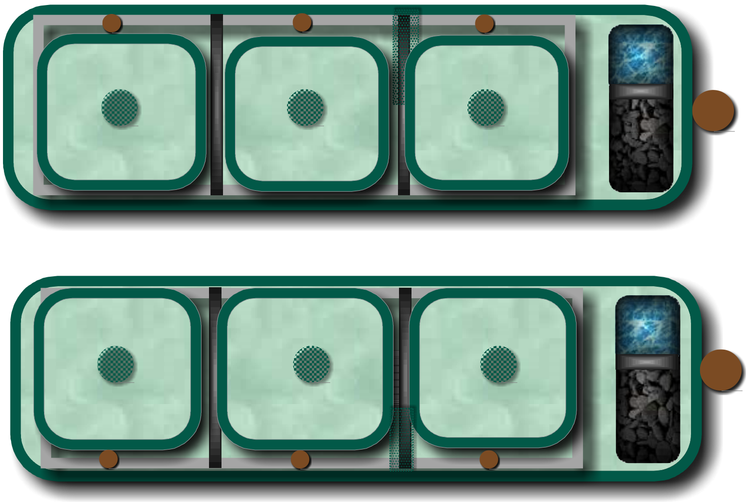


***Fig.: 1:** The hatcheries main elements are two identical units; each unit has a large fiberglass tank with three smaller tanks inside. Dimensions of the large tanks about 6.0 x 1.9 x 1.1 m (L x W x H). Dimensions of the smaller tanks are about 1.3 x 1.2 x 0.7 mm. Each unit has the same equipment and can be operated independently from each other, which allows e.g. rearing trials with different water temperatures.*

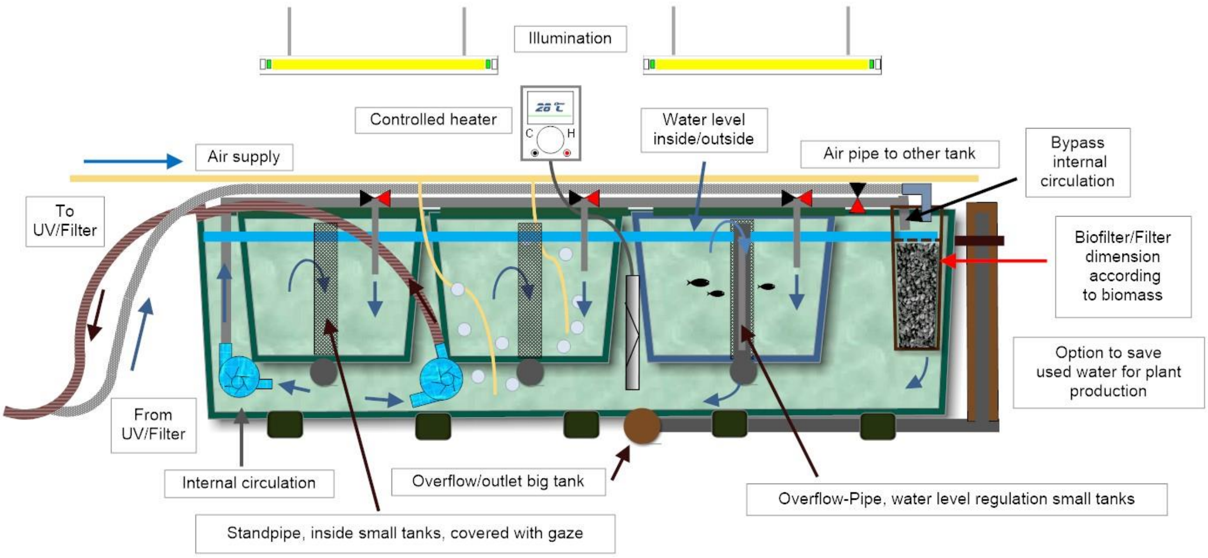


***Fig. 2:** The sketch depicts schematically the water circulation and the equipment installed in one tank unit. Water from the big tank is being pumped through a UV-unit, a filter unit outside which can be equipped with various filter cartouches and goes back to a coarse filter inside of the big tank. Attached to the coarse filter, a biofilter is established which is fed with returning bypass water from the big tank. The other pump circulates the water from the big tank through the small tanks. Heaters are deployed in the water body of the big tanks. Significant aeration is being accomplished in the big tanks, inside of the small tanks only gentle aeration is being applied to keep larvae in the water column. Ball valves at each water inlet into the smaller tanks allows to adjust the water current and, depending on the age, to adjust a more or less gentle current, drifting around the larvae so they cannot stuck in the corners. The tanks can be operated in a batch mode, i.e. a certain water volume can be exchanged on daily basis if necessary, or the tanks can be operated in a flow-through mode.*

The prototype of the hatchery was set up in March and April 2018 Bunda Campus aquaculture and fisheries department farm in Lilongwe which is part of the Lilongwe University of Agriculture & Natural Resources and this facility was ready to operate in the breeding season end of 2018.

In addition to the main rearing tanks, an egg incubation unit was established inside next to the tanks, based on McDonald-type hatching jars. Since the target species in the project are mainly mouth breeders, the eggs can easily be retrieved from the females. This facility along with the rearing tanks completes the full control over the entire hatching and rearing process, facilitating also the effort of selective breeding, in order to improve the performance of the larvae and to control the results of hybridization experiments (one attempt in the project to produce all-male generations).

Solar power supply

Grid power in Malawi fails frequently, at present only an average of 6-8 hours of power from the public grid per day can be expected. Since such a hatchery set-up needs constant power supply in order to run pumps, aeration, illumination and heaters without a break, a solar power unit was attached to the hatchery. Gensets as a continues provider of power are not an option, since fuel is very expensive in Malawi. The solar power unit was designed as an island solution and provides sufficient power for the equipment in the hatchery 24h/7days a week. The solar facility provides about 1.7kW in the night which is sufficient to run the most important equipment without a break. The solar power can automatically switch to grid power when available (Figure 4). A diesel genset which automatically starts is being installed as an emergency back-up when both other sources for electricity fail.

A GPRS modem was connected to the control unit, which allows the remote control of the operating data of the facility through the Internet which is very useful in the period beyond the first start-up of the system. Figure 3 depicts a typical power profile for 30 days.

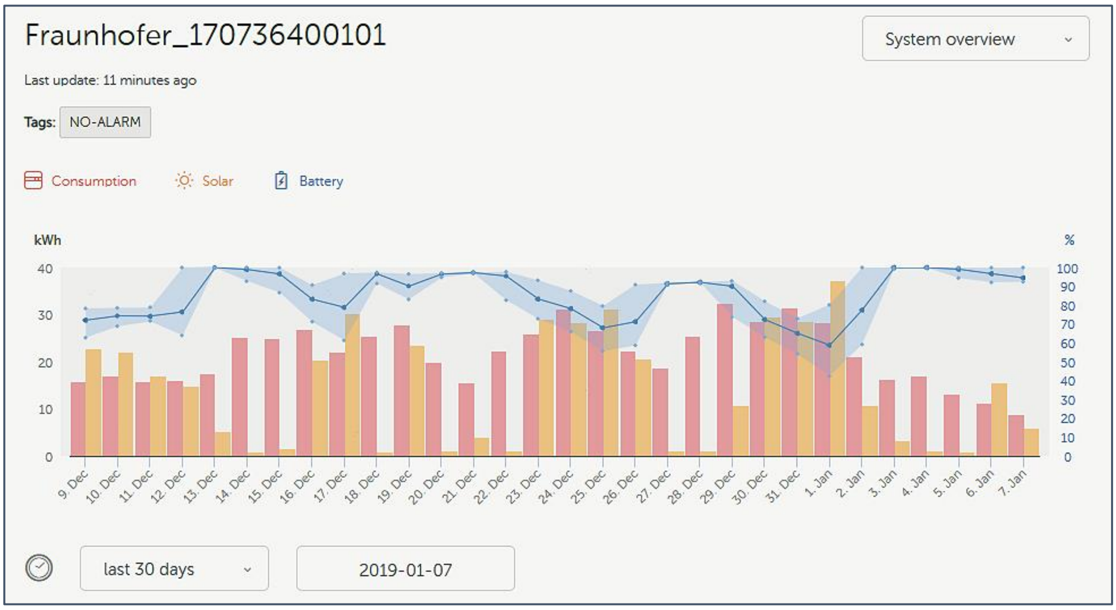


***Fig. 3:** Typical profile of power consumption, solar power and battery charge over 30 days. It can be seen, that the discharge status of the batteries sometimes exceeded the desired range of 30%.*

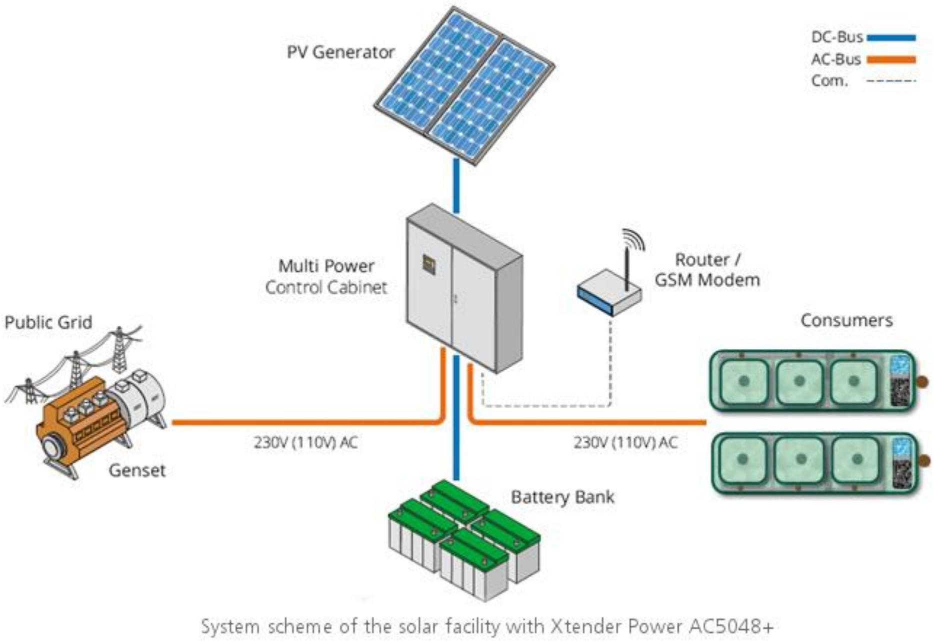


Fig.: 4: *Schematic sketch of the solar power facility which provides permanent electricity for the hatchery operation. The system has 36 solar panels, each providing about 300 Watt. The battery block has 24 batteries with in total 48 Volt and 1270 Ah per battery. The facility is designed as an island solution; however, grid power can be used when available to increase the batteries life time. Additionally, a genset is attached as emergency back-up. The system can be remote-controlled through a GPRS modem.*

Production and research

The hatchery was mainly designed to produce tilapia fingerlings to support stocking of ponds of for the rural farmer. However, the facility can also be used to do research trials; this is important since a number of optimal biotic and abiotic conditions for e.g. the Chambo are not yet known but can be identified in experiments conducted in the hatchery. In order to increase the number of parameters to test and to be able to achieve viable results with more replicates, small floating buckets can be introduced into the tanks with larvae introduced into the buckets.

The capacity per rearing trial is about 40.000-50.000 tilapia larvae per unit. One trial in the indoor hatchery takes about 3 weeks, subsequently the post larvae/fry are introduced into hapas in the ponds of the farm where they are able to adapt to pond conditions in a protected environment, and are raised until they have reached the right size to be disseminated to the farmer (about 5-10 g). In a breeding season, about 8 trials can be conducted, which can provide about up to 0.8 Mill. of fry per breeding season, assuming, there are sufficient brooders available. This capacity is good for stocking the ponds of 10-15 fish farming communities, depending on the number and size of the ponds they are managing.

The following instructions specifically relates to the operation of solar powered hatchery which was installed in March-April 2018 at the Farm of the Bunda Campus.

Instructions on the Operation of the Solar Power Plant

Important note

The solar power facility provides a limited amount of power per 24 hours. The actual amount of power available depends on various factors, such as temporary support from grid power, duration and intensity of solar radiation, ambient temperature and finally of course from the actual battery capacity. Thus, the power supply from the solar facility cannot be compared with grid power, where it (normally) does not matter how many consumers are connected. Please note, that the total battery capacity of 100% can only be used by about 30%; beyond those value, further discharging reduces the lifetime of the battery block. This is different from the battery e.g. in a Smartphone, where the use of 100% of the capacity is not really harmful for battery life (just to mention it, the battery technology in smartphones (lithium-ion/polymer) is different from the technology used in the batteries of the solar power (lead-acid technology).

Because of the limited capacity, the power consumption in the hatchery needs a management plan, in order to make sure that the most important devices in the hatchery (such as pumps and aeration) never stops to run because of exhausted battery capacity. The following instructions will guide through a proper management plan, ensuring that power is always there where urgently needed and to optimize the batteries lifetime.

Power management

To achieve the goal to run the most important devices in the hatchery on a long-term, sustainable basis, 24hours/7 days a week, the power consumers need an appropriate management. This means, that devices are connected when power is sufficient, and that devices need temporarily to be disconnected when power becomes fewer (i.e. charging status of batteries drops towards 70%). There are more details described in the following paragraphs.

Power consumption of devices used in the hatchery

In order to get an idea about the individual power consumption of the electric devices used in the hatchery, the following Table 1 is listing the consumers which are operated in the hatchery, their individual power consumption and the total power needed based on the number of devices.

Device	Number used in the hatchery	Power consumption (Watt/unit)	Total Consumption Watt
Pump AC Runner 5.0	3	44	132
Pump AC Runner 12.0	2	92	184
Aeration	1	130	130
Illumination	6	16	96
Heater	7	300	2100
Summary			2642

***Tab. 1:** the table depicts the number and kind of devices which are used in the hatchery with their power consumption. It is obvious, that the use of all heater in parallel exceeds the mean sustainable power supply from the batteries which is limited to durable 1.7kW. Thus, specifically the use of the heater has to be managed.*

The solar panels are providing theoretically, exposed to full sunshine, 300 Watt per unit. There are two strings with 18 solar panels providing 5.400 Watt each. In total 10.800 Watt is the theoretical harvest from the panels; under practical conditions, however, it is mostly about 25% less what can be harvested, about 8000 Watt. This is sufficient to run all devices in parallel while radiation from the sun is at its maximum or close to it. This is, under local conditions, probably the period between 9am to 4pm; however, the exact behaviour of the solar power facility needs verification through the exact monitoring of the data coming from the control unit in the first couple of months under operational conditions.

Since the mean capacity in 24 hours which is supported from the batteries is about 1.7 kW (this value results from the number and capacity of the batteries and cannot be changed), it is obvious, that not all heater can run in parallel for 24 hours a day (compare with Table 1). Pumps, aeration and illumination have first priority. In the night, when there is no harvest from the sun and no grid available, only the batteries have to supply sufficient power to secure the non-stop operation of pumps and aeration.

Management of battery capacity

During daylight, and even with strong sunshine, or grid power available, it is no problem to run all devices in the hatchery in parallel. However, the status of the battery, i.e. the capacity in the evening is the main indicator (as to read from the monitor of the solar power control unit, see Figure 5, or by means of remote control) which devices can be connected throughout the entire night (presumed there is no grid available, since grid availability cannot be predicted). If you read 100% charged battery in the evening, aeration, pumps and up to 4 heaters may be allowed to run throughout the night (please check and note next morning the status of the battery in the first couple of months). If the battery status is less than 100% (less than 90%) in the evening, some devices need to be disconnected, mainly heaters are concerned. It should be avoided that the batteries are discharged until next morning below about 70%.

Fig. 5: *Colour control of the Solar power facility. The monitor informs about the actual battery capacity and the flow of energy. Left: the hatchery uses mainly grid power, no solar energy available (e.g. in the night). Right: the hatchery uses power from the solar panels and the batteries. An important information for proper management of the battery capacity.*

The following Table 2 depicts the importance of the devices and the options which devices can be stopped to run without threatening the whole hatchery operation. Please note: the devices are considered in this table per tank unit. Same rules apply for both tanks.

Device	Significance	Comments
Hatchery		
Pump from big tank into small tanks	High, MUST run	Shall not stop under any circumstances
Pump circulation big tank, filter and biofilter	High, MUST run	Shall not stop under any circumstances
Aeration	High, MUST run	Shall not stop under any circumstances
Heater 1	Shall run	but can be unplugged at critical battery status
Heater 2	Optional	must not run in the night, shall be unplugged when battery status is critical
Illumination	Shall run	Illumination is automatically switched off in the night, thus not critical during night time operation.
McDonald Hatchery, egg incubation		
Pump	High, MUST run	If this pump stops, eggs/larvae in the jars will die
Heater	Shall run	This heater has higher priority as the heater in the hatchery tanks but can be unplugged at critical battery status.

Tab. 2: *The table lists the devices which are operated in the hatchery (above) and in the MCDonald unit (below) and their significance for the hatchery operation. Mainly the heaters are optional and since they are the largest consumers of electricity when running, these are the devices which need some management*

Maintenance

- Please check occasionally the temperature of the battery poles in the dark, when only battery power is used resp. (check the monitor if only battery power is flowing to the consumer, this is the case under condition that no grid is available and solar panels do not supply power since of darkness). The poles should not be hot, just a slightly higher temperature is acceptable. Please report hot temperatures at the poles.
- Check if batteries are clean on the top, remove coarse particles carefully with a clean cleaning cloth.

- In case of a break in electricity in the hatchery, please check the fuses **AC IN** (F1) **& AC OUT** (F2) for their status inside the control cabinet of the solar facility (the box on the wall with the green cover, see also Figure 6). Switch to ON if applicable.

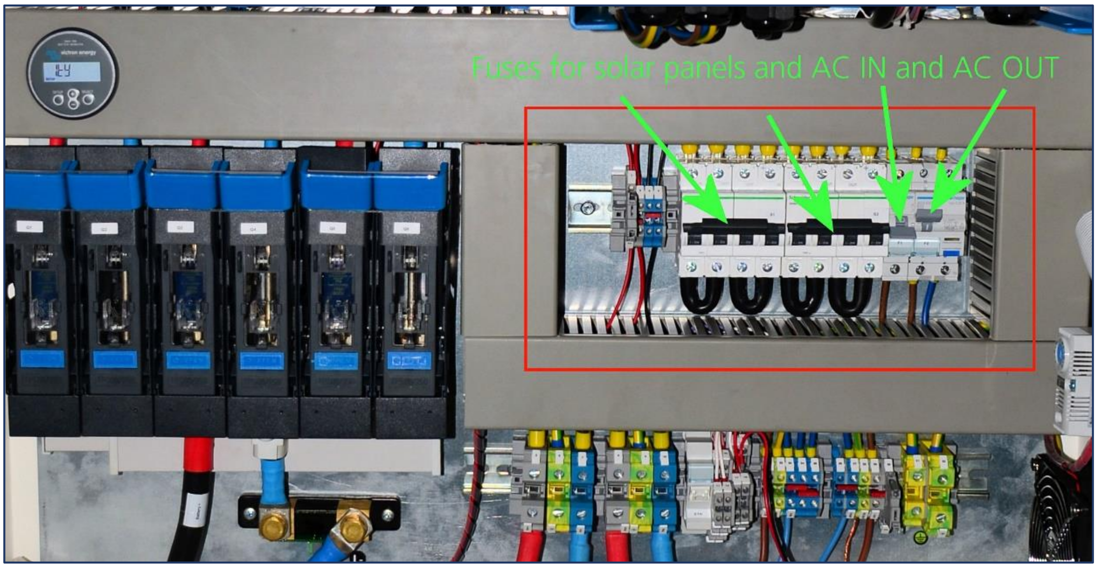


Fig. 6: *The switchboard inside of the control cabinet for the solar power facility. If a failure of AC-OUT power to the hatchery occurs, please check at first the fuses AC-OUT (F2) and AC-IN (F1) The fuse* ***AC-OUT*** *may have reacted on a short circuit in a device which may have been connected to the power sockets in the hatchery.* ***All fuses have to be in the upper position*** *(please note, in the picture, the fuse for AC IN is here in the OFF-position). The fuses for solar power panels normally should not be touched without any advices from authorized personal.*

- If there is no grid power arriving in the control unit, although grid is available, please check the fuse breaker in the cabinet of the ESCOM; this is the grey switchboard cabinet next to the control unit of the solar power. There is a circuit breaker down on the left side, this circuit breaker has to be in the ON (upper) position.
- Check occasionally the surface of the solar panels. They should be clean with no dust layer, which reduces the efficiency in harvesting solar power significantly. Please clean with lots of plain/deonized/distilled water and soft cleaning cloth. **Never use any abrasive cleaning chemicals or rough brushes.**
- In order to get an idea about the dynamic of the battery capacity under various scenarios, it is important to make notes of the battery capacity in the evening (after sunset, when no solar radiation is available) and in the morning for a couple of months until the behaviour of the solar power has a known pattern. Please note also the number of heaters which were connected in the night and if grid power was available in the dark period (**can be read from the remote-control interface**). Use a kind of table like the following template (Table 3):

Time	Date	Battery capacity	Heater connected in night (No)	Grid power available y/n	Notes
Evening	18.12.18	100%	5		
Morning	19.12.18	72%		n	
Evening	19.12.18	95%	4		
Morning	20.12.18	70%		n	Since 24h no grid
tbc….	……	……	…….	……	……
	…….	…….		………	………

Tab. 3: *Template which can be used to record the battery capacity in the evening and the next morning and notes about the number of heaters connected throughout the night.*

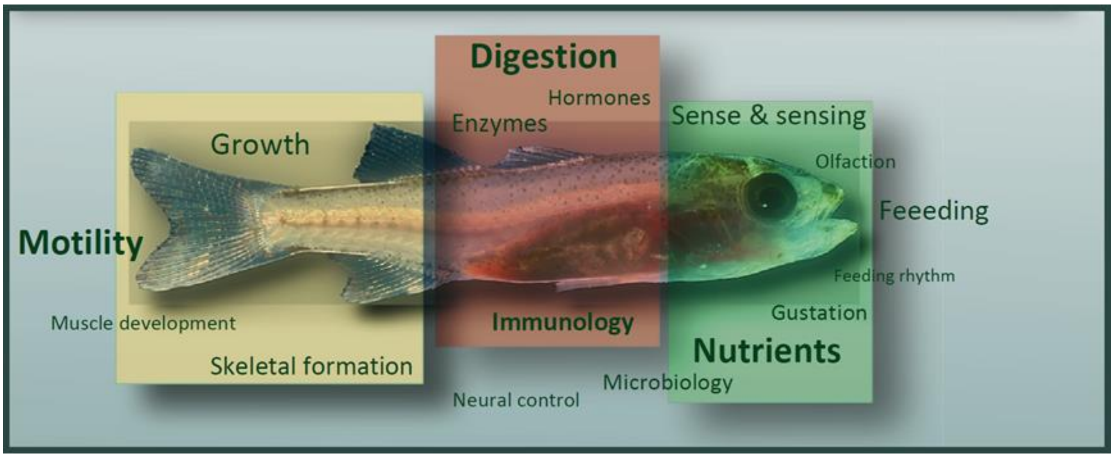
- Please make sure, that there is always airtime available for the Simcard which connects the modem of the solar power controller to the internet.

In case of emergency: no electricity from solar power/batteries/grid available

In case there is a failure of the solar power plant, and neither electricity available from the solar plant nor from grid you have to use a genset. In that case, use "flying cables" from the genset to feed the pumps, aerator and heater with electricity. We have provided sufficient extension cables and power outlet multiplier to enable this emergency setting. When solar and/or grid power is back, remove all those cables and run the hatchery again in the "normal mode" (connect pumps and heater again to the designated electricity cubes and power outlets in the hatchery).

Reporting

Please report any error message or any other unusual behaviour of the solar power facility (batteries, controller, solar panels, circuit breaker…etc.) immediately to B. Ueberschär.



Instructions on the Operation of the Hatchery

Please note, first of all, that basic rules apply in the hatchery:

- Put on working attire and protective clothing when necessary to prevent accidents.
- Avoid eating as well as drinking in the hatchery for there are laboratory chemicals in the facility used to various tests. The food or juice may spill over in the tanks there by affecting the experiments in progress.
- Avoid being in contact or touching the equipment (unless otherwise required) for this may cause a disconnection in aeration of breakage/stoppage of the water flow.
- The hatchery should be operated by an authorised personnel (technician) and anyone willing to see hatchery should do so with the guidance of the technician.

Starting a rearing trial

You always have to start a new rearing trial with clean and empty tanks and with clean, working equipment. If there were any issues with diseases (virus/bacterial infections, fungi) in the previous trial, disinfection of the rearing tanks and the submerged equipment should be considered. If chlorine-based disinfection is applied, be very careful to check if all the materials (of tanks and equipment) are sensitive to chlorine. Please apply disinfection always according to the advices of the manufacturer; wrong application may be harmful for humans, the equipment (chlorine is basically may be corrosive!) and subsequently for the fish larvae which will be stocked. Rinse all equipment which got in touch with chlorine thoroughfully with clean water.

Then you have to fill both large tanks with water well in advance to the next trial (a week before is fine, recommendation at this point in time is the well water, since it has no or not that much calcium carbonate as the borehole water, which may ruin, from experience, the pumps in the tanks and the heater, which may be incrusted with calcium and reduce their efficiency tremendously).

Measures when filling completely empty tanks

Take care that the following conditions apply before filling of the large tank starts:

1. Standpipes (those with the wholes and the gauze outside) inside of the small tanks temporarily removed (Figure 8).
2. Overflow regulating pipes from the small tanks temporarily removed, so that water can penetrate from outside into the small tanks (Figure 9). Failing to do that, will lift up the small tanks with increasing water level outside in the big tanks and may break the pipes!
3. Fill water into the large tanks. Use a filter cartouche (as shown in Figure 9) to prevent debris flowing into the tanks from the well. The water level should finally be the same inside and outside of the smaller and the big tanks (check the water level after introducing the overflow pipes in the small tanks and after starting the pumps. It may be necessary to add some water outside in the big tanks after the small tanks are completely filled; as mentioned water level inside and outside of the small tanks

should be almost at the same level). Use the circular tanks which are available in the hatchery to store water for the next water exchange in the tanks (Figure 7).

Fig. 7: *Hatchery ready to operate. The circular tanks in the background can be used as store tanks for water exchange. They can always be filled when well-water is available and sufficient solar power is available to operate the water pump at the well.*

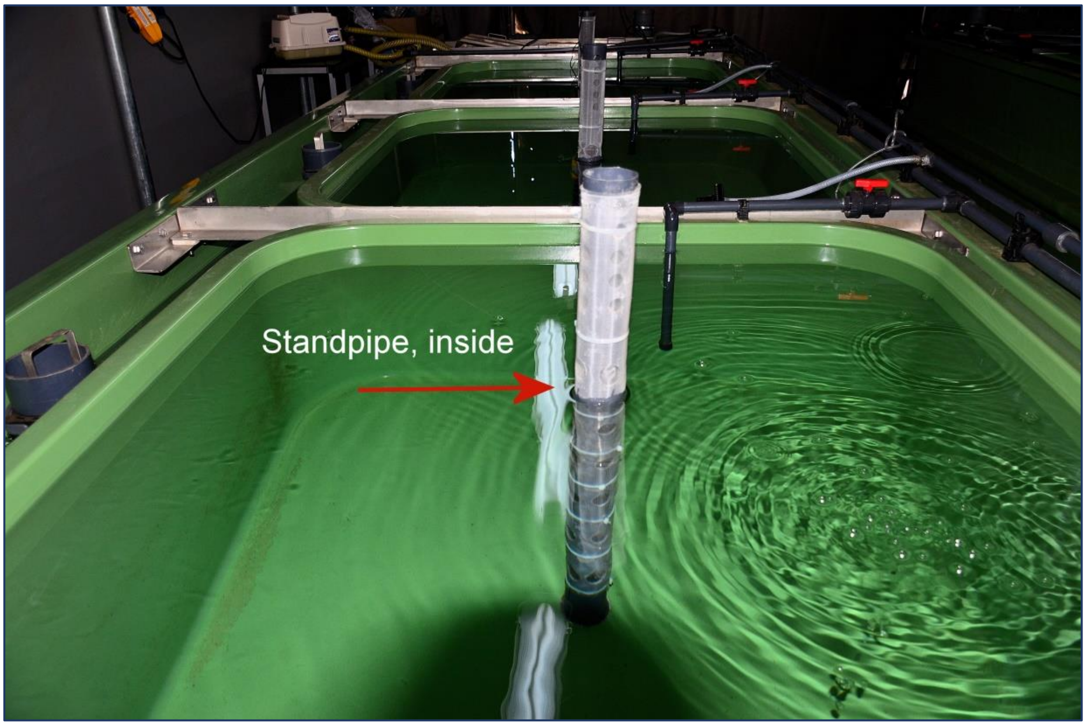


Fig. 8: *Standpipe inside of the rearing tank. Prevents larvae from escaping of the rearing tank. Need to be removed when filling the empty tanks (start of a rearing trial) until tanks are completely filled (please compare water level as shown in the picture with the water level in the big tanks).*

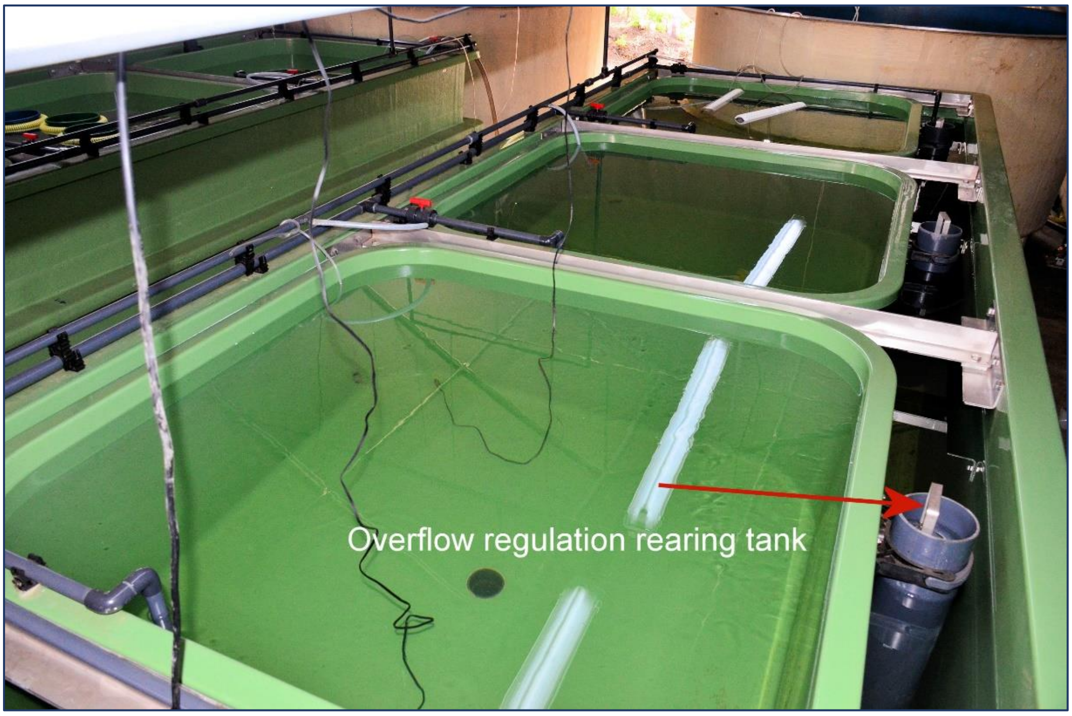


Fig. 9: *Picture shows the location of the overflow pipe which regulates the water level inside of the rearing tank and and relates to the water level outside in the big tanks. Needs to be removed when filling the empty tanks (start of a rearing trial) until tanks are completely filled (please compare water level in the small tanks as shown in the picture with the water level in the big tanks). The level inside and outside should be almost the same.*

Measures after filling the tanks

- When all tanks are filled with water to the desired level, the pumps, aeration and heaters can be switched on. The power socket for the heater is connected with a control unit. Never connect a heater right away to a power socket, always use the power socket of the control unit! Please make sure that the heater is connected to power socket I (Figure 13). The other one cannot be used with the controller type "Duo". Make sure that the sensor of the control unit is deployed and free floating in one of the rearing tanks and well separated from the main heater in the large tank.
- Plug-in the standpipes in the middle of the rearing tanks (Figure 8), and put back the overflow pipes outside of the rearing tanks (Figure 9, which fixes the water level inside of the rearing tanks).
- Make sure that all pumps are running as desired (for the circulation in the big tanks check at the end of the tubes, coming from the bigger pump in the large tank, ending up in the filter box, Figure 18). It is important to check the water flow into the filterbox every day, since sometimes the pipe which sucks the water from the big tank may be clogged (debris or dead fish which stick on the protective gauze).
- Check if the heaters are working (remove them BRIEFLY out of the water and feel if they are getting hot, then put them back quickly). Heaters have to hang free floating in the water body of the big tank, without touching anything (Figure 16). Please note: if you want to handle heaters outside of the water (e.g. cleaning) ALWAYS disconnect them before removing them from the water, otherwise hands can get burned and heaters will be damaged.

- Adjust a strong aeration in the big tanks (at both ends of the big tanks, there is an aeration device on the bottom of the tanks, check the video)
- Make sure, that there is a strong aeration in the biofilter (Figure 12)
- Adjust a very gentle aeration in the rearing tanks (check the video)
- Adjust the ball valves at the water inlets of the rearing tanks to achieve a gentle current in those tanks. Please note: the aeration in the rearing tanks need adjustments according to the larval stage. The older the larvae are, the more oxygen they need, the stronger the current should be (check the videos).
- Make sure that the sensor of the control unit is deployed and free floating in one of the rearing tanks and well separated from the main heater.

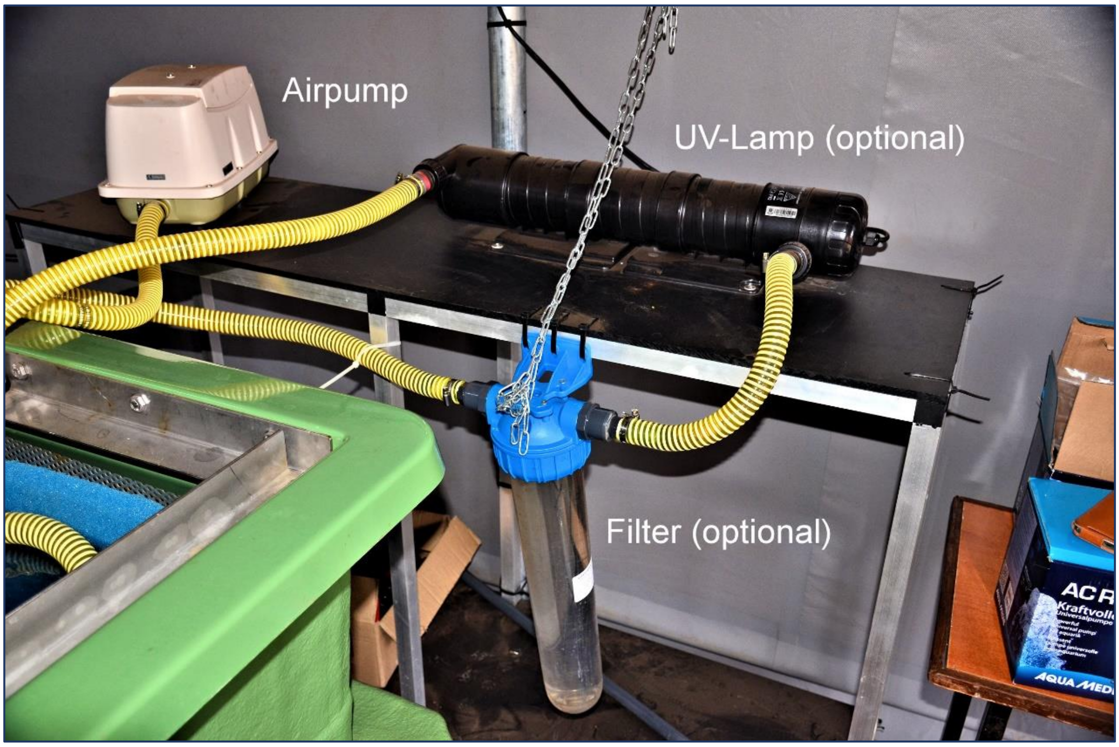


Fig. 10: *The figure depicts the devices outside of the tank. Left the air pump which provides aeration for both units, has always to run. In the middle, above, a UV-Lamp which can be used to reduce the bacterial load in the water. This is an optional device and does not need to run under regular conditions (concern: consumes significant electric power). In the middle, below, a water filter which can be equipped with a filter cartouche to remove fine particles from the water (no filter cartouche installed in the photo)**. Please note: if a filter cartouche is used, please clean the cartouche every day! Stop the circulation in the big tank, remove the cartouche, clean with pure water. Put back and re-assemble the filter. Please note, that a cartouche has a limited life time and needs to be replaced at least every month of operation (depending on the water conditions).***

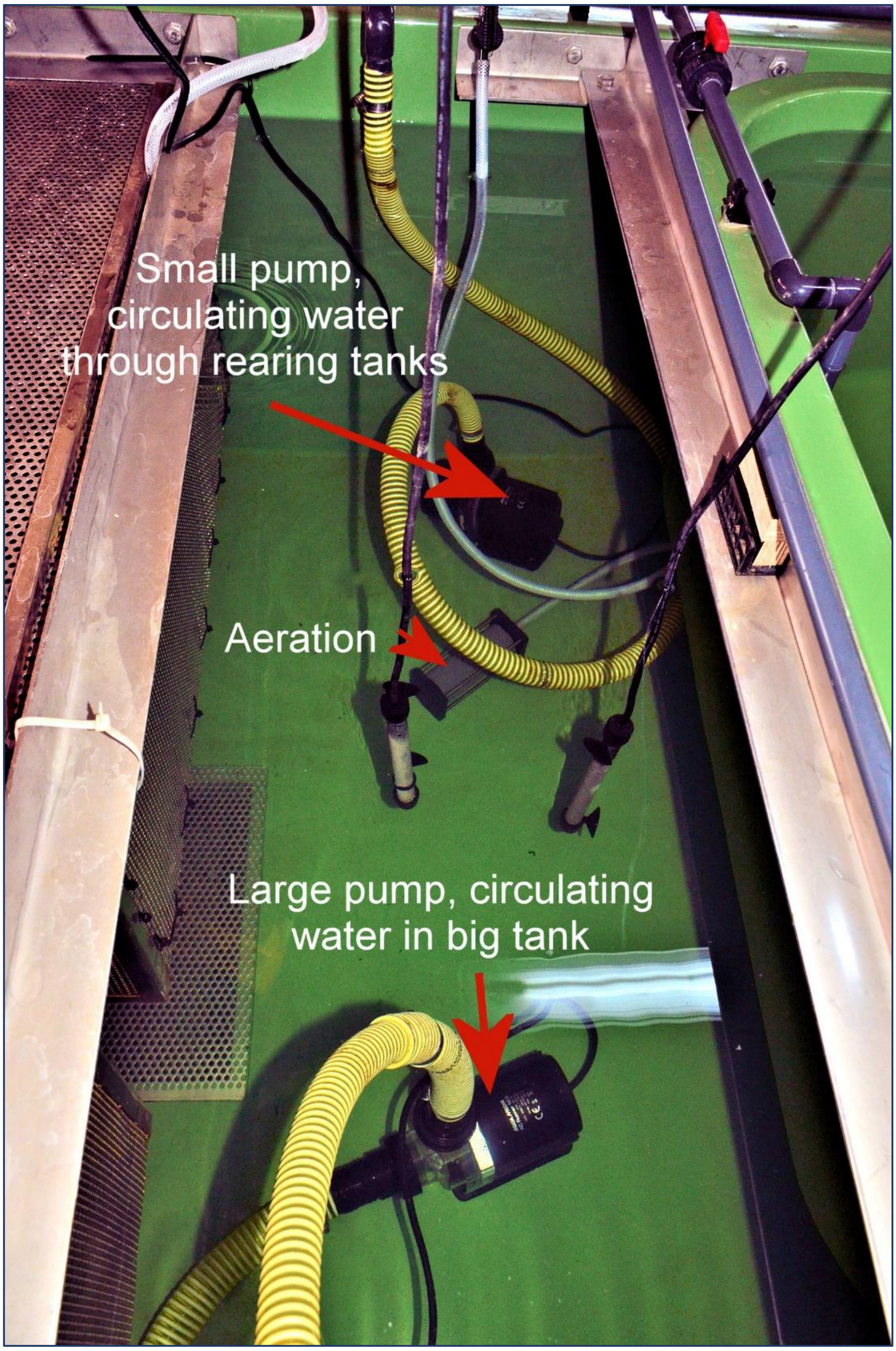


Fig. 11: *The figure depicts the location of the pumps, the air diffusor and the heater. These devices are all installed in the large tank, between filter/biofilter box and first rearing tank. Access to these devices for maintenance work etc. is easy. Take care that the pump suction can operate properly and that there is no debris clogging the openings (in the small pump, there is a coarse filter box attached at the pump, with the large pump there is a tube with coarse gauze at the mouth opening which needs an everyday-check if not clogged.*

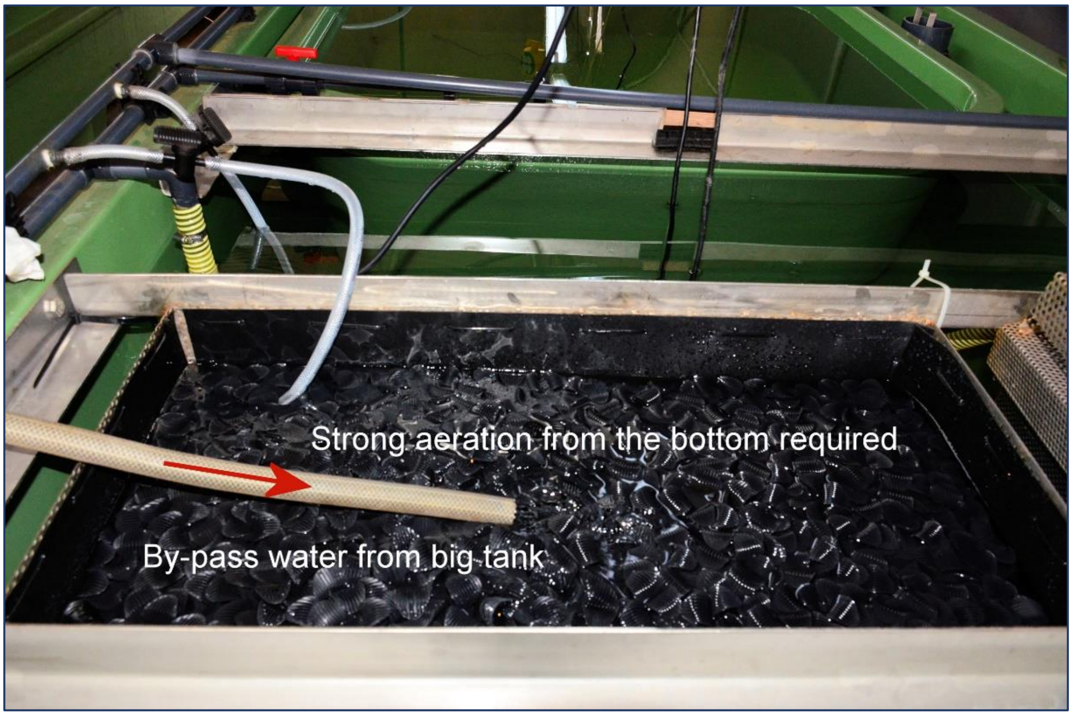


Fig. 12: *The biofilter box, open. The biofilter is fed with water from the circulation to the rearing tanks which comes through the small pump from the big tank (by-pass water). Please note that the substrate for bacteria in the biofilter does normally not need maintenance while running a trial but needs always a strong aeration from below.*

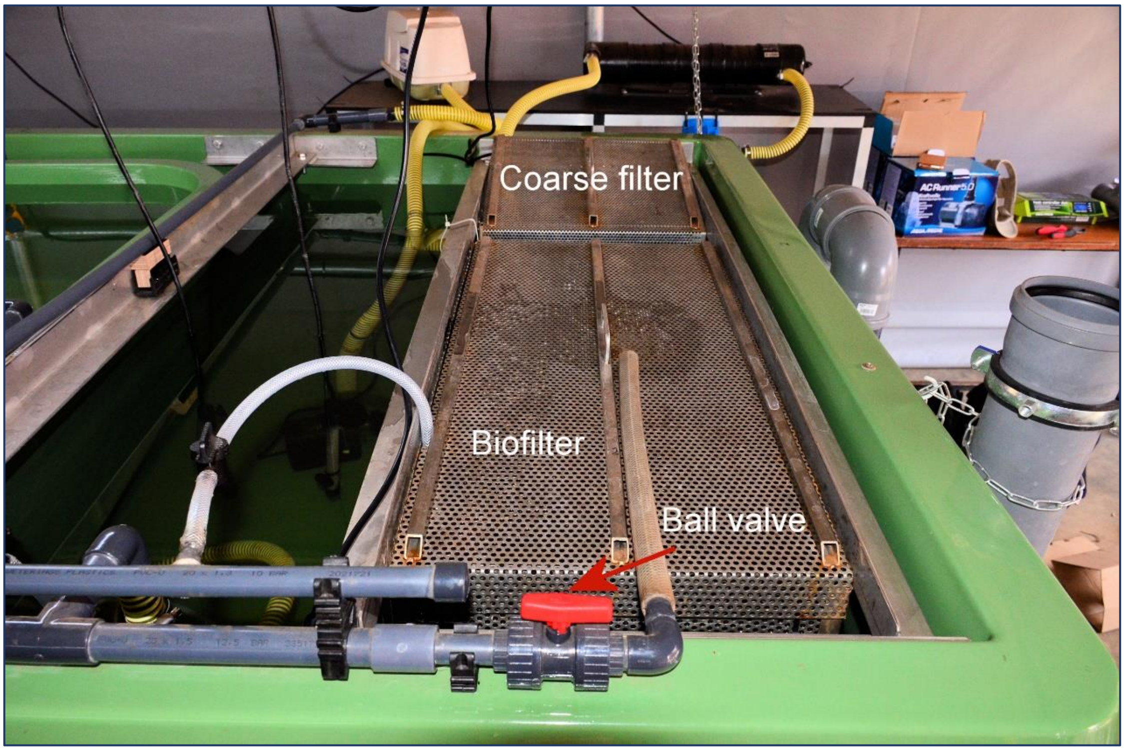


Fig. 13: *Biofilter/Filterboxes. The water to the biofilter is by-pass water from the circulation through the rearing tanks. The amount of water which passes through the biofilter can be controlled with a ball valve and needs to be adjusted according to the efficiency of the biofilter (refer to ammonium measurements). The more efficient the biofilter works, the more water can be guided through the filter.*

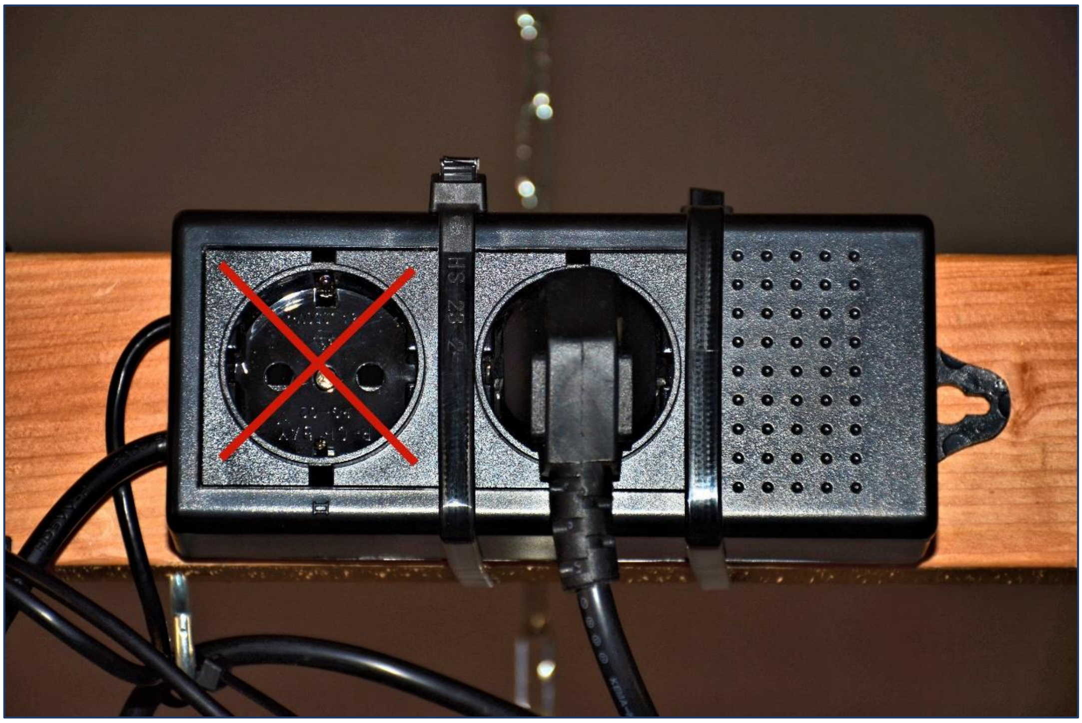


Fig. 14: *Power socket of the control unit for the heater. Please note that only socket I can be used for the type of heater which is installed in the hatchery.*

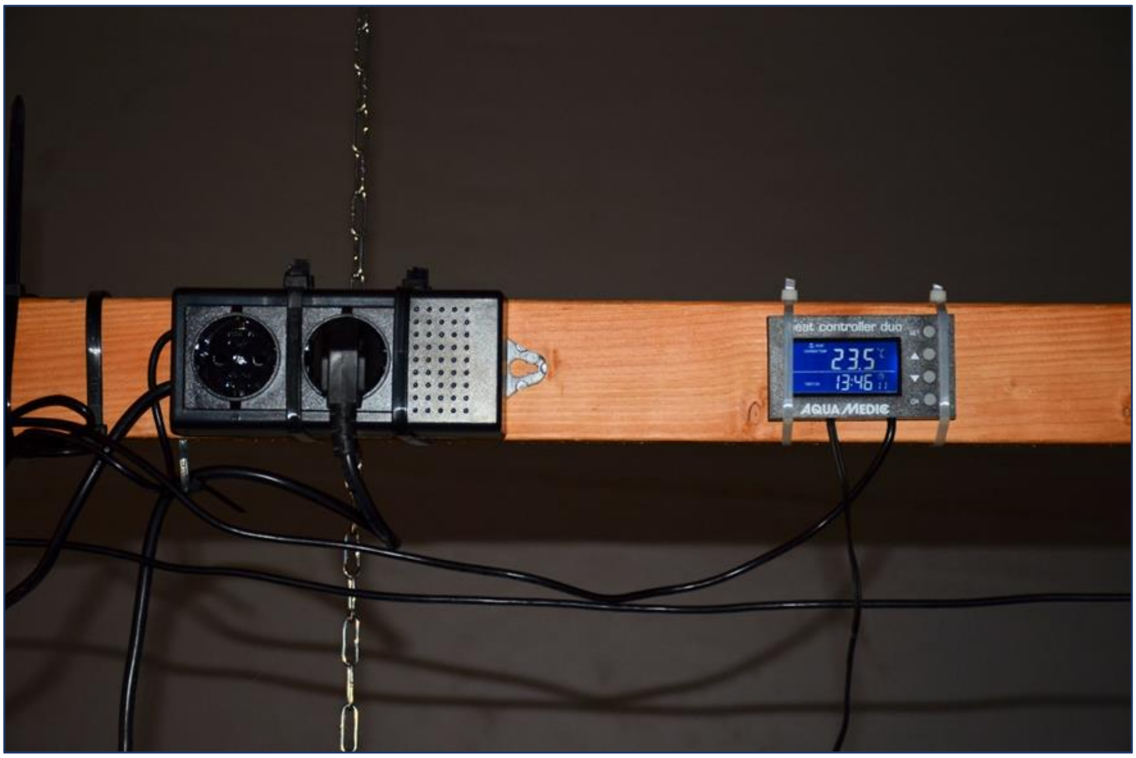


Fig. 15: *Control unit for the heater with power socket (left) and main temperature control unit (right). Make sure that the sensor of the control unit is deployed and free floating in one of the rearing tanks and well separated from the main heater. For the adjustment of temperature at the control unit please consult the instruction manuals either of the Duo- or Twin Controller (Annex 1, attached to this manual). There are two types of controller in the hatchery, please check for proper instruction manual!*

Fig. 16: *Heater in the big tank. Please make sure that they are always well submerged and free floating without touching other devices.*

Water circulation

It is important to understand exactly the water circulation in the tanks of the hatchery. There are two independent ways of water circulation per unit.

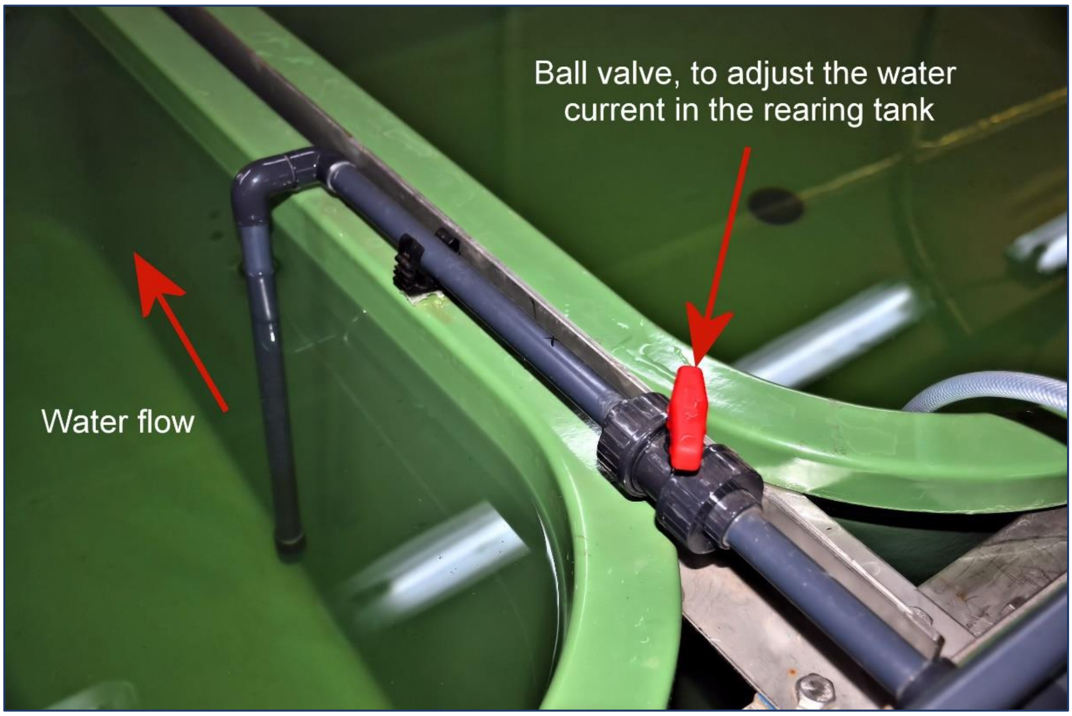


Fig. 17: *The picture shows the water inlet pipe into the rearing tanks. The ball valve is needed to adjust the inflow of water from the big tank into the rearing tanks. With young larvae, the inflow needs to be rather gentle, with larger larvae the inflow shall be increasing. The vertical pipe has holes on one side (not visible here) and creates a circulating current inside of the rearing tank over the whole water column.*

One way circulates the water from the big tank out to the filter device, through the UV-Lamp unit and arrives back in the tank in the large filter Box (compare Figure 10, 17 & 18).

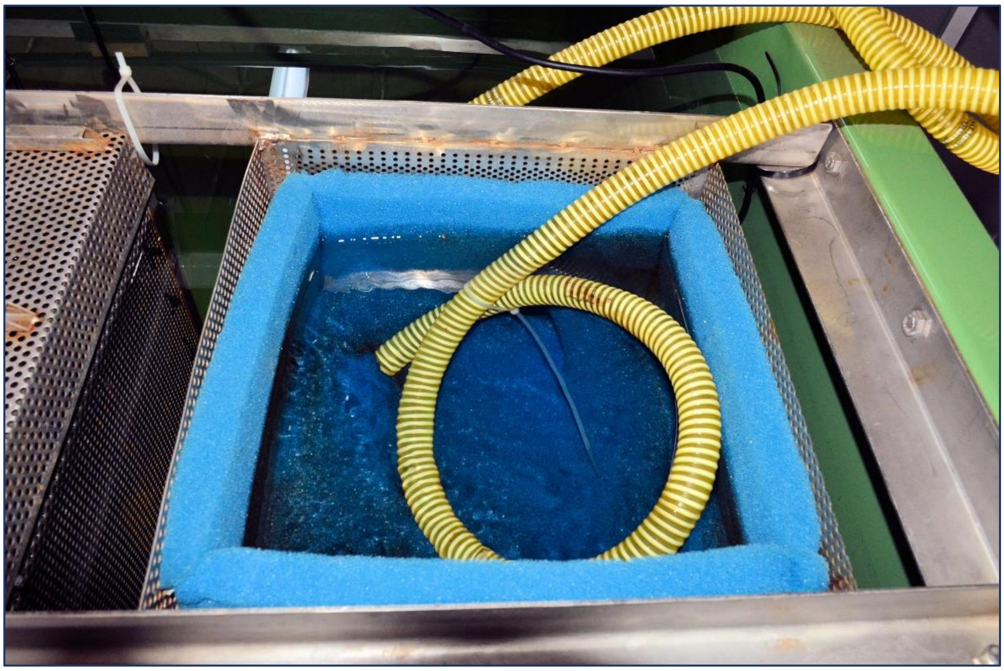


Fig. 18: *The water circulation out of the big tank, through filter and UV-Lamp, ends up in this filter box inside the big tank (box shown here with cover removed). Please check on daily basis, if the water flow into the box from the pipe is "normal", low water supply means that the other end in the big tank, where the pump sucks the water, may be clogged. Please clean and check again the water flow.*

The smaller pump circulates the water from the big tank through the small rearing tanks, a by-pass guides water back to the big tank; another by-pass is feeding the biofilter (Figure 13). Each of the outlets has a ball valve, which can be used to adjust the water flow.

The following circulation scenarios for the smaller pump are common ins such a set-up (Table 4). The large pump does not need an adjustment.

Larval Stage	Rearing tanks	By-Pass	Biofilter	Notes
Newly hatched	Gentle current	Almost open to slightly closed	Gentle flow of water	
Started to take feed	Gentle current	Almost open to slightly closed	Gentle flow of water	Check oxygen level
≤ 2weeks	Intermediate current	Half to three quarter closed	Gentle flow of water	Check oxygen level
≥ 3 weeks	Stronger current	Almost closed	Gentle flow of water	Check oxygen level

Tab. 4: *The table depicts the adjustment of the ball valves for the different outlets of water for the circulation inside the rearing tanks, the by-pass and the biofilter. In older stages, it is important to measure the oxygen level and to adjust the water exchange in the rearing tanks on the basis of these measurements.*

Please note, it is important that the pumps are never pumping against almost closed ball valves. This will destroy the pumps. Always adjust all ball valves for the internal circulation in a way, that the pump can promote almost the same amount of water. Use the table above as an estimation how to adjust the various ball valves (a thumb rule is, that the by-pass has to be wide open when the circulation through rearing tanks is low, and the other way around).

The flow through the biofilter-box may needs adjustments according to the efficiency of the filter but should never be too strong. In order to allow the nitrification in the biofilter, water has to pass rather slowly though the filling material. Make the decision about the flow-through based on the measurements of ammonium and nitrate. Low ammonium and increasing nitrate values in tank water indicate a well-working biofilter (refer also to the Chapter "Water parameter measurements").

Aeration

A proper aeration is important to recharge the water in the big tank with oxygen from the atmosphere. The most efficient enrichment with oxygen takes place on the surface of the water, less through the upcoming bubbles (check the video, see ANNEX 1).

The system is mainly aerated in the big tank. Here, the aeration can be very strong, since this cannot harm the larvae inside the smaller tanks. The oxygen enriched water will then recirculate through the rearing tanks. Two air diffusors are installed in the big tank (compare with Figure 11, showing one diffusor, not working in this picture). There is one diffusor at each end of the tank in order to care about a homogenous water movement.

Inside of the rearing tanks, the aeration shall be very gentle, some coarse bubbles cares about a light upwelling (check the video, see ANNEX 1) specifically in very early larval stages; rough aeration has to be avoided since it will rather harm the small larvae. With post-larvae, aeration can be slightly increased, but do not use air stones in the rearing tanks.

As mentioned above, the biofilter need a continuous strong aeration from below in order to supply sufficient oxygen to the nitrifying bacteria. Weak aeration may result in the growth of the "wrong" bacteria, which may produce hydrogen sulphide, which is very toxic for fish (has a strong smell like rotten eggs).

There is only one aerator needed for both rearing units; the airpipe connects both tanks, which needs, however good care that all the regulating valves in both units are well adjusted to each other. Open valves 100% in one unit causes less air pressure at the other side, please always double check all air outlets when changing adjustments. Please check occasionally, if there are leaks where air can get lost and fix immediately.

Please have always in mind, that well-adjusted aeration, specifically in the large tanks, is a kind of life guard for the welfare of the larvae in the rearing tanks.

Illumination

Proper illumination is an important issue in indoor hatcheries, specifically when there is no daylight available. Fish larvae are visual feeder and do only feed when there is sufficient light available. The day/night rhythm (D/N, the hours with light and darkness) necessary for proper growth depends from the species; however, there are not yet sounding scientific data available which justify a certain D/N rhythm. In the case of the endemic tilapia species which are reared in the hatchery, a D/N rhythm of 12/12 is recommended. This rhythm should be adjusted with automatic timer which were provided with the hatchery equipment and need, once adjusted, no special maintenance.

Maintenance of the Hatchery

Maintenance has two meanings in a hatchery. On one hand, intensive carness is required to maintain optimal rearing conditions when a trial is running. On the other hand, maintaining all equipment and tanks in a good condition while running a trial and beyond make sure that the hatchery has a long life.

PLEASE NOTE: a clean and well-arranged hatchery is key to success. Please do not allow that any equipment from the hatchery is used outside of the tent; this can be a vector of diseases (e.g. standpipes from the rearing tanks should under no circumstances used in outdoor tanks of the farm). There shall be no debris on the bottom and frequent cleaning of the bottom and the equipment helps to maintain a healthy and well-working environment for fry production.

Maintenance of rearing conditions

There are a number of issues to care about when a larval rearing trial is running. Specifically, it is very important to maintain a good water quality. This needs some measures on various scales, such as daily maintenance, several days, a week or once at the end or the beginning of a rearing trial or even on a variable scale, according to the actual conditions in the hatchery.

The following paragraphs will list the maintenance issues sorted for the various scales.

A Daily maintenance

To maintain the optimal water conditions when running a trial is the major daily issue.

1. When arriving at the facility, check if all devices which should run, are running (pumps, aeration, illumination, heater).
2. Check every day the pumps for a clean entrance (the pump in the big tank sucks the water through a tube which is covered with a net, to avoid coarse particles sucked into the pump). Please check, if the flow into the filter box is "normal". If not, check the pipe at the pump if debris clogs the net which is covering the mouth of the pump (sometimes small fishes which escape into the big tank, are sucked from the pump and may clog the net).
3. In the morning, measure the water parameter, such as temperature, oxygen, pH; ammonium should be checked according to the stocking density once a week in the beginning of a trial and every third day towards the end of a trial. Record the measurements into an appropriate table for statistics and overview about the dynamic of the values.
4. Clean the rearing tanks, mainly siphoning trash from the bottom of the rearing tanks. Be careful not to catch fish larvae when doing this cleaning. It is advisable, to run the siphoned water first into a bucket, thus larvae which were sucked of the tank can be put back from the bucket. The same time, dead larvae can be counted in the bucket in order to get an idea about daily mortality rates.
5. According to the oxygen level, adjust the flow through the rearing tanks on daily basis. If oxygen level drops below 60% saturation level, increase the flow.

6. According to the ammonium level, change a certain water volume in each of the units if values are above desired levels (please refer to the chapter "Water parameter measurements" in this manual). In order to drain water, use the turning pipe, compare with Figure 19. In case, values are above the desired threshold, the water volume to exchange should roughly be calculated based on the ammonium values. For example, if the ammonium value is double the amount of the desired value, change about 50% of the water volume in the tanks, thus achieving a dilution. According to literature and own experience, ammonium concentration (NH_4^+ - NH_3) should not be measured much higher than 0.5-0.7mg/l (more information in the chapter "Water parameter measurements").
7. Feeding of the larvae has to be accomplished several times a day, how often depends from the age of the larvae and the species. More about larval feed and feeding is described in a special paragraph in this manual.

Fig. 19: *The picture shows the outlet pipes of one of the units. The left pipe is used to drain water from the big tank. Remove the chain and turn the pipe slowly to the left until the desired water level after draining is adjusted. Secure the pipe with the chain and let the water drain out of the tank until the desired level is achieved. After finishing the draining process, put the pipe back to the default position as shown in the picture. Do not forget to fix the position of the pipe again with the chain. The pipe on the right side can be used when a flow-through set up is desired. The water which runs continuously out of the tanks can be collected with a tube to e.g. water plants.*

B Frequent maintenance

Frequent measures mean not daily but every 2 days or even longer. A couple of maintenance issues are also variable, depending on the actual need, e.g. cleaning of the filter box. The most probable intervals are mentioned in the following list.

1. Cleaning of the blue foam mat in the filter box is most probably not necessary every day, thus it was not mentioned under daily maintenance. Depending of the water quality, the cleaning should be accomplished every second to third day. Figures 23 &

24 demonstrate the cleaning process. Stop the large pump which circulate the water in the big tank, remove the mat from the box and wash in a box with plain water (do not use detergents in the hatchery while running a trial). Depending of the amount of dirt coming out, rinse it two or three times until the water in the box is clean.

2. Partial exchange of water in the big tanks depends very much from the water condition and the efficiency of the biofilter. In the beginning of a rearing trial, the larvae are producing very few ammonium, this is increasing when they are getting older and get more feed. Thus, it is not a fixed issue, but has to be managed according to the water parameter (mainly measurements of oxygen, ammonium and pH) This is not exactly predictable in this manual, but rather based on experience with age, stocking densities and amount of feed administrated. Compare also with the instructions mentioned above in A 3 & A 6.

   Please note, that the most toxic form of ammonium (NH_3) increases significantly with increasing pH (acidity or alkalinity of the water). Compare with Figure 20 below. Please have this in mind when rating the measured values for ammonium/ammonia.

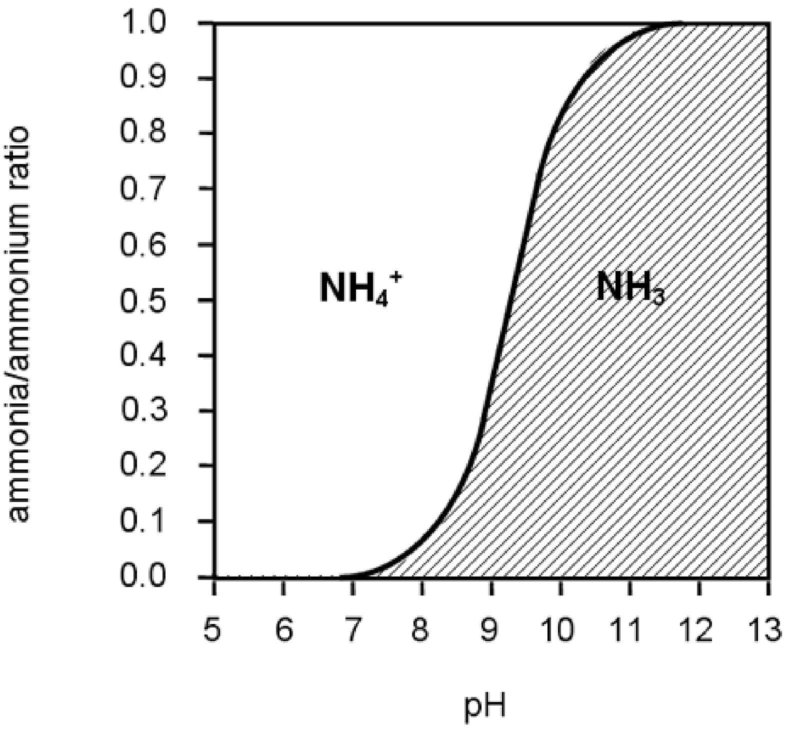


Fig.: 20: Ammonia and ammonium are different forms of nitrogen. The major factor that determines the proportion of ammonia to ammonium in water is the pH. The activity of the ammonia is also influenced by ionic strength and temperature. It is important to remember as un-ionized NH_3 can be harmful to aquatic organisms, while ionized ammonium is basically harmless. The chemical equation that drives the relationship between ammonia and ammonium is:

$$NH_3 + H_2O <-> NH_4^+ + OH^-$$

When the pH is low, the reaction is driven to the right, and when the pH is high, the reaction is driven to the left. In general, at a temperature of around room temperature, at a pH less than 6.0, the proportion of ammonium-N plus ammonia-N as NH_3 is very-very low and as NH_4^+ is very-very high. At a pH around 8.0, the proportion as NH_3 is 10 percent or less, and at a pH slightly above 9.0, the *proportion is about 50 percent. The activity of aqueous ammonia also is much lower at low temperatures and higher at warm temperatures. This means that at low temperatures and low pH the activity as NH_3 is even lower, and as NH_4^+ is even higher. Once the pH is > 11, all ammonium-N ions in solution will be converted to ammonia-N. When you test for ammonia with your test kit, the reading you actually have is a combination of ammonium (NH_4^+ or ionized ammonia) and ammonia (NH_3 or unionized ammonia) known as* ***Total Ammonia Nitrogen*** *(TAN). Ammonia is the toxic part of the TAN. Ammonium, even at high concentrations, does not cause mortality in fish. Please note, however, that a "normal" pH in the hatchery will be between 7-8.*

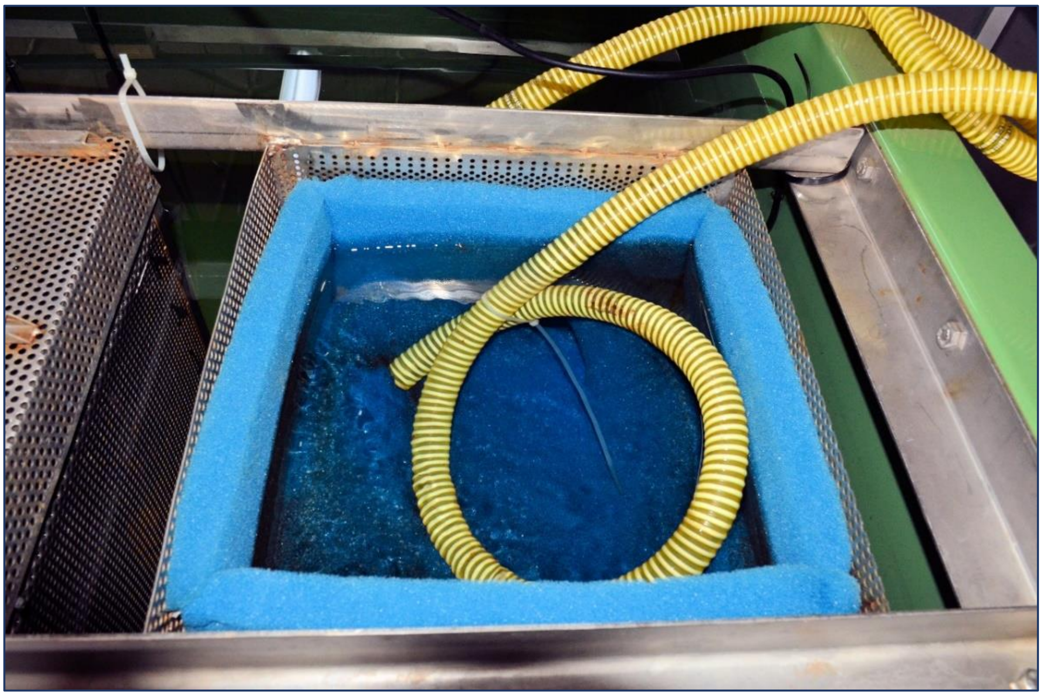


Fig. 21: *The picture shows the filter box with the blue foam. Remove carefully all the blue foam and wash accordingly to the instructions above and Figure 21 & 22 below.*

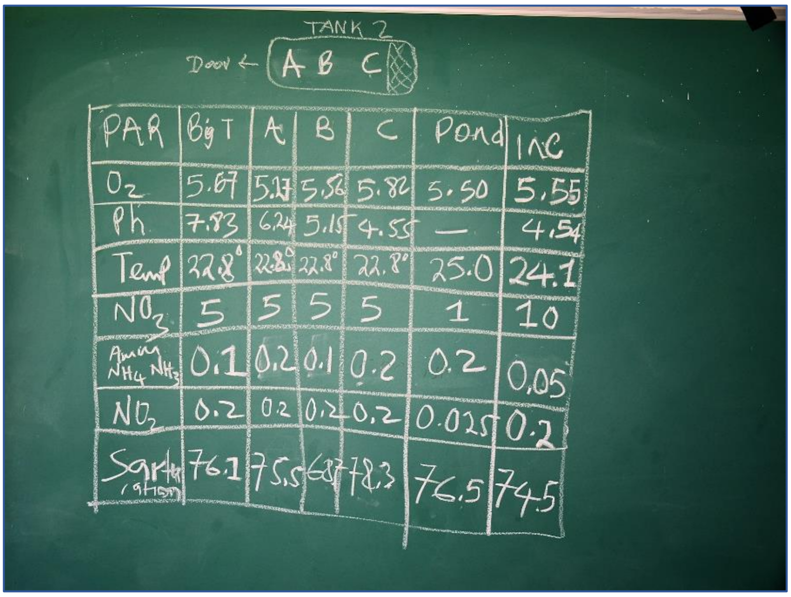


Fig. 22: *The picture shows "real" water parameter measurements in Tank No. 2, taken at the hatchery training course. The values of Ammonia/Ammonium, Nitrite and Nitrate are in a safe range, although the hatchery was fully equipped with larvae and fingerlings and no water exchange was accomplished*

for 8 days. Please note, that the pH values are irregular because of a technical failure of the pH probe. For comparison, a water sample from a pond and from the McDonald (Inc) were measured as well.

Fig. 23: *The picture depicts the washing procedure of the blue foam. Press and rinse the foam carefully until the water in the box is becoming clean. There might be several re-fillings of the box necessary until all debris is removed from the foam.*

Fig. 24: *The picture demonstrates the efficiency of the filter. This was the colour of the water after the first cleaning procedure. Continue until the water is almost clear. Put back the foam into the filter box, adjust the yellowish pipe into the foam box and re-start the pump.*

C Individual maintenance measures

There are maintenance measures which are only needed in the beginning and the end of a trial. They are mentioned in the following list.

1. When finishing a rearing trial, the tanks have to be drained completely and a careful cleaning of the big tank and the rearing tanks is necessary. Do not use the same water again when re-starting! Tanks need to be cleaned from any debris; use brushes and cleaning cloth to wash the tanks from inside and outside. If the large tanks need a thorough cleaning of the bottom, it is possible to remove temporarily the rearing tank in the middle. Disconnect the water pipe at the ball valve and remove all other pipes and tubes from the tank in the middle and remove it carefully from the big tank. Put back the tank after cleaning in reverse order, re-connect all pipes into the previous position.
2. There might be conditions, that complete draining is not possible when delivering a batch of late larvae to the Hapas after about 3 weeks, since in one of the other rearing tanks there are already newly hatched larvae. In that case run the trials continuously, but then stop to use the units latest after 6 weeks and apply a complete cleaning as described above.
3. All equipment which was used in the rearing trial should be cleaned as well, such as heaters, including the sensors, pumps, tubes, air stones and all other equipment which was submerged. Do not forget to open the filter bodies which are outside of the tank and to clean the filter cartridges if applicable.
4. The bacterial substrate in the biofilter does not need a special cleaning. In case, rearing trials are stopped, just rinse the plastic flakes with clean water and let them dry. DO NOT CLEAN THE FLAKES WITH CHLORINE. This will destroy the spores of the "good" bacteria which may help to re-start the biofilter in the next rearing trial. You may remove the flakes when cleaning the tank with chlorine solution und put back afterwards.
5. Disinfection of the tanks might be necessary, specifically when there are indications of bacterial/virus infections or problems with fungi in the last trial. Use a disinfectant which is available according to the manufacturer's advices. If chlorine is used, make sure that no sensitive equipment is in touch with the chlorine solutions. Let the system run as in a rearing trial mode for a day (pumps and aeration on). Please note, that the nitrifying bacteria in the biofilter are also destroyed in the disinfection process and need to re-establish. On a short scale, (within one or two days) it could be a good idea to remove part of the substrate from the biofilter and to keep it submerged in water and put it back when restarted the system. Thus, a kind of inoculation with the "right" bacteria ensure a quick re-start of the biofilter. Please be sure, that a thorough rinsing of the tanks is applied after a disinfection procedure. Let the tanks dry for a couple of days, which helps to kill germs.
6. For a re-start with completely empty tanks, follow the advices above in section "Measures when filling completely empty tanks". Please note that pumps, heaters and aeration are only switched on when tanks are close to be filled with water completely.

Measurement of water parameter

Water quality is a critical factor when culturing any aquatic organism. Optimal water quality varies by species and must be monitored to ensure maximum growth rate and survival. This is specifically true for an indoor hatchery but also for pond systems where larvae and fry are produced. The quality of the water in the production systems can significantly affect the organism's health and the costs associated with getting a product to the market. Water quality parameters that are commonly monitored in the aquaculture industry include temperature, dissolved oxygen, pH, alkalinity, hardness, ammonia, nitrite and nitrate. Depending on the culture system, carbon dioxide, chlorides, and salinity may also be monitored. Some parameters such as alkalinity and hardness are fairly stable, but others like dissolved oxygen and pH may fluctuate daily. It is important to establish a standardized water quality testing protocol for your particular situation. Know the tolerance range for your culture species, establish critical levels, and be prepared to act if a problem occurs. The Table 5 below indicates the water quality preferences for some commonly cultured species. For more information about a particular parameter, click one of the links below. If you need assistance in this area, contact the local experts or the German partner in the "Ich liebe Fisch" project (e.g. Bernd Ueberschär).

Species	Temp (C°)	Dissolved Oxygen mg/L	pH	Alkalinity mg/L	Ammonia mg/L	Nitrite mg/L
Baitfish	16-24	4-10	6-8	50-250	0-0.7	0-0.6
Catfish/Carp	18-26	3-10	6-8	50-250	0-0.7	0-0.6
Hybrid Striped Bass	21-29	4-10	6-8	50-250	0-0.7	0-0.6
Perch/Walleye	10-18	5-10	6-8	50-250	0-0.7	0-0.6
Salmon/Trout	7-16	5-12	6-8	50-250	0-0.7	0-0.6
Tilapia	24-34	3-10	6-8	50-250	0-0.7	0-0.6
Tropical Ornamentals	20-29	4-10	6-8	50-250	0-0.7	0-0.5

Tab. 5: *The table provides some examples of recommended water parameter for various fish species. The oxygen saturation is a relative measure of the concentration of oxygen that is dissolved in water as a proportion of the maximal concentration that can be dissolved in that medium. It can be measured with a dissolved oxygen probe such as an oxygen. The standard unit of oxygen saturation is percent (%). Please note: the higher the water temperature, the lower is the amount of dissolved oxygen for a saturation of 100%.*

Practically, ready-to-use test kits can be used the best to measure the necessary parameter. There are test kits available e.g. from the company JBL which are quick and easy-to-use, even under field conditions (example for ammonia measurements, www.jbl.de/en/products/detail/2438/jbl-ammonium-test-NH4, for easy access scan the QR-code with your smartphone). The choice of test kits covers almost any kind of interesting parameter, even oxygen and pH can be measured with these kits. However, for daily oxygen and pH measurements, a durable probe is more appropriate, but needs a signifcant one-time investment. An e.g. "Oxyguard" (www.oxyguard.dk/products/hand-held-instruments/handy-polaris-2/#) which measures dissolved oxygen and oxygen saturation according to temperature is the best and robust equipment under field conditions, but quite expensive.

Using the test kits of e.g. JBL to measure water parameter is quite easy. The principle is a reaction among the parameter to measure (e.g. ammonia in the water) and one or two reagents which produce a certain colour in the sample after a given time. All the necessary equipment comes with the test kits (small glasses for the samples, spoon for powdered reagents, syringe and a colour card, which is being used then used to compare with a blank (see Figures 25– 28 below).

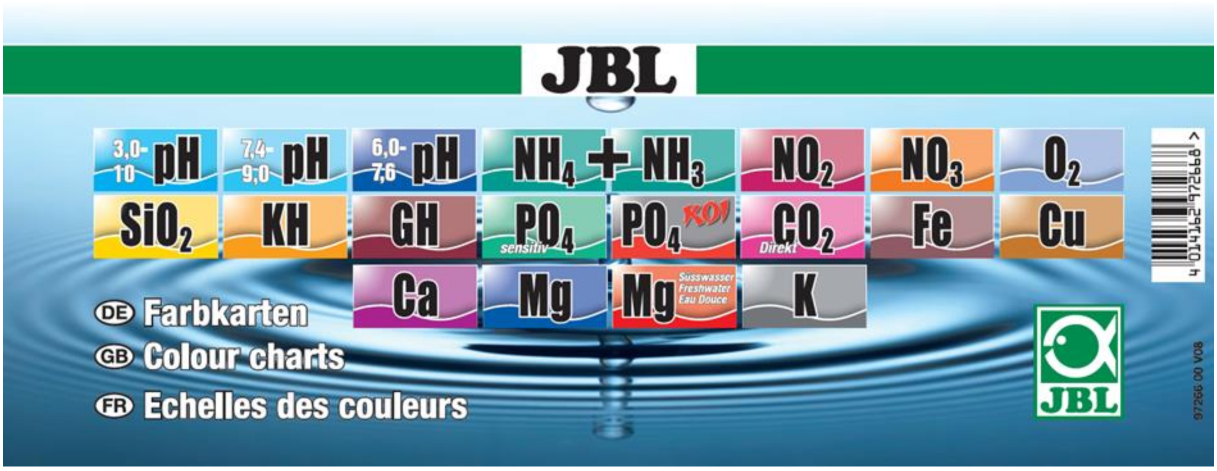


Fig. 25: *This table indicates the wide variety of parameters which can easily be measured, using the test kits of JBL.*

***Fig. 26**: Usually, two small glass vials are needed for a measurement. Both vials are filled with the water sample. In one vial reagents are added according to the manufacturers advices and some time is needed to develop the reaction (the colour).*

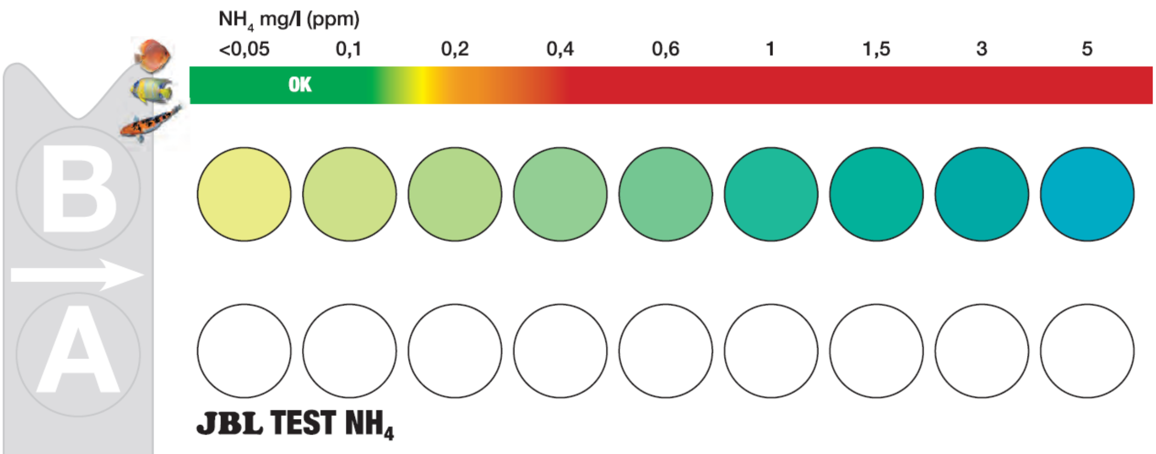


***Fig. 27**: The picture depicts an example for a colour card which is used to read the measured value. The example shows the colour card for the measurement of NH_4 – NH_3. The blank has to cover the coloured spots, the sample the white spots. The colour card provides an estimation about the save range (on top) concerning the measured parameter. Please note that these values are related to pet fish environment; safe values for commercial aquaculture may differ from this recommendation (e.g. for NH_4 – NH_3 values in the hatchery are safe until about 0.7-0.9 mg/l, compare with Table 5 above).*

Fig. 28: *After the given time, the tray with the two vials gas has to be placed on the related colour card (for each parameter, a specific colour card is available). The blank is put on the coloured spots, the sample on the white spots. Move the tray to the position where both vials show the same colour and read the value. Each colour card provides a recommendation for a safe range.*

Costs for JBL-Testkits:

A complete case with test kits for 11 parameter: about 75 Euro. Recommended as the basic kit, since it comes with all necessary equipment (glasses for samples , glass tray, syringe, spoon, colour cards and instruction manual. For further use, only replacement kits are necessary. Following some examples for replacements.

Replacement kit NH_4 -NH_3: c.a. 6 Euro (about 50 measurements)

Replacement kit NO_3: c.a. 8 Euro (about 50 measurements)

Replacement kit NO_2: c.a. 6 Euro (about 50 measurements)

Egg incubation: McDonald Unit

There was a McDonald unit installed next to the hatchery. The purpose of this unit is to provide full control over the egg breeding and hatching period (Figure 29). The eggs are retrieved from the female tilapia and incubated into the jars.

Fig. 29: *Mc Donald unit, installed in the hatchery. The system has a head and bottom tank, a tray for the jars and water is pumped continuously from the bottom tank to the head tank. A 300-Watt heater is installed in the bottom tank to achieve an appropriate temperature (optimal temperature is supposed to be 28°C for e.g. O. karongae). Flow through the jars can individually be adjusted.*

The McDonald unit follows a very traditional method in Europe to breed eggs from salmon or trout. The breeding was accomplished in Zuger glasses or Zuger jars, the basic principle is the same as with the McDonald jars (Figure 30).

Fig. 30: *Zuger glasses or Zuger jars are a type of equipment to breed fish eggs. Funnel shaped glasses contain the eggs while water is supplied from the bottom in an amount that the eggs are just kept in motion. The hatched fish larvae are usually collected with the spill over water from the top. Please note the high density of eggs which can be accommodated in the jars.*

Before using the McDonald unit, it has to be filled with water. Head and bottom tank need to be filled completely with water and the flow from the top to the bottom is a combination of pumping, flow through the jars and the water running through the by-pass. Check carefully for a balanced flow before incubating eggs. The bottom tank shall not spill over.

When everything runs well with the water circulation, the heater in the bottom tank can be turned on.

Egg collection

Eggs are collected by capturing the brooders; since the target species are mouth brooders, females are targeted. To retrieve the eggs, females are put into a box with water and eggs are carefully rinsed out of the mouth (Figure 31). Subsequently, eggs are collected from the box and put into clean water-filled beakers. The beakers are used because currently the farm has no egg collecting plates. The collected eggs are then made sure that they are free from debris by sieving out all the debris using fine mesh min-hand nets. (Figure 32). These eggs are usually of different stages and are thus categorised and put into incubation jars depending of the stage of egg development and species. Water flow and temperatures in is regulated as described above.

Fig. 31: *Box with fish and eggs on bottom. The eggs are retrieved out of the parent buccal cavity, collected on a piece of gauze and then put into clean water-filled beakers.*

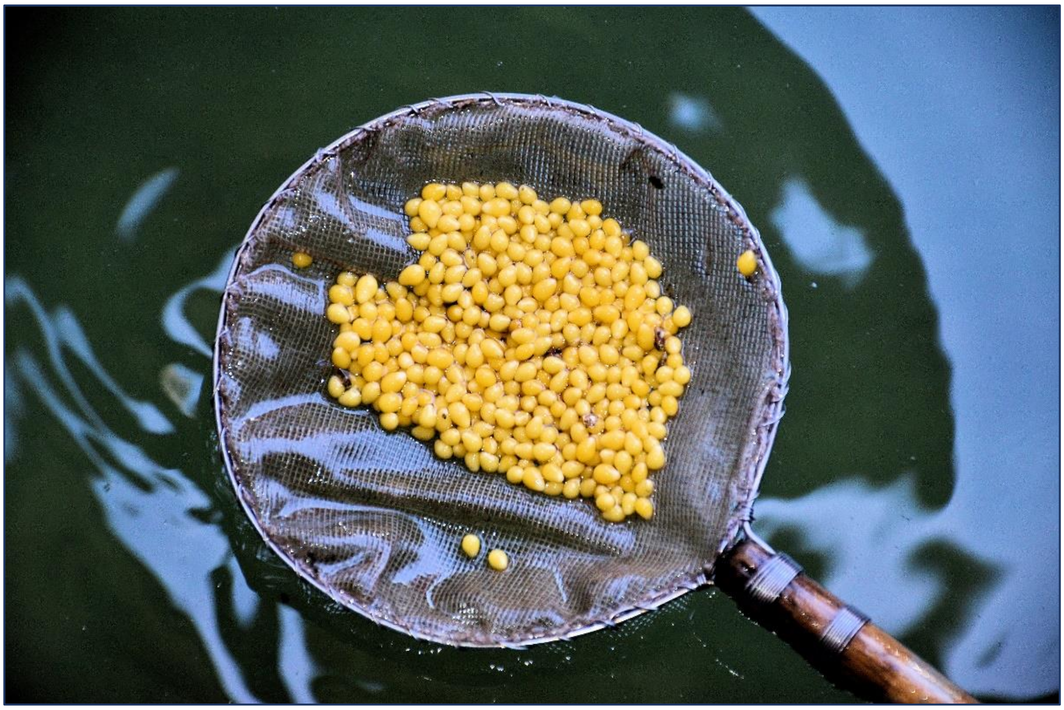


Fig. 32: *The collected eggs are then cleaned by sieving out all the debris using fine mesh mini-hand nets.*

Egg incubation

Egg incubation starts immediately after retrieving the eggs from the brooders and eggs are put in the incubation jars according to the stage and species (Figure 33). Water flowing into these jars is carefully regulated and any remaining debris is carefully removed from these jars. Incubation period varies depending on the stage at the time of collection. On one end, stage one eggs take six to seven days before reaching swim up stage while on the other end stage 4

Fig. 33: *McDonald jar with incubated eggs from Chambo. The eggs are incubated in separated jars according to their developmental stage. Unfertilized eggs and debris (white colour) can be carefully removed from the jars using e.g. a small tube. The eggs shall float freely around and are not allowed to settle on the ground without no movement.*

eggs take only 48 hours before reaching a swim up stage fit enough to be transferred into rearing tanks. Hatching rates can reach as high as 98 %. Most of the eggs that have been observed to die are those which are not fertilised and these are mostly seen to be white in colour at the time of collection. These are however left together with the fertilised eggs to minimise handling which could cause injuries to the fertilised eggs there by affecting the hatching rates (check the Video).

Larval incubation

Upon reaching swim up stages, the larvae are collected from the jars and transferred into the rearing tanks (Figure 34). If larvae are hatching more or less at the same point in time, the complete jar can be removed from the McDonald unit and drained into a rearing tank. The stocking density may reach up to 10.000-15.000 larvae per cbm (the optimal density for *O. karongae* under intensive rearing conditions is still not known and at present under investigation as part of a master thesis).

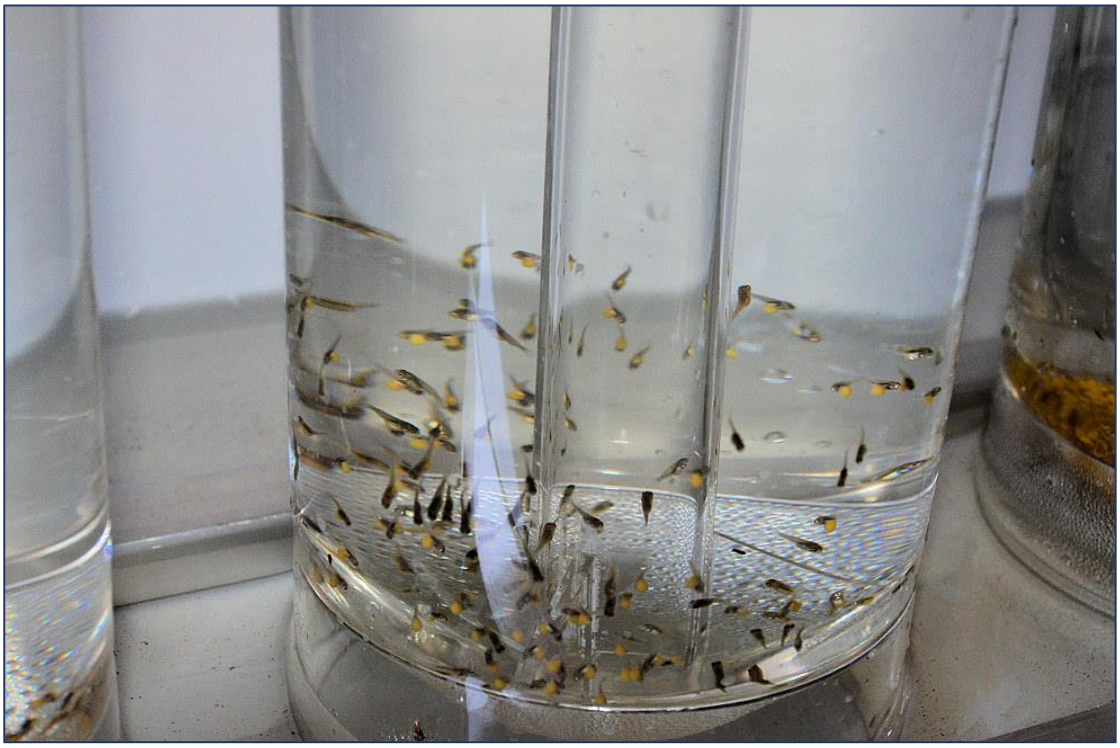


***Fig. 34:** Newly hatched larvae, ready to be incubated into the rearing tanks. If all larvae in a jar are hatched at the same point in time, the jar can be carefully disassembled from the unit and drained directly into the designated rearing tank.*

Changing water in the hatchery tanks or McDonald Unit

When re-starting the McDonald unit, it has to be filled with clean water and adjustments of the water flow have to be made as mentioned above. Although the eggs may not produce much ammonium, this has to be controlled from time to time. If partial water exchange is necessary, turn off the heater first, then the pump and drain water through the pipe in the bottom tank. Remove the standpipe in the bottom tank and turn the pipe at the outside of the bottom tank to the desired draining level.

Please note, that the jars with the eggs are not running empty with a partial water exchange. Refill the bottom tank, turn on the pump and refill water as long as the previously adjusted balance among the water level in the head and bottom tank was achieved. Please note, that head and bottom tank have to be filled always completely with water. Otherwise, the pump in the bottom tank can run dry and fail eventually.

In case, fungal or parasites attacks has been observed, disinfection may be necessary. Disinfect according to the manufacturer's advices and rinse thoroughly the whole unit with clean water subsequent to the removal of the disinfectant (at present, the manufacturer of the jars cannot answer the question, if the jars are resistant against chlorine; thus, some tests are necessary before using a disinfectant which contains chlorine).

Handling of fry beyond the hatchery stage

One trial in the indoor hatchery takes about 3-4 weeks (depending on the temperature), subsequently the post larvae are introduced into Hapas in the ponds of the farm (Figure 35) where they are able to adapt to pond conditions in a protected environment, and are raised until they have reached the right size to be disseminated to the farmer (about 5-10 g, Figure 36).

Fig. 35: *Hapas at Bunda Campus farm; post larvae from the hatchery are transferred into Hapas in order to adapt to pond conditions and to grow until fingerling size.*

Fig. 36: *Tilapia fingerling size (5-10g), ready to be stocked in farmers ponds.*

Feeding of fish larvae

Proper feeding of the larvae in the rearing tanks is of vital significance to achieve finally viable fingerlings. Since the feeding conditions are somewhat different depending from the species, only general instructions are given here. For more detailed feeding instructions consult the related literature and rely on previous experience. Moreover, data about optimized feed quality, feeding frequency, stocking density and more can be expected from a master thesis which is on the way; the data are collected from experiments which are at present accomplished with *O. karongae* larvae in the hatchery.

Nevertheless, what can be claimed here in general is that two parameters are of major importance:

- the quality of the feed, which needs to be adapted at least in size to the ontogenetic stages (thumb rule: the older the larvae the larger the size of the feed particles)
- the frequency and amount of feed administered to the larvae (thumb rule: older larvae need less frequent feeding but higher amount per feeding event)

Feeding frequency has to be higher in younger larvae, every 30-60 minutes, new feed should be delivered to the larvae. The amount of feed needs to be adapted to the ontogenetic stage of the larvae. Feeding amount should be in a range that larvae are apparently saturated after each feeding event. Often, the amount of feeding is being calculated on the biomass of the fish in the tanks, this is, however, quite difficult in the larval stage.

It is useful, to prepare the amount of feed in advance for each feeding event per day, using small cups for each feeding event per tank. This makes sure, that also rather unexperienced persons do feed the right amount.

Feed quality for fish larvae and juveniles

Newly hatched fish larvae are very vulnerable organisms. This is specifically true for the offsprings of marine species, but also for the larvae from Tilapia. The larvae of Tilapia are hatching with a huge yolk-sac, which provides nutrition in the first couple of days. Beyond that stage, feeding is required. The onset of feeding should start when the larvae have still a small yolk-sac, in order to avoid that they are starving, which may cause low growth rates and higher mortality. The picture below (Figure 37) provides an impression about the larvae of O. karongae in the first feeding stages (compared with an early juvenile).

Please keep in mind following features of newly hatched larvae and early juveniles:

- At hatching supposed to be the smallest autarkic vertebrates at earth. They put on body mass from larval size to adults by a factor of 10^5 to 10^7!
- Highly vulnerable (predation, starvation, mechanical stress, cannibalism, parasites, diseases);
- Reduced motility
- No buoyancy control right after hatching (swimbladder not yet developed);
- Limited size spectrum of potential prey (size of the mouth);
- Simply organized digestive organs;
- Ontogenetic deficiencies in establishing digestive enzyme capacity;

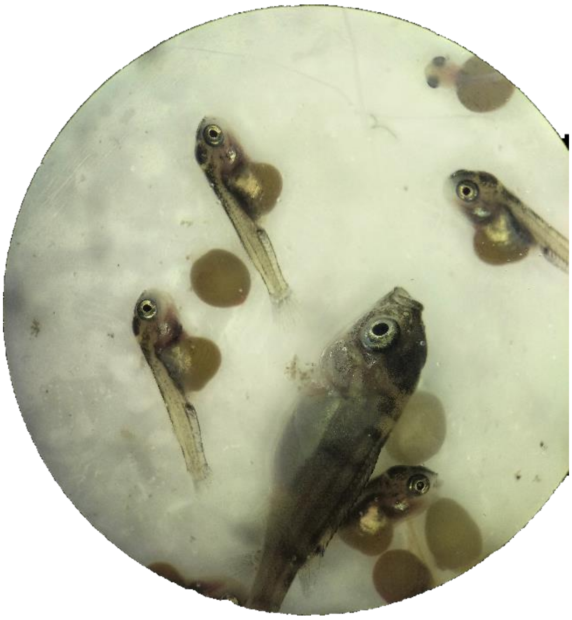


Fig. 37: *The photo depicts first feeding stages of O. karongae. The larvae have still some yolk remaining, but need to be feed already. Next to the small stages a post larval stage.*

If we consider here the propagation of tilapia in an indoor hatchery, in the beginning the tilapia larvae needs micro particulate feed as small as about 300µm (since live feed is normally not available). The size of the feed needs gradually to be increased until fingerling size. Figure 38 depicts some examples for modern larval feed with two different sizes, produced under professional conditions. Figure 39 depicts some feed recipes made in Malawi.

Fig. 38: *Micro Diets (powdered feed) for fish larvae, the examples depict two different sizes, as small as 150µm (lower row) and 500µm (upper row). Various professional brands of Micro Diets, produced in Europe.*

Fig. 39: *Some feed recipes "Made in Malawi". In the lower row, insect protein powder which can be used e.g. in larval feed to represent the protein fraction and for comparison feed pellets (professional product) for juvenile tilapia.*

The quantitatively most important ingredients in larval and juvenile feed are proteins and lipids. Proteins from the feed are essential for the larvae to build their own body protein, and since the growth rate in fish larvae is tremendous, they need a lot of protein in the feed for optimal growth. In fish food, protein provides the essential and non-essential amino acids to synthesize body protein and in part provides energy for maintenance. When protein levels are inadequate in the diet of fish, a reduction of growth is observed. Dietary protein content is the most important factor affecting fish growth and feed cost. For many fish species, there is an optimum requirement of dietary protein to supply adequate amino acids for maximizing growth. If too much protein is supplied in the diet, only part of it is used to make new protein for growth, and the remainder will be converted into energy, which results in increased feed cost and increased ammonia nitrogen excretion. Therefore, from both, the economic and environmental perspective, it is important that inclusion of the dietary protein should be optimized. For Tilapia larvae, a protein content of 35-40% is recommended; this amount can be reduced to 30-35% in juveniles.

The lipids in the feed are the fuel for the larvae in order to accomplish their biosynthesis. Lipids are much more efficient in fuelling the metabolism compared to proteins. However, the lipid content should not much higher than 15% in the feed for larvae and early juveniles. Table 6 provides some information about the protein and lipid content as common in microparticulate feed which is used in the rearing of fish larvae in professional aquaculture.

The sources for protein and lipids in larval and juvenile feed can be variable. The best performing sources are fishmeal and fish oil. However, these ingredients are quite expensive and probably not a realistic choice under Malawian conditions.

Brand	Othohime	INVE Orange	GEMMA Micro	BioMar	MicroPro, R 4
Macro Nutrients					
Moisture	6.3%				5.1%
Crude protein	56.3%	56%	59%	58%	49.14%
Crude fat	15%	13%	14%	12%	20.47%
Crude fibre	2.8%	1%	0.2%	0.5%	
Crude ash	14.2%	10%	13%	11%	17.3%
Caloric energy					22 MJ/kg

Tab. 6: *Composition of a selection of high quality microparticulate feed (micro diets) for fish larvae. These brands are common in feeding protocols for larvae of commercially important (marine) fish species. Although this feed is not affordable under Malawian conditions, it provides some information about the protein and fat content in larval feed.*

The following recipe was produced for experiments in the hatchery at the Bunda farm and can be considered as a basic recipe for those who want to produce their own larval feed.

Larval feed, Malawian recipe	
Ingredient	%
Fishmeal	16
Fat soybean	19.5
Low fat soybean	19
Sunflower oil	10.5
Rice bran	9.0
Wheat bran	12.0
Maize flour	12.0
Cassava flour	1.0
Vitamin premix	0.7
Mineral premix	0.7
Salt	0.3
∑	100

Tab. 7: *The table provides a recipe which is being used at Bunda farm to feed the early larval stages and juveniles. The growth rate was tested against highly professional feed made in Europe; the first results depict, that this feed is a bit behind concerning growth rate, but still in an acceptable range. Precise results are expected with the termination of a master thesis which has dealt with the Tilapia larval feed quality.*

The following table depicts the result of the analyses of the macro nutrients in a couple of feed recipes, including a professionally produced pelleted feed for Tilapia juveniles and adults, and some recipes of feed which was prepared under Malawian conditions; further specifications are described in the caption of Table 8.

Measured in dry matter, feed samples from January 2019						
Parameter	% DM	% Ash	% Protein	% Lipids	% total Carboh.	Energy MJ/kg
Sample						
Aller Aqua*	93.12	5.71	41.35	15.95	36.99	22.37
Hermetia**	97.75	12.09	62.35	7.17	18.39	20.63
Farmer Feed	84.90	4.59	12.76	12.47	70.18	20.15
Larval Feed	90.53	11.49	37.42	12.30	38.79	20.50
Juvenile Feed	88.58	8.05	38.44	15.18	38.33	21.73
Project Feed	90.04	8.19	34.06	13.66	44.08	20.50
*Commercial Tilapia feed, purchased from Aller Aqua in Europe **Please note: Hermetia is the pure insect protein powder, not a formulated feed						

Tab. 8: *The table provides data on the analyses of the macronutrients in various recipes of Tilapia feed. Aller Aqua is professiponally produced pelleted feed; Hermetia is not a feed, but a pprotein concentrate extracted from the maggots of the black soldier fly; Farmer feed represents the feed which is usually produced from the farmer to feed the ongrowing Tilapia in their ponds; Larval Feed is related to the feed recipe which is provided in Table 7; Juvenile Feed was made at Bund Farm to feed juvenile Tilapa in a research trail with hybrids; Project feed which is the feed which is produced at Bund farm in behalf of the project "Ich liebe Fisch" and provided to the farmer along with fingerlings;*

The results of the analyses of the macro nutrients of the various feed depicts a quite different protein content specifically in the Farmers feed, only 12% are crude protein; compared with the professional feed from Aller Aqua, there is a gap of 28% of protein, which explains the weak growth rate in the farmers pond. The protein content in the larval feed is in a safe range, however, the lipid content can be raised a bit, 15% would be the optimal value.

Propagation of Tilapia, general introduction

Seed supply

Please note: the following instructions relate mainly to the propagation of Nile Tilapia (*Oreochromis niloticus*) but are in many perspectives common standard.

Tilapia are asynchronous breeders. Hormones are not used to induce spawning, which occurs throughout the year in the tropics and during the warm season in the subtropics. Breeding is conducted in ponds, tanks or hapas. The stocking ratio for females to males is 1-4:1 with 2 or 3:1 being the most common. The brood fish stocking rate is variable, ranging from 0.3-0.7 kg/m^2 in small tanks to 0.2 - 0.3 kg/m^2 in ponds. The popular Hapa-in-pond spawning system in Southeast Asia uses 100 g brood fish stocked at 0.7 kg/m^2. Spawning ponds are generally 2000 m^2 or smaller. In Southeast Asia, a common hapa size is 120 m^2.

Brood fish are given high quality feed at 0.5-2 % of body weight daily. Swim-up fry gather at the edge of a tank or pond and can be collected with fine-mesh nets. Fry collection can begin 10 to 15 days after stocking.

Multiple harvests (six times per day at 5-day intervals) are conducted up to a maximum of 8-10 weeks before pond drainage and a complete harvest is necessary. Tanks must be drained and recycled every 1-2 months because escaped fry are very predaceous on fry from subsequent spawns. Alternatively, tanks or ponds are harvested completely after a 2-4 week spawning period. Production of optimum-sized (<14 mm) fry ranges from 1.5 to 2.5 fry/m^2/day (20 to 60 fry/kg female/day).

In the South East Asian Hapa method, fish are examined individually every 5 days to collect eggs. This system is much more productive, but it is labour intensive. Brood fish are more productive if they are separated by sex and rested after spawning.

Sex-reversal

Commercial tilapia production generally requires the use of male monosex populations. Male tilapia grow approximately twice as fast as females. Therefore, mixed-sex populations develop a large size disparity among harvested fish, which affects marketability. Moreover, the presence of female tilapia leads to uncontrolled reproduction, excessive recruitment of fingerlings, competition for food, and stunting of the original stock, which may not reach marketable size. In mixed-sexed populations, the weight of recruits may constitute up to 70 percent of the total harvest weight. It is therefore necessary to reverse the sex of female fry. This is possible because tilapia do become sexually differentiated for several days after yolk sac absorption. If female tilapia receive a male sex hormone (17-α-methyltestosterone, MT) in their feed, they will develop as phenotypic males. Fry collected from breeding facilities need to be graded through 3.2 mm mesh material to remove fish that are >14 mm, which are too old for successful sex reversal. Swim-up fry are generally <9 mm. MT is added to a powdered commercial feed or powdered fish meal, containing >40 % of protein, by dissolving it in 95% ethanol, which is mixed with the feed to create a concentration of 60 mg MT/kg feed after the alcohol has evaporated. The alcohol carrier is usually added at 200 ml/kg feed and mixed thoroughly until all the feed is moist. The moist feed is air dried out of direct sunlight, or stirred in a mixer until dried, and then stored under dark, dry conditions. Androgens break down when exposed to sunlight or high temperatures. Fry are stocked at 3000 to 4 000/m^2 in hapas or tanks with water exchange. Stocking densities as high as 20 000/m^2 have been used if good water quality can be maintained. An initial feeding rate of 20-30 % of body weight per day is gradually decreased to 10-20 % by the end of a 3 to 4-week sex-reversal period. Rations are adjusted daily, and feed is administered four or more times per day. If sex-reversal is conducted in hapas, the feed must be of a consistency that allows it to float. Otherwise a considerable amount of feed would be lost as it settles through the bottom of the hapa. Sex-reversed fry reach an average of 0.2 g after 3 weeks and 0.4 g after 4 weeks. The average efficacy of sex-reversal ranges from 95 to 100 % depending on the intensity of management.

Nursery

After sex-reversal, fingerlings are generally nursed to an advanced size before they are stocked into grow-out facilities. This procedure increases survival in the grow-out stage and utilizes growing space more efficiently. Sex-reversed fingerlings are stocked at approximately 20-25 fish/m^2 in small ponds and cultured for 2-3 months to an average size of 30-40 g. The ponds should be filled immediately before stocking to prevent the build-up of predaceous aquatic insects. Final biomass at harvest should not exceed 6000 kg/ha. In ponds, fingerlings are given extruded feed (30 % protein) at an initial rate of 8-15% of biomass per day, which is gradually decreased to a final rate of 4-9 percent per day. A series of small cages (<4 m^3) with increasing mesh size can be used to rear advanced fingerlings. Sex-reversed fingerlings can be stocked at a rate of 3 000 fish/m^3 and grown for 6 weeks until they average 10 g. Fish of this size can be restocked at 2 500 fish/m^3 to produce 25-30 g fingerlings in 4 weeks. These fish can be stocked at 1 500 fish/m^3 to produce 50-60 g fingerlings in 4 weeks. A recirculation system stocked at 1000 fish/m^3 will produce 50 g fingerlings in 12 weeks. Fingerlings should be fed 3-4 times daily; the recommended amount of feed is mentioned above.

General issues in Tilapia production

Tilapia grow rapidly on formulated feeds with lower protein levels and tolerate higher carbohydrate levels than many carnivorous farmed species. They can also accept feeds with a higher percentage of plant proteins. It is easy to breed tilapia and culture them intensively and economically. They are relatively resistant to poor water quality and disease. Their ability to over-reproduce in ponds requires the use of male monosex populations. Their hardiness and adaptability to a wide range of culture systems has led to the commercialization of tilapia production in more than 100 countries. Their widespread consumer appeal will fuel the expansion of the tilapia industry in Africa for years to come.

ANNEX 1: Basic principles on production cycle of Tilapia-like species

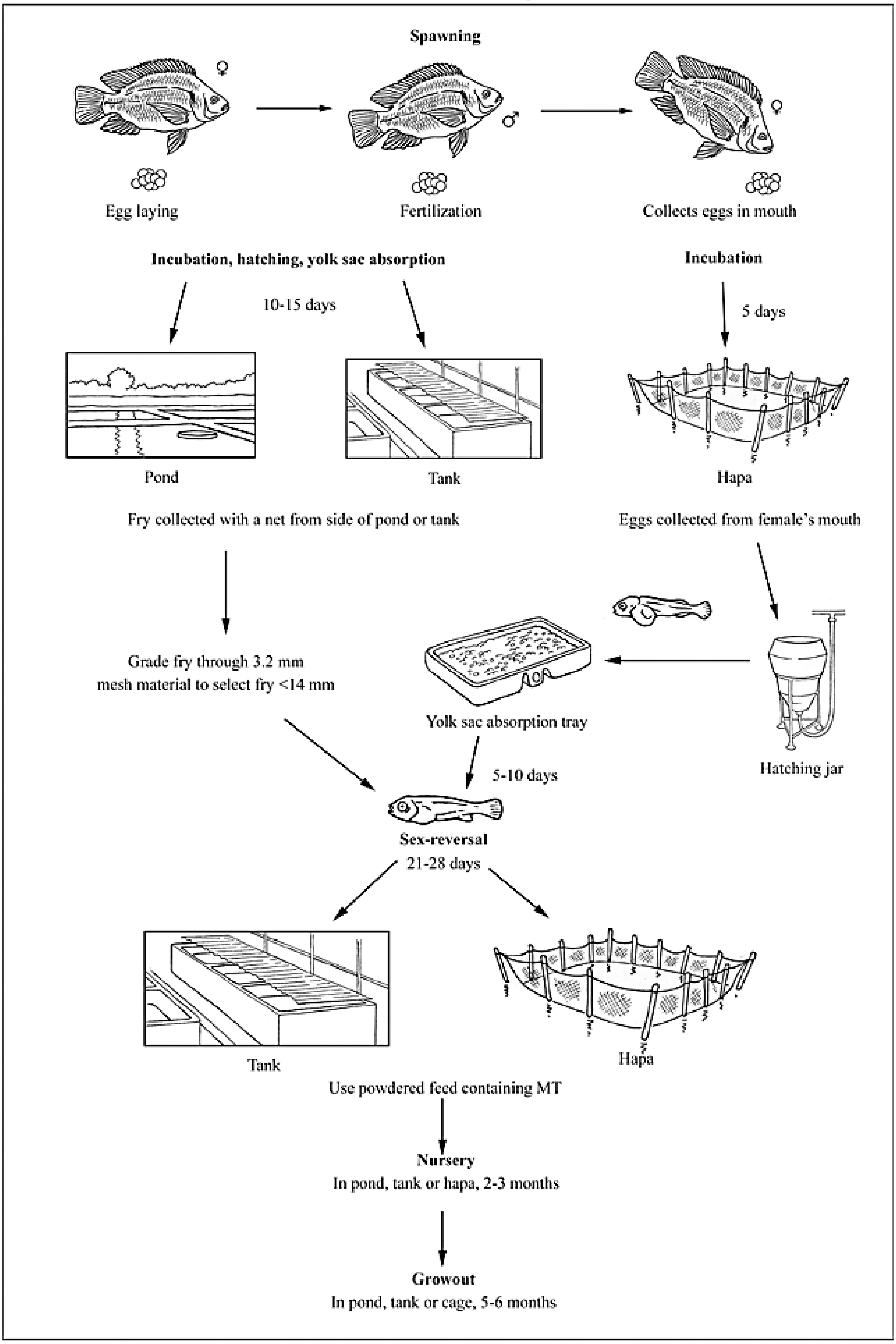


Fig. 40: *Basic principles on the production cycle of Tilapia-like species. Please note that there are various options from eggs to fingerlings for grow-out ponds. Fry can be reared indoor in tanks (comparable to the hatchery at the Bunda Farm) or in small Hapas/fry ponds outside.*

ANNEX 2: Links to videos

Table with links to the instruction videos, mentioned in the manual

Title/URL	QR-Code
Slow moving water body for early larval stages www.youtube.com/watch?v=EW1nZyV_PzI	
Fast moving water body for late larvae and juveniles www.youtube.com/watch?v=UaAA9MVk0D0	
Water flow in McDonald unit www.youtube.com/watch?v=goHGbt6cGzs	
Bubbles for newly hatched and young larvae www.youtube.com/watch?v=HWNxhDRVkRw	
Aeration in the big tank www.youtube.com/watch?v=F2js5YgMV8U	

ANNEX 3 (next pages): Instruction manual for heater

The following Annex 2 provides instruction manuals for the two types of heater control units: **Heat controller Duo** or **Twin controller** (please check which type you want to manage).

heat controller duo

Operation Manual ENG

Digital temperature monitor and controller for aquarium and under gravel heater

With the purchase of this digital measuring and regulating unit, you have selected a top quality product. It has been specifically designed for aquaristic purposes.

With this unit, you can continuously measure and control the water temperature of your aquarium and ensure a flow of the under gravel.

AB Aqua Medic GmbH
Gewerbepark 24, 49143 Bissendorf, Germany

1. Included in shipment

The Aqua Medic heat controller duo is generally delivered with a water-resistant temperature sensor. The unit is ready for connection. The units to be controlled (heaters, heating cables or mats) are connected to the double socket.

2. Description

At socket No. 1, an aquarium heater can be controlled. Socket No. 2 is provided for controlling heating cables or mats by a timer. The maximum output is approx. 1,200 Watt.

3. Installation

- Connect to 220 V power source.
- Place the temperature sensor into the aquarium and fix it with an Aqua Medic electrode holder. After a few minutes, the actual aquarium water temperature is indicated.

Pict. 1: heat controller duo

1. Socket No. 1 – heater
2. Socket No. 2 – heating cable
3. Operation symbol "heating"
4. Arrow keys to adjust the parameter
5. Display heating cable ON – OFF

4. Adjustion

By pressing an arrow key, the display light will be turned on.
Unlock the keys: LOC appears on the upper display. The keys can be unlocked by pressing the SET and arrow down key for 10 seconds simultaneously. Instead of LOC, the temperature is displayed.

To adjust the setpoint, press "SET" key until the setting menu appears. First of all, the controller has to be in the "HEAT" mode (Fig. 1, No. 3). The setpoint can be changed with the arrow keys after pressing the SET button shortly.

The setting "COOL" can be used when a fan is to be used for cooling at high temperatures instead of a heater. But then the cable may not be too strong (max. 10 W per 100 liters), so only a slight flow of the under gravel is ensured without significant heating of the water.

Then, you press the "SET" button shortly, the setpoint appears flashing and can be changed with the arrow keys. By briefly pressing the "SET" button, there will be access to adjust the temperature difference between the setpoint and emergency shutdown of the heating cable at an excessively high water temperature. If the setpoint plus this set value is reached, the heating cable is switched off until the temperature in the aquarium has dropped again below the setpoint.

By pressing the "SET" button again, you can set the alarm. When reaching the setpoint plus the adjusted value, you will hear a beep. As soon as the temperature falls below the adjusted value, the unit activates the power socket No. 1 and switches the consumer (heating) on. The heating cable is controlled by the timer and power socket No. 2.

If you keep pressing the "SET" button for a quite a while, you will reach the timer menu. Here, you can set the time also by pressing the "SET" button and the arrow keys. Then, the time how long the heating cable should be turned on and switched off has to be adjusted. A mode of 15 minutes each have been proved suitable. Again, the value to be changed is selected and then adjusted using the arrow keys by pressing the "SET" button.

By pressing the OK button you can leave the setting menu.

The heat controller duo has got a rechargeable battery so the programmed data will not be lost in case of power failure. After starting the unit up, it takes about 24 hours until the battery is charged and the data remain stored.

For safety reasons, you should control the nominal values, especially after a power failure.

5. Technical Data

Display:	0.1°C
Measurement range:	0.0 up to +50.0°C
Resolution:	0.1°C
Loading capacity of contact:	1,200 Watt at 220 V AC
Air Humidity:	below 80%
Adjustment range:	16 – 40°C
Adjustment accuracy:	+/- 1°C
Power requirements:	220 V / 50 Hz
Humidity:	< 85%

6. Warranty

Should any defect in material or workmanship be found within 12 months of the date of purchase AB Aqua Medic GmbH undertakes to repair or, at our option, replace the defective part free of charge – always provided the product has been installed correctly, is used for the purpose that was intended by us, is used in accordance with the operating instructions and is returned to us carriage paid. The warranty term is not applicable on the all consumable products.
Proof of Purchase is required by presentation of an original invoice or receipt indicating the dealer's name, the model number and date of purchase, or a Guarantee Card if appropriate. This warranty may not apply if any model or production number has been altered, deleted or removed, unauthorised persons or organisations have executed repairs, modifications or alterations, or damage is caused by accident, misuse or neglect.
We regret we are unable to accept any liability for any consequential loss.
Please note that the product is not defective under the terms of this warranty where the product, or any of its component parts, was not originally designed and / or manufactured for the market in which it is used. If your AB Aqua Medic GmbH product does not appear to be working correctly or appears to be defective please contact your dealer in the first instance.
Before calling your dealer please ensure you have read and understood the operating instructions. If you have any questions your dealer cannot answer please contact us.

Our policy is one of continual technical improvement and we reserve the right to modify and adjust the specification of our products without prior notification.

AB Aqua Medic GmbH - Gewerbepark 24 - 49143 Bissendorf/Germany
- Technical changes reserved – 09/2015

T Controller Twin

Operation Manual ENG

Digital measuring and regulating unit to control heating and cooling devices

With the purchase of this digital measuring and regulating unit, you have selected a top quality product. It has been specifically designed for aquaristic purposes.

With this unit, you can continuously measure and control the temperature of the water in your aquarium.

AB Aqua Medic GmbH
Gewerbepark 24, 49143 Bissendorf, Germany

1. Included in shipment

The Aqua Medic Temperature Controller Twin is generally delivered with a saltwater-resistant temperature sensor. The unit is ready for connection. The units to be controlled (heaters, fans, coolers) are connected to the double socket.

2. Description

Heaters of any type (i. e. glass or metal aquarium heaters, low voltage heating cables with transformer, warm water supply by a magnetic valve) can be connected to socket No. 2. The maximum output is approx. 1,200 Watt. Socket No. 1 is provided for controlling fans or coolers. The maximum output is again approx. 1,200 Watt. Due to the high starting current, cooling units may be connected only to a power consumption of 400 W.

3. Installation

- Connect to 220 V power source.
- Place the temperature sensor into the aquarium and fix it with an Aqua Medic electrode holder. After a few minutes, the actual aquarium water temperature is indicated.

Pict. 1: T Controller Twin:

1. Socket No. 1 – cooling
2. Socket No. 2 – heating
3. Operation symbol “heating” (sun) or “cooling” (snow flake)
4. Arrow keys to adjust the parameter
5. Set key
6. Temperature sensor incl. sucker

4. Adjustion

By pressing an arrow key, the display light will be turned on. To adjust the nominal values, press "SET" key. The temperature display starts flashing and can be adjusted to the nominal value by the arrow keys. After pressing the SET key again, the display branches to the setting for the cooling control precision (snow flake symbol lights up). Use the arrow keys to set the desired value, usually 1° C. By pressing the set key again (sun icon appears) the area for the heating control precision can be reached. By pressing the SET key again, the unit jumps back again to the temperature display. Now, the unit is ready for use.

As soon as the temperature falls below the adjusted value, the unit activates the power socket 2 and switches on the consumer (heating). When the adjusted temperature is exceeded, the unit activates power socket 1 and switches on the consumer (cooling).

Example: The nominal value is set to 25° C, the cooling and heating control precision at 1° C.

As soon as the temperature rises to 26° C (nominal value + cooling control precision) the cooling unit starts. As soon as the temperature drops below the nominal value (here 25° C) the cooling unit will stop.

If the temperature drops to 24° C (nominal value - heating control precision) the heating unit starts. As soon as the temperature rises more than to the nominal value (here 25° C) the heating unit will stop.

A minimum deactivation of 3 minutes prevents heating and cooling work against each other.

The T Controller Twin has got a rechargeable battery so the programmed data will not be lost in case of power failure. After starting the unit up, it takes about 24 hours until the battery is charged and the data remain stored.

5. Technical Data

Display:	0.1° C
Measurement range:	- 40 up to 99° C
Resolution:	0.1° C
Loading capacity of contact:	1,200 Watt at 220 V AC
Air Humidity:	below 80%
Adjustment range:	16 – 40° C,
Adjustment accuracy:	+/- 1° C
Power requirements:	220 V, 50 Hz
Humidity:	< 85%

6. Warranty

Should any defect in material or workmanship be found within 12 months of the date of purchase AB Aqua Medic GmbH undertakes to repair or, at our option, replace the defective part free of charge – always provided the product has been installed correctly, is used for the purpose that was intended by us, is used in accordance with the operating instructions and is returned to us carriage paid. The warranty term is not applicable on the all consumable products.
Proof of Purchase is required by presentation of an original invoice or receipt indicating the dealer's name, the model number and date of purchase, or a Guarantee Card if appropriate. This warranty may not apply if any model or production number has been altered, deleted or removed, unauthorised persons or organisations have executed repairs, modifications or alterations, or damage is caused by accident, misuse or neglect.
We regret we are unable to accept any liability for any consequential loss.
Please note that the product is not defective under the terms of this warranty where the product, or any of its component parts, was not originally designed and / or manufactured for the market in which it is used.
These statements do not affect your statutory rights as a customer.

If your AB Aqua Medic GmbH product does not appear to be working correctly or appears to be defective please contact your dealer in the first instance.
Before calling your dealer please ensure you have read and understood the operating instructions. If you have any questions your dealer cannot answer please contact us.

Our policy is one of continual technical improvement and we reserve the right to modify and adjust the specification of our products without prior notification.

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