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DESIGN AND COMPARISON OF THE PERFORMANCE OF THREE RECIRCULATION SYSTEMS FOR FINGERLING PRODUCTION

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ABSTRACT

Three simple recirculation aquaculture systems (RAS) for fingerling production were designed and constructed and their performance compared. Design A was similar to RAS units used currently in Cameroon with a UV filter while design B was without the UV filter. Design C had a simple unit with an airlift pump instead of the mechanical pump used in systems A and B. Each system had three rearing tanks (24 L). The materials for construction were same in all the three designs and all systems had equal volume of water. Arctic char juveniles were stocked at 55 and fed with extruded feed (1.5mm) for 30 days. The final mean weight of char in all systems was similar (0.76-0.80g). The survival rate in design A and C was similar, 97% and 98% respectively, while the survival in system B was lowest (94%). Just after the termination of the experiment nearly all fish in system B died of unknown causes. The performance index (PI) showed that the best performance was from design A (PI=2.6) followed by design C (PI= 2.5) and lastly design B (PI=2.4). The water quality variables were similar in all systems, except the bacterial count was lowest and constant in system A, which included the UV filter, and highest and increasing in system B. The results showed that the UV filters are an important component of the RAS and should be included when systems are designed. System C, with the airlift pump, also performed well and could be an option for RAS systems in Cameroon, depending on their running cost, reliability and efficiency of gas exchange.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

The world aquaculture production has increased rapidly in recent years. The growth has been most rapid in Asia where the total production is 65.6 million mt which is 89% of the world production. The expansion in Africa has been much slower and the current production is 1.72 million mt. representing only 2.32% of the world aquaculture production (FAO, 2016a). The primary aquaculture producers in Africa are Egypt and Nigeria with a production of 1137 and 313 thousand tons respectively (FAO, 2016b).

Official numbers suggest that the annual aquaculture production in Cameroon is about 1000 mt (MINEPIA, 2014a). However, the total production may be a bit higher due to undeclared production. Nonetheless, aquaculture production in Cameroon is very low considering that the climate is favorable, with abundant water resources and along maritime coastline. In total, there are 14000 km^2 of inland waterbodies and 4 million hectares of flood plains, lakes, mangrove forests and lagoons (SDA, 2014). Surveys suggest that annual potential aquaculture output could be between 2 ,300 to 20, 000 mt (FAO, 2016c).

Cameroon has a total population of about 24 million (UN world population prospect, 2016), with an annual fish demand estimated at about 400,000 mt (MINEPIA, 2014b). This translates to a production deficit of 220,000 mt which is imported annually at a cost of 200 million USD (MINEPIA, 2014b) and affecting the trade balance of the country negatively. Aquaculture is the only viable option to increase the supply of fish products.

Aquaculture was introduced in Cameroon in 1948, primarily as extensive production in ponds. Skills and knowledge of production methods are low and this contributes to limited production levels and low productivity. The production is mainly used to supplement the diet of the family. Initially, tilapia (*Oreochromis niloticus)* was the main farmed fish. Later two catfish species *Clarias gariepinus*, and *Heterobrancus longifilis* were introduced for polyculture in ponds with tilapia. Other indigenous species in culture included the African bony tongue (*Heterotis niloticus*), and snakehead fish (*Parachana obscura*). The production of the latter is mainly based on fingerlings taken from the wild and stocked in ponds. Exotic species from China such as common carp (*Cyprinus carpio)* or grass carp (*Ctenopharyngodon idella*), have also been introduced. Initially the production grew very slowly but has risen with increased numbers of fish ponds (7252) and their surface area (650h) in 2014 (Figure 1).

From 1990 to 2014, production increased to 1000 mt (MINEPIA, 2014b) following government initiative to provide subsidies to farmers for ponds and hatcheries, basic fish farming training programs and technical support. Moreover, input for production, such as fish feed and seed, was distributed to encourage farmers. To date, the government has established 10 aquaculture stations and 9 aquaculture pilot units which are used for fish breeding and extension work although some are still not fully functional (SDA, 2014).

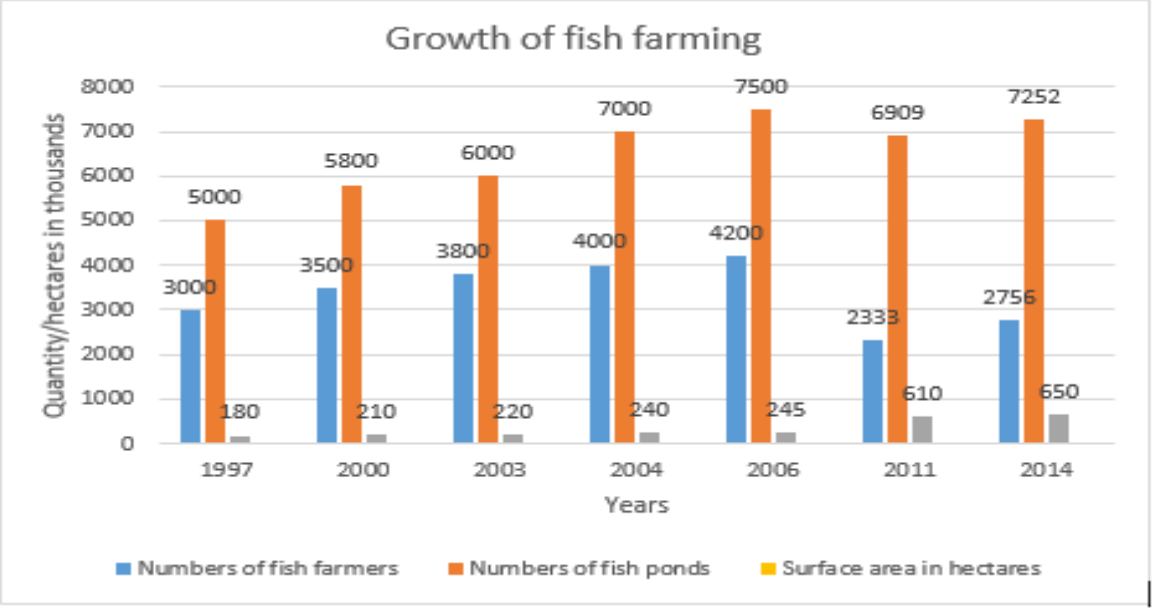

Figure 1: Development of fish farming in Cameroon
(Source : MINEPIA/FAO, 2014)

Regardless of these efforts, the total production today still stands at 1000 mt (Figure 2) and does not reflect the input or the huge potential available in terms of the natural resources.

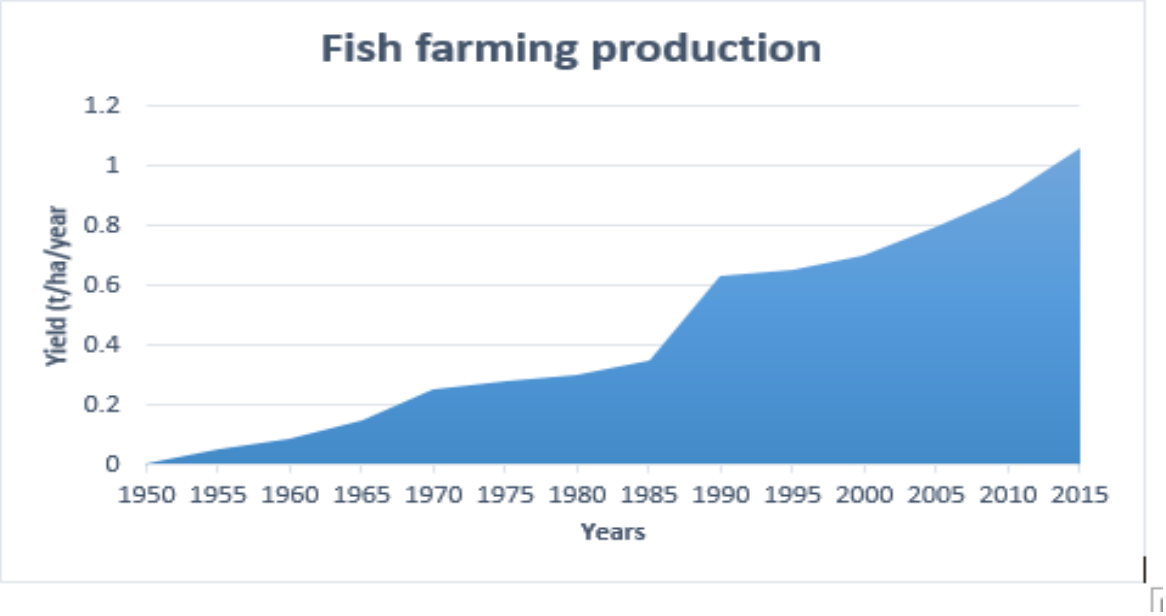

Figure 2: Production data of fish farming in Cameroon
(Source: Sub-Directorate of Aquaculture, 2014)

The government aims to have Cameroon as an emergent country by 2035. To accomplish this, the Strategic Document for Economic Growth (DSCE) was developed in 2009. This document is the road map for development from 2010 to 2020 (SDA, 2014). Through it the government aims to develop the fisheries and aquaculture sector which is under the Ministry of Livestock Fisheries and Animal Industries (MINEPIA). With the assistance of FAO, the government drew up a strategic framework for the sustainable development of aquaculture (FAO, 2016c).

This framework set out the roles of government, the private sector and research for the development of aquaculture. Based on this framework, the government of Cameroon drafted the aquaculture development strategies and launched a development plan (FAO, 2016c).

Many factors have contributed to the slow growth of aquaculture development in the country. These include social issues, such as lack of a legal framework for governing the sector, poor economic situation that has limited the level of support to farmers and their access to loan, and weak extension services. Prohibitive transport costs and poor transport infrastructure leading to restrained movement of goods and services (SDA, 2014). Poor knowledge of both farmed species of fish and aquaculture practices has also restrained the growth of the sector. This has limited the supply of fish feed and seed. Seed production can be greatly improved and achieved through RAS. This project focuses on seed production in RAS.

Production of fish seed in RAS is relatively simple and the management required is not labour intensive. Recirculating systems filter and clean the water before recycling the water back through fish culture tanks. About 10% of the total volume is added to the system daily to make up for splash out and evaporation and for that used to flush out waste materials (Ezenwa and Anyanwu, 2003). In RAS, water quality can be maintained at optimum levels to support maximum growth of fish. There is a continuous supply of clean water at a suitable temperature. Water oxygen content can be kept at optimum levels for growth, while the concentration of waste from the fish, such as carbon dioxide, ammonia and suspended solids, is low enough to support maximum growth. A filtering (biofilter) system is necessary to purify the water and remove or detoxify harmful waste products and uneaten feed. The fish must be fed daily a nutritionally-complete feed to support fast growth and high survival (Louis and George, 2000). The RAS allows for high production of fish in small volume of water and space. It has all the major elements of sustainability; economically sustainable, environmentally friendly, socially acceptable and institutionally durable. However, the major disadvantage of RAS is the high capital intensive in setting up and running the system. It uses energy supply to operate and requires skilled technical staff to manage the system. Scarcity of water and land could be a major hindrance to set up this system in some areas. Research into the use of RAS addresses the question of how to achieve profitable production while consistently recycling water and nutrients with minimal fresh water demand and waste production (Buric *et al.*, 2014).

RAS were introduced in Cameroon by the Ministry of Livestock Fisheries and Animal Industry in January 2011. The aim was to implement the new technology for intensive fish production. In September 2012, the Minister of Livestock Fisheries and Animal Industries, Dr Taiga inaugurated the first constructed Recirculating Aquaculture System in Logbaba-Douala for table fish production and a modern hatchery (Figure 3) in 2014.

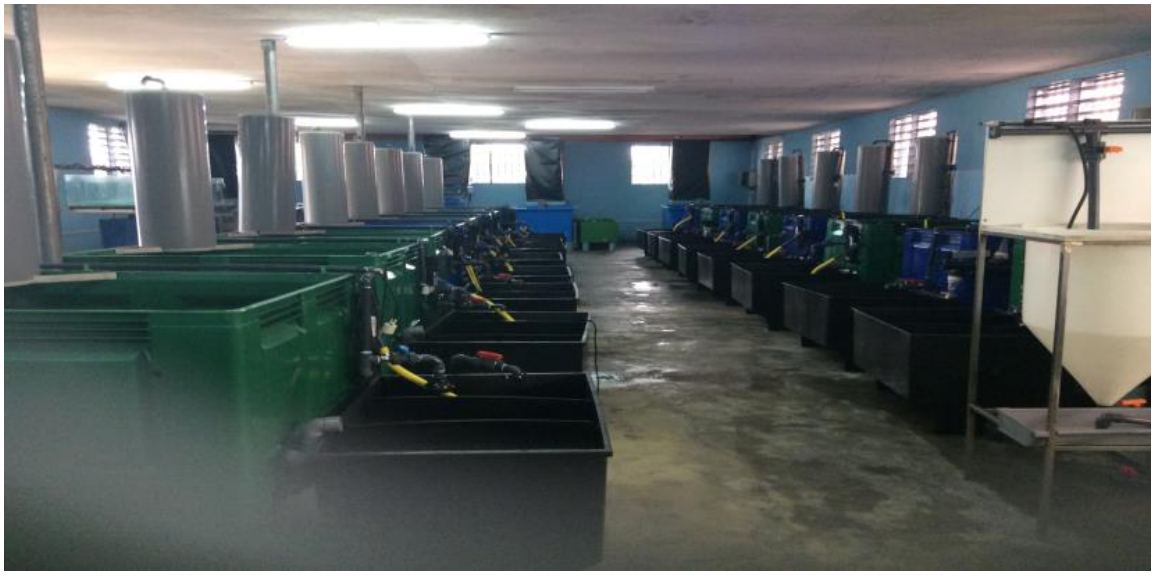

Figure 3: RAS hatchery in Logbaba-Douala
(Source : Sub-Directorate of Aquaculture, 2014).

Today, this center serves as a pilot unit for training, production and distribution of fingerlings for fish farmers in the sub region and the whole country. This has now created an awareness in homestead fish farming nationwide and a lot of people have become interested in this form of fish production with more than 50 public and private hatcheries operating in the country using RAS technology for fingerlings production (SDA, 2014).

1.2 Project Goal

One of the primary obstacles to the growth of aquaculture in Cameroon is the lack of quality seed. Of the species cultured in the country, only tilapia can spawn naturally in ponds. However, that is not a good way of propagating aquaculture fish since it may lead to over-population of ponds and, thus, stunt growth of fish. Ideally fingerlings should be produced in hatcheries and stocked as required. Although catfish and carp fingerlings are produced in hatcheries, the production is still very low due to lack of adequate management technics. The goal of this project is to test different simple designs of RAS.

1.2.1 General Objective of the study

The purpose of this work is to design and compare the performance of three different designs of recirculatory systems similar to those used in Cameroon for the production of catfish fingerlings and to appreciate the feasibility of the use of airlift pump.

1.2.2 Specific objectives:

To design and compare the performance of three recirculating systems for fingerlings production on:

1. The importance of ultra violet (UV) filters in RAS
2. Water quality in the three systems
3. Growth and survival rate of Arctic char in the three systems

2 RECIRCULATING SYSTEMS

Fish require good water quality for maximum growth and survival. Oxygen for respiration must be provided in the water. The metabolism in fish produces metabolites such as carbon dioxide and ammonia which are released into the water. Suspended solids are produced when uneaten feed or faeces disintegrate in the water. The metabolites and suspended solids must be removed either with water exchange or some form of filtration. If water exchange is low, the concentration of the metabolites increases and water quality degrades. If the concentration of the metabolites in the water surpasses critical levels, the growth of the fish may be retarded and at very high levels mortality may increase. In RAS systems, water is continuously recycled with little addition of new water (Bregnballe, 2015). As a result, water quality would deteriorate were it not for many treatment units which add oxygen and remove metabolites from the fish and other wastes (Figure 4). The function of these and other components of RAS are described below.

To maintain good water quality, the water is treated by removing particulate matter, through the conversion of harmful accumulated chemicals into nontoxic ones and the addition of oxygen and removal of carbon dioxide (Ezenwa and Anyanwu, 2003).

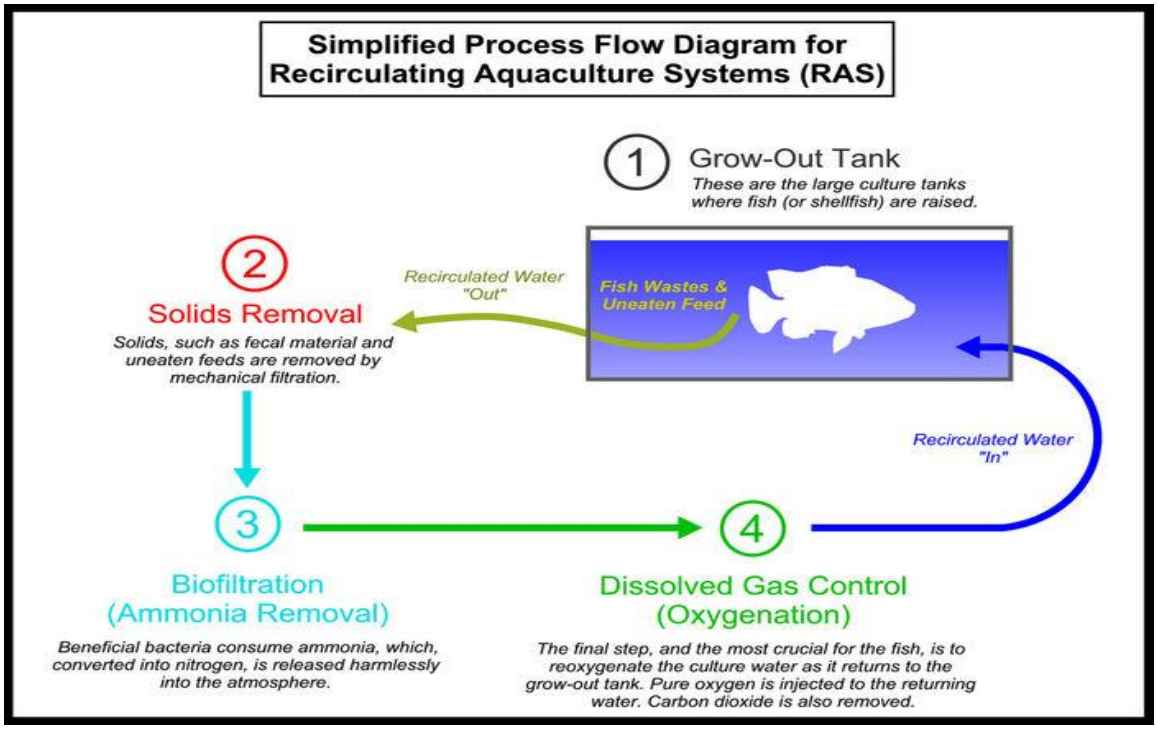

Figure 4: Simplified process flow diagram for RAS
(Source: Design by recirculating aquaculturesystem.net, 201)

2.1 Mode of Operation

The mode of operation of a typical RAS is that the water is recycled through several water treatment units; Some form of filtration must be applied to remove suspended solids. In the biofilter NH_3 (Ammonia) is removed. In the gassing/degassing unit CO_2 is removed and O_2 is added. Several other components can be added to the system, such as oxygenation with pure oxygen, ultraviolet filter or ozone for disinfection, automatic pH regulation a temperature control depending on the intensity of the recirculation (Keith *et al*., 2011).

2.1.1 Culture tanks

Culture tanks can be of any shape and size but must hold fish in water without leakage. Normally the size of the tank is determined to accommodate the biomass required for the production volume. Materials such as plastic, concrete, metal and fiberglass can be used to construct tanks and the material chosen should not be toxic to fish. Smooth surfaces on the inside of the tanks are recommended to prevent skin abrasions and infections to the fish and to permit clearing and sterilization. Plastic tanks are not expensive, can be conveniently moved and readily cleaned when necessary. Concrete tanks may be relatively economical to build, but they are permanent and immovable once constructed. Fiber glass tanks are the most durable and most expensive (Losordo *et al.*, 1998).

2.1.2 Pumps

The pump collects available filtered water from the sedimentation unit and pumps into the biofilter for nitrification. The amount of water pumped into the biofilter depends on the horse power of the pump. The higher the horsepower, the greater the flow pressure of water being pumped into the biofilter. Larger biofilters require bigger pumps.

Air lifts add oxygen by injecting air into the water through a vertical pipe, agitating and circulating the water. This serves to both increase the dissolved oxygen level and degas the CO_2. The density difference between a column of water and a column of air/water mixture drives the pump. An external air blower provides the air and one blower can service a number of small systems. Airlift pumps (Figure 5) can move large volumes of water against a low waterhead. Large diameter airlifts (>8 inches or 20 cm) have recirculation capabilities of several hundred gallons per minute (2,000 to 3,000 litres per min.), with lifts <18 inches (46 cm) (Malone, 2013). The air injected to move the water also aerates and degasses the circulating water. Airlift systems can be as energy efficient as mechanical pumps, but this depends on the exact system design. However, the height water the can be lifted by an airlift is limited, so careful attention must be given to head loss when the system is designed (Malone, 2013).

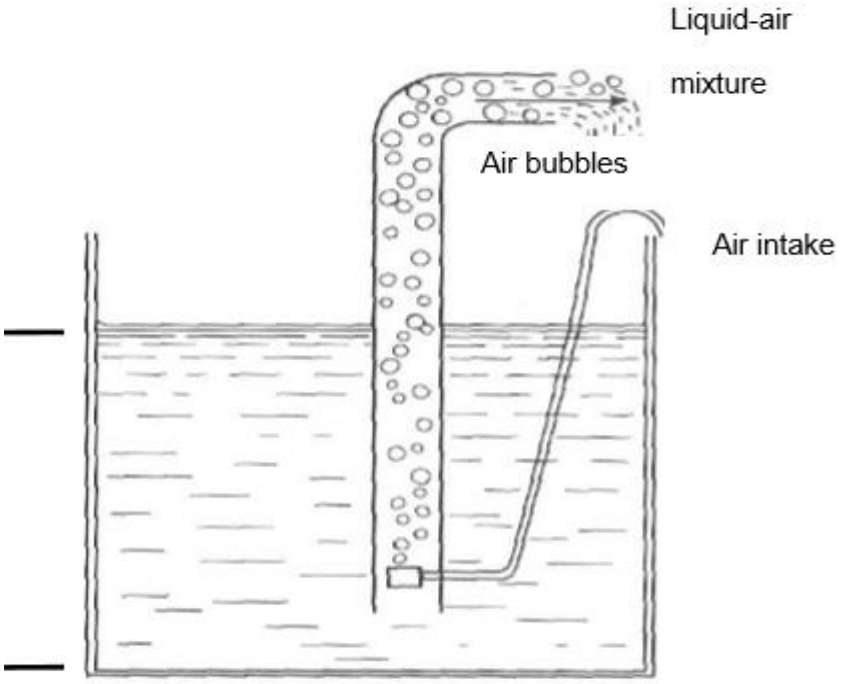

Figure 5: An air lift pump. Flow rate is a function of pipe diameter, airflow, bubble size and degree of pipe submerged.

2.1.3 Aeration/oxygenation

The aeration process of the water, which is the same physical process as degassing or stripping CO_2, will add some oxygen to the water through simple exchange between the gases in the water and the gases in the air depending on the saturation level of the oxygen in the water. Water in equilibrium with air is 100% saturated. When the water has been through the fish tanks, the oxygen content has been lowered, typically down to 70%, and the oxygen saturation is reduced further in the biofilter. Aeration of this water will typically bring the saturation up to over 90% and, in some systems, 100% saturation can be reached. Oxygen saturation higher than 100% in the inlet water to the fish tanks is often preferred fish density is high. Saturation levels above 100% call for addition of pure oxygen (Bregnballe, 2015).

Dissolved oxygen is a major limiting factor in RAS (Timmons *et al.*, 2002). Stocking fish at a high density and feeding them feeds that contain high levels of protein will increase oxygen consumption of the fish and, thus, reduce the amount of oxygen available in the water. Aeration is important because it replaces that which is consumed by fish and the breakdown of wastes. Also, it removes other dissolved gases that are in high concentrations and can be harmful to the fish such as CO_2 and NH_3 (Timmons *et al.*, 2002). Several methods are used to aerate systems, including packed column aerators, air lifts and air diffusers. In packed column aerators, water with low oxygen saturation is sprayed in at the top of the column which is packed with a plastic medium, and the flow rate is kept low to keep the column from flooding. Oxygen saturation increases as the water trickles down the column. Air diffusers or air stones are commonly used in stagnant systems and in home aquariums. While fine-bubble air stones are efficient, these types of aerators require high-pressure sources of oxygen and easily become blocked by growth of bacteria and algae (Timmons *et al.*, 2002).

Carbon dioxide is a highly soluble gas, whereas, oxygen is a poorly soluble gas (Grace *et al.*, 1989). In a poorly designed RAS, the respiration activities of both fish and bacteria produce

carbon dioxide and elevate the concentration in water. High carbon dioxide level lower pH. Carbon dioxide should be kept between 10 to 15mg/l and not more than 20mg/l. $C0_2$ is usually removed by blown air or by unpressurized packed columns. (Grace *et al.*, 1989).

2.1.4 Ultra Violet Filter

Ultraviolet filters (UV) can control micro-organisms in aquaculture. The UV used is typically produced by mercury vapour bulbs/lamps that emit radiation at wavelengths from 100 – 400mm, that is in the blue - violet range of the visible spectrum and the shorter wavelength rays. UV radiation at 260mm provides maximum germicidal activity chiefly due to interaction with components of DNA (Lawson, 1995).

Effectiveness of UV filter will be reduced in turbid water containing suspended solids and dissolved organic matter that reflect or absorb the UV radiation, or provide "shadows" to protect micro-organisms from exposure. So, to avoid this limitation, UV is installed after mechanical filtration (LaDon, 1990).

The effectiveness of the UV radiation intensity expressed as microwatt seconds per square centimetre (ws/cm^2) is proportionate to the level required to kill micro-organisms within RAS units and ranges from 35,000 – 1,000,000Ws/cm^2.

2.1.5 Water Heater System

A water heating system may be necessary depending on the water temperature and species selected. This uniformity must be met before water gets into the rearing tanks using a water heater.

2.1.6 Particle filtration

Suspended solids are organic and inorganic substances in suspension in water and cause turbidity. Suspended solids will not settle to the bottom of the fish culture tank and cannot be removed easily in conventional settling basins. Suspended solids are not always dealt with adequately in a recirculating production system. If not removed, suspended solids can significantly limit the amount of fish that can be grown in the system and can irritate the gills of fish. The most popular treatment method for removing suspended solids generally involves some form of mechanical filtration. The two types of mechanical filtration most commonly used are screen filtration and granular media filtration (sand or pelleted media) (Thomas *et al.*, 1998).

As water leaves the rearing tanks, solid particles must be removed. This can be done either through mechanical filtration or sedimentation. It concentrates and remove solids, fish faeces and uneaten food particles. Suspended solid can be harmful to fish health and provides food and shelter for bacteria that consume valuable oxygen supplies.

2.1.7 Biological filter

The biological filter is an important component of RAS (Dennis *et al.*, 2012). Finfish excrete ammonia (NH3), mostly from their gills, and it dissolves in the water in which the fish must live. This waste product is toxic to the fish and is an environmental stressor that causes reduced appetite, reduced growth rate, and death at high concentrations (Ezenwa and Anyanwu, 2003) and must be removed for fish to stay alive.

The biological filter is composed of a media (corrugated plastic sheets, tubes, beads or sand grains) upon which a film of bacteria grows (Louis and George, 2000).

Total ammonia nitrogen (TAN) nitrogen bound as ammonium ion (NH_4^+-N) and un-ionized ammonia (NH_3-N). Nitrogen is in the form of free ammonia (NH_3) and is toxic, and needs to be transformed in the biofilter to harmless nitrate (Bregnballe, 2015). The breakdown of organic matter and ammonia is a biological process carried out by bacteria in the biofilter. Nitrifying bacteria convert ammonia into nitrite and finally to nitrate by Nitrosomonas and Nitrobacter bacteria, respectively (Thomas *et al.*, 1998) as shown in the equation below.

$-NH_4 + 2O_2 \longrightarrow NO_3 + H_2O + 2H^+$
$-NH_4$ (ammonium) + 1.5 $O_2 \longrightarrow$ NO_2 (Nitrite) + H_2O + $2H^+$ + 2e
$-NH_3$ (toxic) NO_2- (toxic) NO_3 (non-toxic) nitrosomonas and nitrobacter
$-NO_2$ (nitrite) + 0.5 $O_2 \longrightarrow$ $N0_3$ (Nitrate) + e

The efficiency of biofiltration depends primarily on the water temperature and the pH level in the system. Regulation of pH in relation to biofilter efficiency is however important as lower pH level reduces the efficiency of the biofilter. The pH should therefore be kept above 7. On the other hand, increasing pH will result in an increasing amount of free ammonia (NH_3), which will enhance the toxic effect. A recommended pH level is between 7.0 and pH 7.5.

Two major factors affect the pH in RAS. The production of CO_2 from the fish and from the biological activity of the biofilter and the acid produced from the nitrification process. CO_2 is removed by aeration of the water. The nitrifying process releases (H+) and the pH level falls (Boyd, 1991). In order to stabilize the pH, a base must be added, e.g. sodium bicarbonate. Ammonia is toxic to fish at levels above 0.02 mg/L (Bregnballe, 2015); (Keith *et al.*, 2011); (Losordo *et al.*, 1998) (Figure 7).

If fish in a recirculation system are gasping for air, although the oxygen concentration is fine, a high nitrite concentration may be the cause. At high concentrations, nitrite is transported over the gills into the fish blood, where it obstructs the oxygen uptake. By adding salt to the water, reaching as little as 0.3 ‰, the uptake of nitrite is inhibited (Louis & George, 2000). Nitrate (NO_3-) is the end-product of the nitrification process, and although it is considered harmless, high levels (above 100 mg/L) seem to have a negative impact on growth and feed conversion. If the exchange of new water in the system is kept very low, nitrate will accumulate, and unacceptable levels will be reached. One way to avoid the accumulation is to increase the exchange of new water, whereby the high concentration is diluted to a lower and trouble-free level.

Nitrification is an acid-producing process. Levels of pH below 4.5 are dangerous to fish; a pH below 7.0 will reduce the activity of nitrifying bacteria. If the source water for a recirculating system is low in alkalinity, then pH and alkalinity should be monitored and alkalinity must be maintained with additions of bases. Some bases commonly used include hydrated lime [$Ca(OH)_2$] quick lime (CaO), and sodium bicarbonate ($NaHCO_3$).

2.2 Operating the system

A biofilter is started by adding bacteria to the system, which can be done in several ways. Nitrifying bacteria can be introduced with water or bits of biofilter media from an already operating system, with pond sediment or with small numbers of "starter" animals (Delong and Losordo, 2012). The system should be operated by passing water through the biofilter. If the culture tank is not yet ready for use, it is possible to recirculate water only through the biofilter unit. System water should be free of residual chlorine that may have been used for disinfection or pathogen control (Timmons *et al.*, 2007).

2.3 pH and alkalinity

The pH is an important parameter to be monitored and controlled in RAS, with optimum range between 7 and 8. Alkalinity is a measure of the capacity of the water to buffer pH (hydrogen ions). Bicarbonate (HCO_{3-}) and carbonate (CO_{3-}) are the predominant bases or sources of alkalinity in most waters. Highly alkaline waters are more strongly buffered against pH change than less alkaline waters (Thomas *et al.*, 1998). pH can be controlled by adding sodium bicarbonate (NaHCO3), or common baking soda, to increase alkalinity. Baking soda is inexpensive and safe to use.

3 MATERIAL AND METHOD

3.1 Experimental Area

The experiment was performed at the Verid aquaculture research station at Saudarkrokur, North Iceland. The experimental tanks were indoor facilities with artificial lights provided continuously. The experiment started on 1/12/2016 and ended on 28/2/2017. The freshwater used came from the municipal source and was UV treated before entering the station. The juveniles used in the experiments came from the Icelandic breeding program for Arctic charr at Hólar University College (Iceland). The rearing conditions at Hólar breeding station were a temperature of 6-8 °C and continuous light.

3.2 RAS design and construction

Three different RAS systems were designed and constructed for the experiment: System A is like units used in Cameroon for production of catfish fingerlings. It included an UV filter for sterilization (Figure 6). System B was identical to system A, but without the UV filter (Figure 7) to test the importance of the UV filter. System C included an air lift pump (Figure 8) that aerated the water circulating it in the system. The airlift pump is a simple option for pumping, aerating and degassing water and may be a suitable solution for aquaculture in Cameroon.

All systems (Figure 6) consisted of three 24L rearing tanks (56cm x 36cm x 12cm) and two rectangular plastic tanks of 80 liter capacity each (56cm x 36cm x 40cm). These tanks were used for the biofilter and as for settling of solids. The same material was used for biofilter and settling filters in all the systems. In systems A and B, the biofilter and sedimentation units were in separate tanks and a submersible electric pump to moved water up to the biofilter. In design C, the sedimentation unit and biofiltration were together and an air lift pump propelled the

water from the biofilter to the culture tanks. Each tank was stocked with 55 Arctic char juveniles of initial average weight and length of 0.84g and 5cm respectively.

The total volume of water in each system was 112L (24x3 + 40). Every day 4L of water was removed when siphoning uneaten feed and this was replaced daily. No cleaning of sedimentation units was done throughout the experiment. System A and B were aerated with an aeration column with air blower while system C was aerated through the airlift system. Aeration was provided continuously throughout the experiment. Before the fish were stocked, the systems were kept running for one week. Flow rate was similar in all the systems with a total flow of about 4 liters per minute. The main tools used in the systems construction were supplied by Verid aquaculture centre workshop, these include: PVC pipe cutter or hacksaw, saber saw or sawzall, electric drill, ruler or tape measure, hole saw to cut, drill bits, marker, sandpaper, rubber gloves, screwdriver (to match bolt heads) and pliers or 1⁄2-inch ratchet.

The plumbing materials were purchased form a local store. The pipes were cut to specified length using PVC-pipe cutters or hack saw. The pipes were connected to the rectangular small tanks with their fittings designation for appropriate flow of water. Using a saber saw or Sawzall the flat plates were cut to dimension for water to shower down throw the trickling filters. Using a 1⁄2-inch hole saw holes were drilled for piping through the tanks using an electric drill machine. The three systems were all connected with ½ inch (21.34mm) PVC pipes and their accessories to ensure a smooth flow of water to the system.

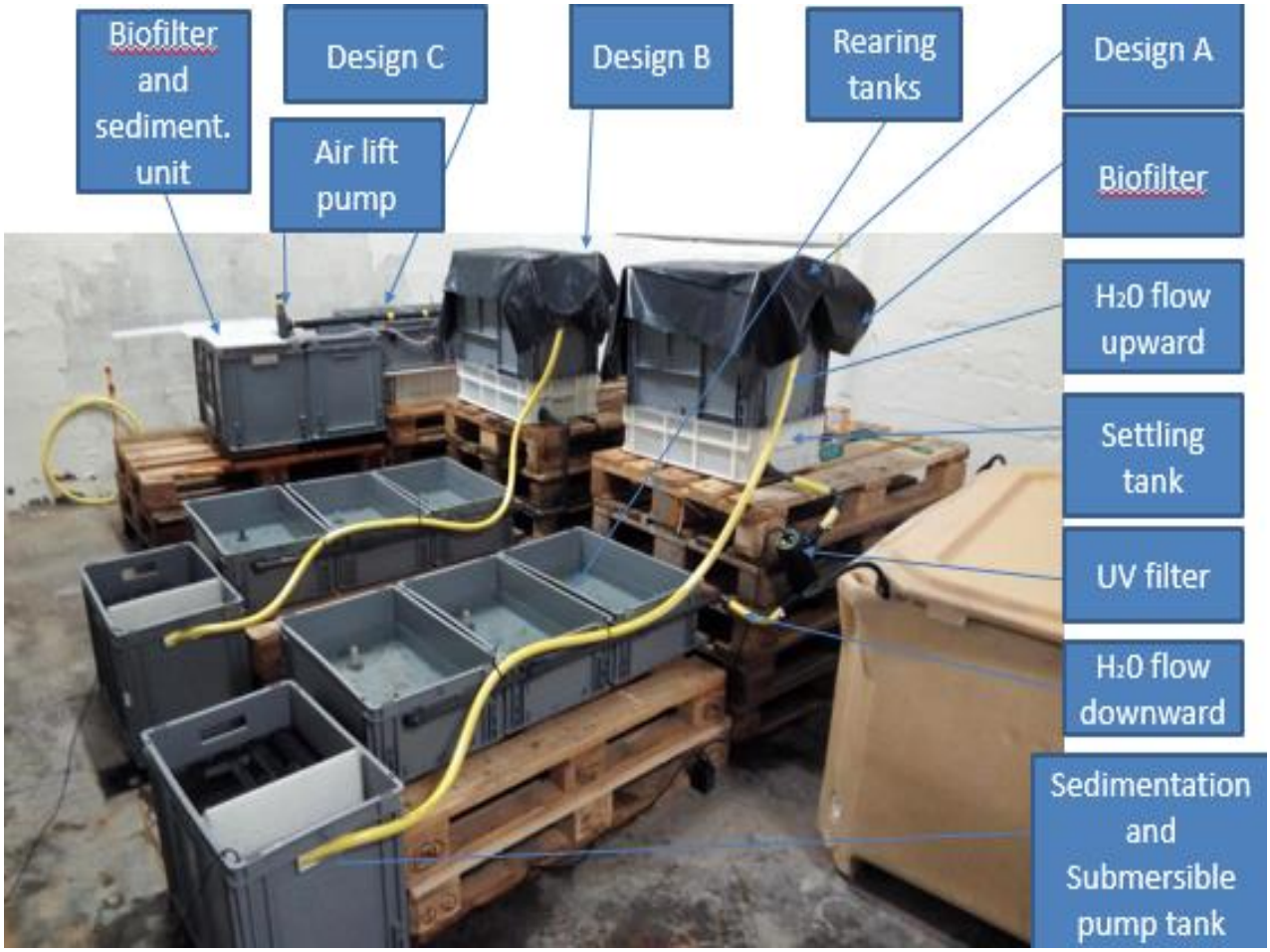

Figure 6: Complete setup of design systems. System A, with UV filter.

Figure 7: System B, operating without UV filter.

Figure 8: System C, design with airlift pump mechanism in biofiltration unit.

3.3 Test running and system operation

The flow of water in the system was from the biofiltration to the parallel culture tanks. From the tanks the water flowed to the sedimentation unit. Here the water passes through several layers of filter material that capture the uneaten feed and solid faeces.

In system C, the water then passes through holes in a separating plate which divides the tank into two sections. In systems A and B, a submersible pump then moves the water up to the biofilter. At the biofilter level, the water trickles down via a porous distribution plate at the top

of the biofilter barrel down the biofilter media to remove nitrogenous wastes (biofiltration). The water then falls into a settling chamber and then in system A, passes through the UV filter for sterilisation of microorganisms before returning to the fish tanks. System B is designed in the same way but without a UV filter. In system C, an air lift pump lifts the water from the in biofiltration chambers to the rearing tanks. In system C, the water level in the rearing tanks, sedimentation tank and the biofilter unit was at the same level. In systems A and B, the biofilter was covered with a black nylon leather on the top to allow the bacteria to function properly (Louis & George, 2000).

3.4 Evaluation of system performance:

The performance of the systems was compared by measuring water quality and fish growth.

3.4.1 Physiochemical Parameters

To compare the physiochemical parameters of water in the three systems, data were obtained to evaluate the performance of the systems. Water quality parameters including DO (mg/L), carbondioxide and temperature (^oC) were measured daily in each tank utilizing handheld monitors (Figure 9). DO – OxyGuard Handy Polaris portable Dissolved Oxygen meter, pH – Oxyguard Handy PH, Temperature – Extech 39240 Digital Waterproof Pocket Thermometer and Oxyguared carbon dioxide meter.

Ammonium-nitrogen (NH_4-N), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N) were equally measured once daily from water samples collected in the RAS distribution sump using water test kits.

3.4.2 Biological oxygen demand or BOD

The biological oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down the organic material present in a water sample. It also gives an indication of the oxygen consumed by bacteria and other microorganisms in the system. Usually, BOD is measured over 5 days (BOD_5) of incubation at 20 °C. However, in this experiment the samples were incubated at 13 °C, the same temperature as was in the systems.

The BOD was measured in 300 mL black plastic bottles. The oxygen level was measured as the water sample was taken and then again five days later. The BOD, was calculated as the decrease in oxygen concentration (mg/L) over the five-day period.

3.4.3 Total suspended solide (TSS)

Total suspended solids (TSS) are a measure of turbidity in water. The solids are organic and inorganic particles suspended in the water.

The suspended solids were measured in a 1 L sample of water from the systems. Filter paper, of 47mm in (CAT No 1825-047) was weighed and dried at 110 °C for 24 hours. Then the sample was filtered under vacuum. The filtered paper was then dried for 24 hours at 110 °C and weighed again. The total suspended solids were determined as the difference in weight in

the filter paper before and after filtering and expressed as mg dry weight of solids per litre of water.

3.4.4 Total bacterial level (TBL)

Total bacterial level were mearsured thrice during the experiment in the microbiology laboratory of Verid. Water samples were collected, diluted in peptone water and distributed on plate count agar (PCA). The agar plates were allowed to dry before being transferring to an incubator for 42 hrs at 30 degrees. If the concentration of bacteria was too great the colonies will merge and the plate will be uncountable. To ensure that countable plates would be obtained a series of dilutions was plated. The serial dilutions gave at least one countable plate in the series (25-250 or 30-300 (Figure 10). The total number of bacteria colonies was counted and expressed as colony forming unit (CFU) of TBL.

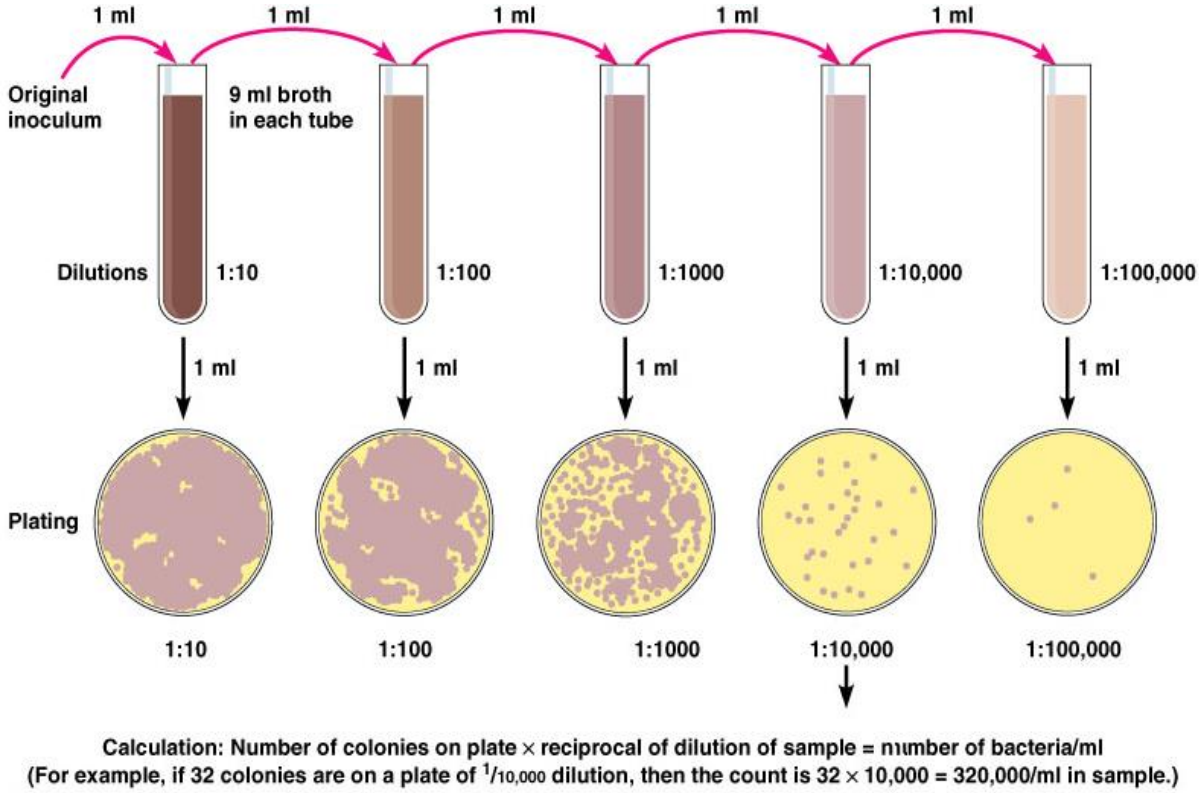

Figure 9: Procedure used for obtaining total bacteria level (TBL) (Cummings, 2015).

3.4.5 Measurements of TAN, NO_2 and NO_3

Total ammonium nitrogen was measured using 5 standard solutions of ammonium chloride to give 0.5,1,1.5,2 and 2.5 mg L^{-1} of TAN. The standards were made by diluting NH_4^+ 50mg/L stock solution in water. After this, 18 smaller test tubes were used to prepare the solution as follows;

I. Test tube 1 and 2 had 1ml of water
II. Test tube 3 and 4 had 1 ml of ammonium chloride
III. Test tube 5 and 6 had 2mg/l of ammonium chloride
IV. Test tube 7 and 8 had 3mg/l of ammonium chloride

V. Test tube 9 and 10 had 4mg/l of ammonium chloride
VI. Test tube 11 and 12 had 5mg/l of ammonium chloride
VII. Test tube 13 and 14 had water samples from design A
VIII. Test tube 15 1nd 16 had water samples from design B
IX. Test tube 17 and 18 had water samples from design C.

A linear model was fitted to the relationship between absorption and concentration and used to calculate the TAN, NO_2 and NO_3 concentration in biofilter.

The TAN concentration was analyzed in 1 ml samples with JBL and Sera Ammonium Test kits. The instructions from the JBL manufacturer called for 10 ml samples to which were added 4 drops of reagent 1 and 2 and then 5 drops of reagent 3. The weight of one drop of the reagents was determined and estimated to be 40µl. Using this information, the sample was scaled down to 1ml and added 16µlof reagents 1and2 and 20µlof reagent 3. After that the sample was allowed 15 minutes to develop the color and then the samples were mixed well and pipetted into the wells of a plate and read at 650 nm in a spectrophotometer (Lysakovskaa, 2014).

3.5 Fish husbandry and measurement of fish

The fish were fed with extruded fish feed (Floating diet 1.5mm) containing 47% crude protein, 12% fat, 2.2% calcium, 1.2% potassium, 0.5% Ash, 2.2% fiber, 60 ppm minerals and vitamins. The juveniles were fed 5% of their body weight or until they no longer took the feed. The fish were fed in the morning and afternoon all days of the experiment.

The mean weight and length of the fish was recorded at the beginning of the experiment. The body weight was recorded to the nearest 0.01g, using electronic weighing balance (Metller PC 180). Samples of fish were weighed very week during the experiemnt. The final body weight and length were recorded at the end of the experiment.

3.5.1 Growth performance

Growth parameters were calculated as follows:

- Mean weight gain (MWG) = Mean final weight (g) – Mean initial weight (g).
- Growth Rate = $\frac{\text{Mean final weight – Mean initial weight}}{\text{Duration}} \times 100$
- Specific growth rate was computed as (SGR) %days:

$$SGR = \frac{\log W2 - \log W1}{T} \times 100$$

Where: W1 = initial weight (g) at stocking,
W2 = final weight (g) at the end of experiment,
logW2 – logW1 = natural logarithms of both the final and initial weight of fish,
T = duration (in days) of trial. (Okomada *et al.*, 2016)

- Feed conversion ratio was computed as:

$$FCR = \frac{\text{Dry feed intake}}{\text{Wet weight gain}}$$

- Feed efficiency (FE) (%) = 1/FCR x 100
- Survival rate = ((Total number of fish -Mortality) × 100)/Total number of fish (Okomada et al, 2016).

To evaluate the effect of stocking density on production performance with more precision the performance index (PI) was calculated (Pangni *et al.*, 2008) This index was calculated by combining two responses such as growth and survival.

- PI = Survival rate x (Final mean weight – Initial mean weight)/Duration.

3.6 Statstistical analysis

The data was recorded in Excel where statistical analyses were performed.

4 RESULTS

At the beginning of the experiment, 20 fish died in system A and 50 in system B. These juveniles were immediately replaced and the systems thoroughly cleaned. The cause of these mortality was probably due to small particles of plumbing materials that were left after the construction of the systems and were either eaten by the fish or blocked their respiratory systems. At the end of the experiment, the juveniles in system A and C were visibly active with good appetite for feed and no signs of stress and low mortality (Table 2). However, in B, there was high mortality just after the end of the experiment. (Table 2).

4.1 Average growth performance and survival

The growth performance of the fish in all systems was similar (Table 1) in terms of weight gain, SGR and performance index (Table 1). The FCR was also similar in all systems and was lowest in system A (0.91) and highest in system C with (0.96), while system B (0.93) was intermediate. The survival was highest in system C (98% and similar in system A (97%), while survival was lowest (94%) in system B. Furthermore, most of the fish in system B died after the experiment ended.

4.2 Physiochemical Parameters of water

The performance of three designed systems in terms of the physicochemical water parameters was similar (Table 2). The highest mean temperature was in system A (14.5 °C), intermediate in system B (13.1 °C and lowest in system C (11.6 °C). The initial temperature recorded at the beginning was 4.2°C in all systems from same water source. Temperature started rising after the third day where changes became visible in temperature meter readings with design A, having the highest value followed by B and then C. Notice a considerable drop in temperature three days to the end of the experiment due to drop in ambient temperature.

Meanwhile the pattern in oxygen was unique and closely similar with design A taking the lead and C having the lowest value. The most obvious noticeable fact in the pattern is that oxygen level in design B started rising three days to the end of the experiment and took the lead (Figure 11). The oxygen saturation was similar in all systems with mean values being 90-93%.

Table 1: Average growth performance and survival rate of fingerlings

Parameters	Design A	Design B	Design C
Duration of experiment	30 days	30 days	30 days
Total feed given 4g/system/day	120g	120g	120g
Total stocking density	165fry	165fry	165fry
Total harvested	160	155	162
Survival rate	96.97%	93.93%	98.18%
Mean initial weight (g)	0.84g	0.84g	0.84g
Mean final weight (g)	1.64	1.62	1.60
Mean weight gain (g)	0.8	0.78	0.76
Mean initial length (cm)	5.0cm	5.0cm	5.0cm
Mean final length (g)	7.2cm	7.1cm	7.0cm
Mean length gain (cm)	2.2cm	2.1cm	2.0cm
Mean growth rate, MGR (g/day)	0.027g	0.026	0.025
Feed conversion ratio, FCR	0.91	0.93	0.96
Specific growth rate %	2.23	2.19	2.15
Performance Index (PI)	2.59	2.44	2.49

The CO_2 levels were also similar in all systems (29-30 mg/L). The CO_2 concentration appears to be excessively high compared with the high pH. Calculating CO_2 concentration based on pH values and alkalinity (200-800 umol/L) suggests that the actual CO_2 concentration was in all cases less than 10 mg/L. The pH meter was calibrated daily, but the CO_2 meter had not been calibrated for some time. Therefore, the CO_2 values read with the meter are too high. The pH was highest in system B (7.91) while being 7.68 and 7.58 in systems A and C respectively and within the recommended range (Table 1). The ammonia and ammonium levels were similar in all systems and below the recommended levels. The final total suspended solids were similar in all systems and below the recommended levels. The final total bacteria level (TBL) was highest in system B, being 15 times higher than in system A which included a UV-filter. The TBL continued to increase in system B while in system A it remained constant. The TBL in system C was intermediate and increased during the experiment. The BOD was highest in system B and lowest in system A (Table 2).

4.2.1 Water quality results

Table 2: Water quality during the experiment

Parameters	Design A	Design B	Design C
Average Temperature T. (°C)	14,5	13,1	11,6
Average Oxygen Saturation 0_2 (%)	93.00	92.29	90.43
Final Total Ammonium Nitrogen TAN (mg/l)	0.596	0.648	0.648
Carbon dioxide $C0_2$ (mg/l)	29	29	30
Ammonium NH_4 (mg/l)	0.593	0.641	0.645
Ammonia NH_3 (mg/l)	0.004	0.006	0.003
Ph	7,68	7,91	7,58
Suspended Solids final values TSS. (mg/l)	1.5	0.6	1.5
Total bacteria level. TBL. (cfu/ml)	6400	97000	52000

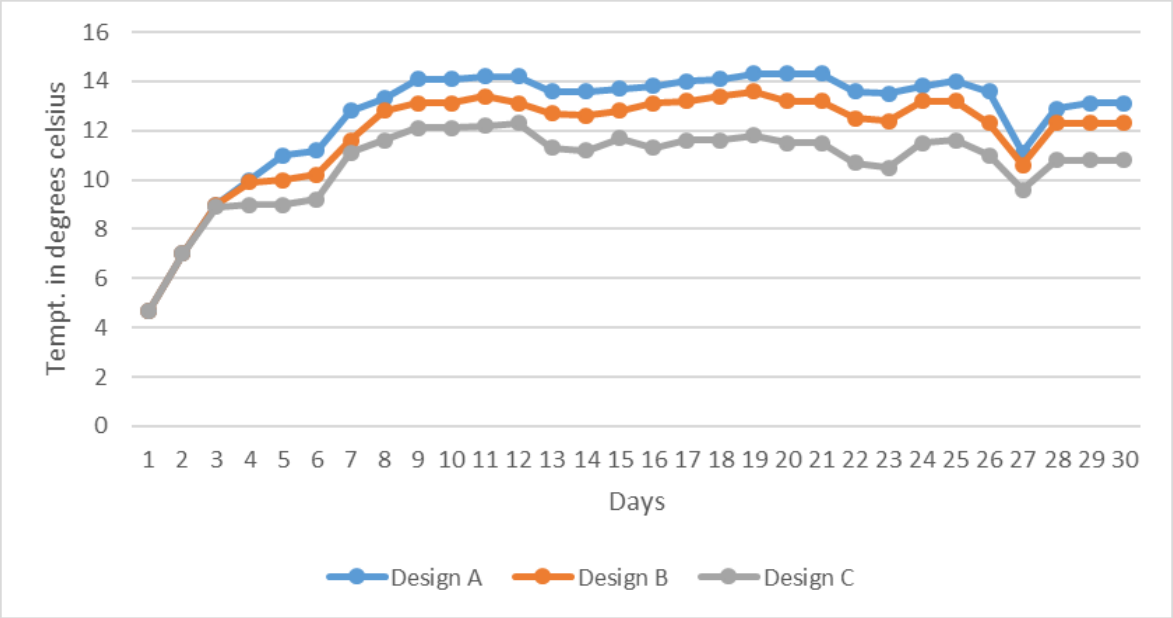

Figure 10: Temperature in all systems during the experiment.

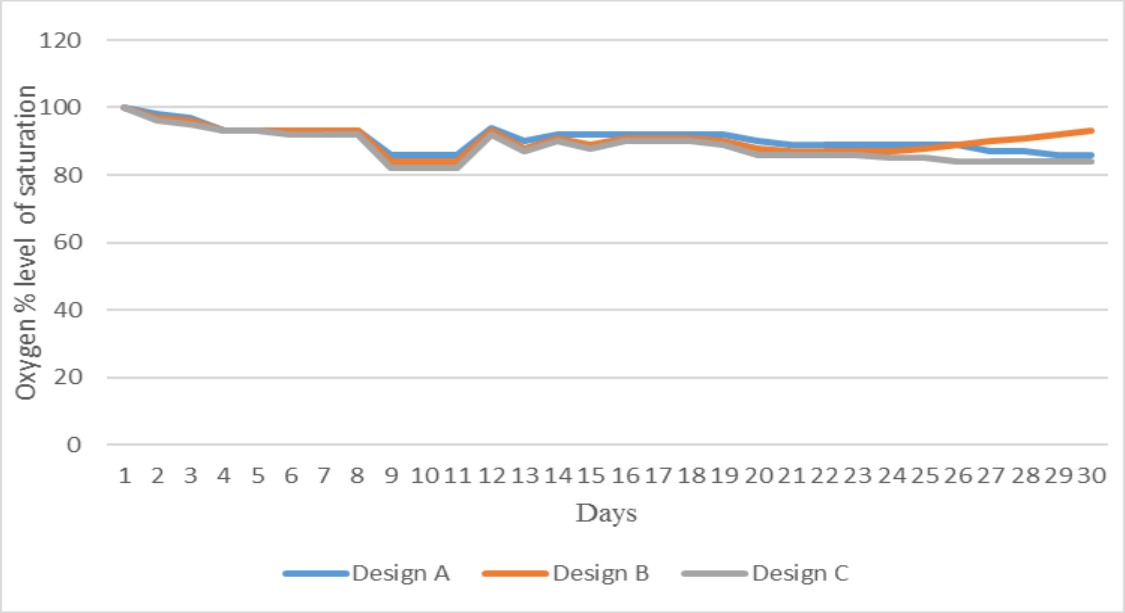

Figure 11: Oxygen saturation in all systems during the experiment.

The biological oxygen demand was measured thrice during the experiment and increased in all the three systems. system B, had the highest BOD (6.7mg/L) followed by system C (5.7 mg/L) and lowest was in system A with 5.3 (Figure 12). However, all values were similar.

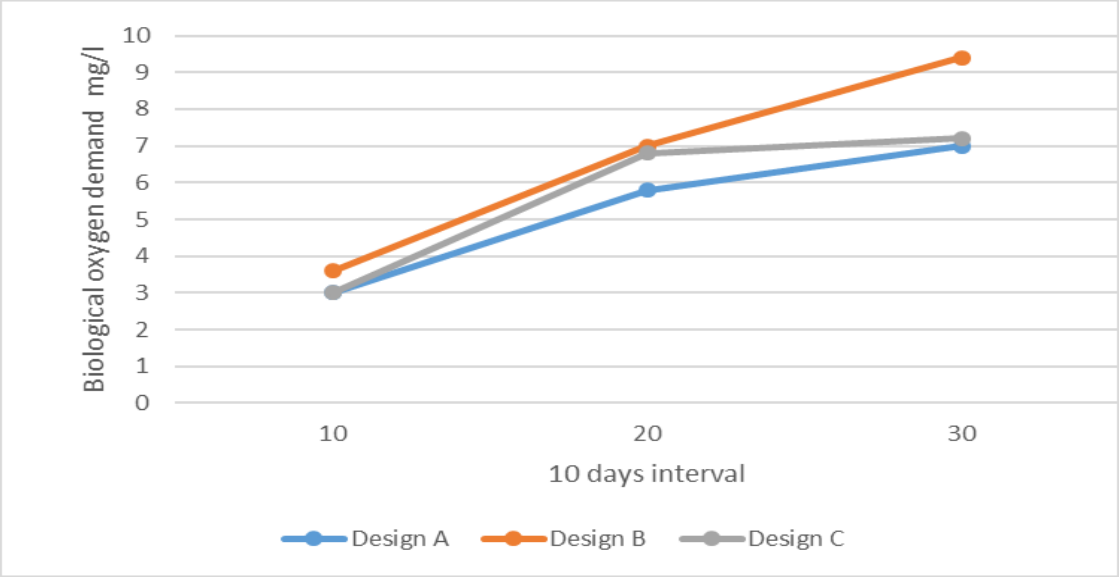

Figure 12: Biological Oxygen demand in the three systems during the experiment.

The total TBL was measured thrice. The TBL increased progressively in system B while TBL in system A was unchanged during the experiment. TBL in system C was intermediate (Figure 13).

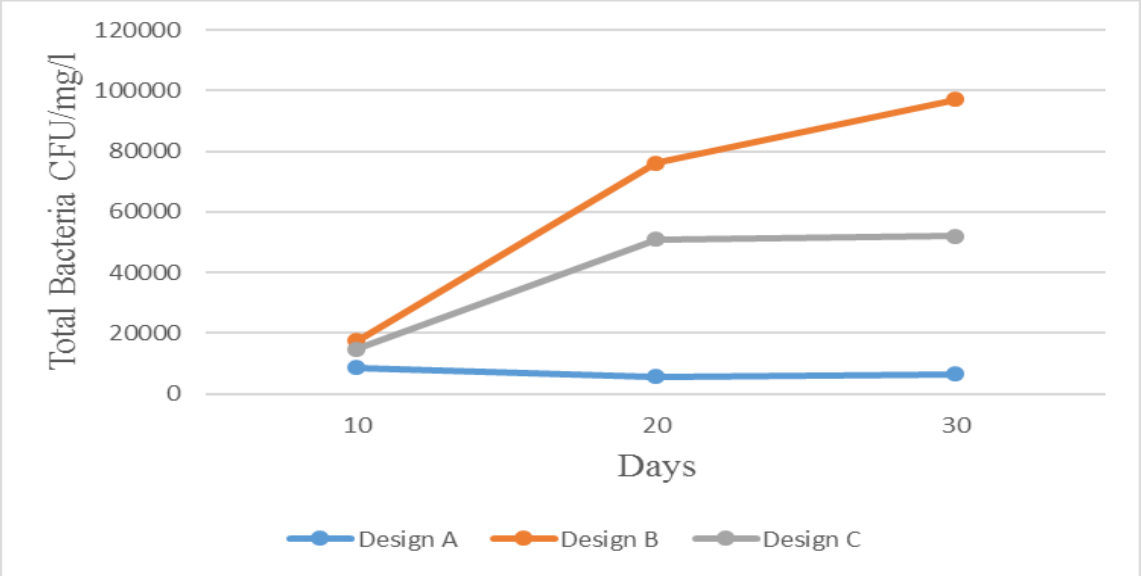

Figure 13: Total bacteria level in the three systems during the experiment.

5 DISCUSSION

In general, performance of all systems was similar. Both growth performance and water quality was in most cases similar. The water quality was in all cases within the acceptable levels. The growth rate was about half of what could be expected for Arctic char of this size, but it was similar in all systems. The culture tanks used were rectangular and open leaving the fish easily stressed. However, apart from the higher mortality in system B, the fish in all systems performed similarly.

There were slight differences observed in some of the water quality parameters. The temperature was highest in system A (Figure 10). This may have been caused by the heat from the UV filter which may have raised the temperature in the system. Similarly, the cold air in the airlift system may have reduced the temperature in system C, where the temperature was about 3 °C lower than in system A. The slight differences in temperature did not translate into differences in growth, but they may have contributed to lower TBL than in system B.

The presence of the UV filter in design A, added direct benefits to the system by reducing bacteria. System A, had the lowest values in BOD and TBL. Certainly, the lower TBL was due to the UV-filter and possibly the lower TBL may have contributed to lower BOD in system A. The absence of the UV filter could clearly be seen in design B which had the highest values in BOD, TBL and mortality. Although the UV filter is beneficial in a culture system it is relatively expensive and the efficiency depends on it position in the systems. However, the filter can maintain low TBL and this will in turn increase survival in the system. Therefore, it is recommended that UV-filters are included in the RAS in Cameroon.

System C, with the airlift pump, performed well compared with the other systems. It both aerates and pumps the water in RAS. The best survival rate was seen in design C, with the airlift. The reduced temperature in this system may have been due to cold air being driven through the water. This may be both beneficial or not depending on conditions and where the optimum temperature for growth of the fish lies in relation to water temperature. However, the difference in temperature between systems A and C was only 3 °C. These results suggest that airlift pumps should be considered for RAS in Cameroon. However, before they are employed it is necessary to consider in detail the design of the systems because that will determine their efficiency and capacity to pump water. It is possible that on air blower that can service many small RAS systems is more efficient and inexpensive than many small mechanical pumps. However, it is also necessary to consider the reliability of the air blowers and what would happen during breakdown.

6 CONCLUSION

This research has revealed certain considerably important facts in fingerlings production in RAS. It has demonstrated beyond doubts that design differences can affect production parameters which could either improve or inhibit the growth rate of fish. Good design systems will always produce good results. The usage of UV filters in fingerlings production in RAS system can never be over emphasized for healthy production and fast growth of fish. It uses no chemicals and does not create by products, which could harm the fish stock, or other aquatic life. Unlike other treatment methods, water purification systems using UV light also avoid the expense of complex monitoring systems required for adding and removing chemicals before the water reaches the fish. So, UV water purification systems did not alter the pH level of the water either. UV water purification systems was regarded based on the results obtained as an effective and economical disinfection technique for use in fish aquaculture. However, the cover of the UV bulb should never be open when connected to current because the radiation from UV-lamps can pose a health risk. It can cause conjunctivitis and erythema (sunburn) after only brief exposure. The skin and eyes must be protected against direct exposure (Lawson, 1995).

UV filter are expensive but necessary in hatcheries. Design C, with the airlift pump was found to be good in fingerlings production for many reasons such as lower initial cost and maintenance, easy installation, small space requirements, simplistic design and construction, ease of flow rate regulation, and ability to handle with easy. Airlift systems are equally good but should be incorporated with a UV filter for best performance. System designed with no UV filter in RAS is a potential danger that can result to huge economical loss in fingerlings production this was the outcome of the results in system B, without UV filter where all the juveniles died few days after the experiment.

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To God be the Glory.

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Appendix

Water quality equipment

Figure 14: Equipments used for water quality measurement. Source : Billund aquaculture service (Aquatech, 2016).

BOD measurement

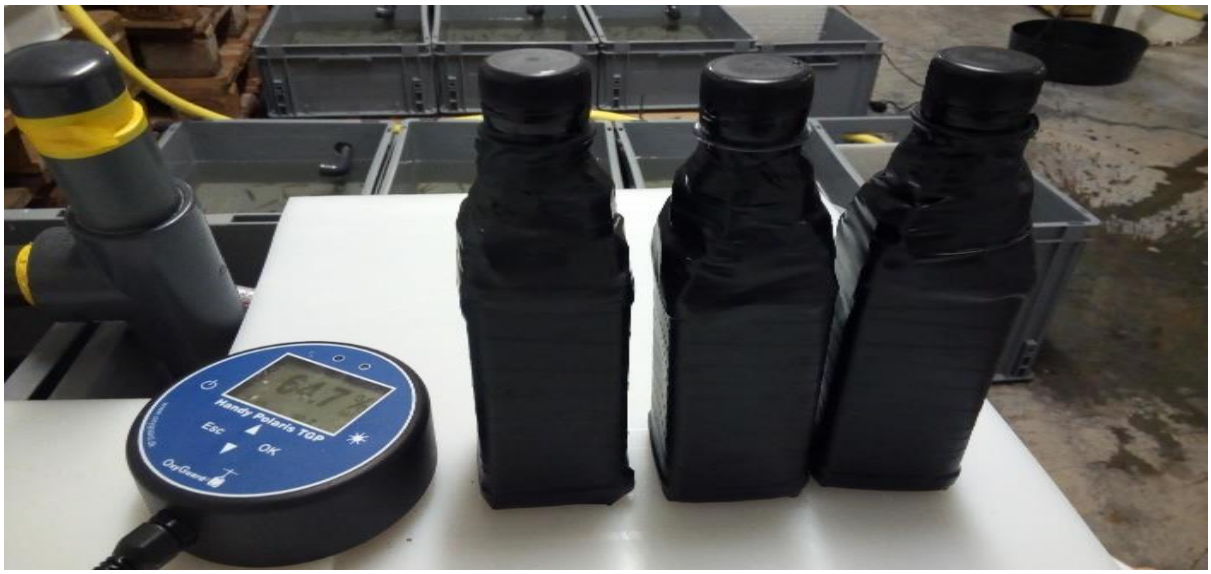

Figure 15: Measurement of Bacteria Oxygen Demand (BOD).

Total suspended solids measurement

Figure 16: Measurement for total suspended solids (TSS).

Total ammonium nitrogen measurement

Figure 17: Measurement of total ammonium nitrogen (TAN).

Design A, B, and C

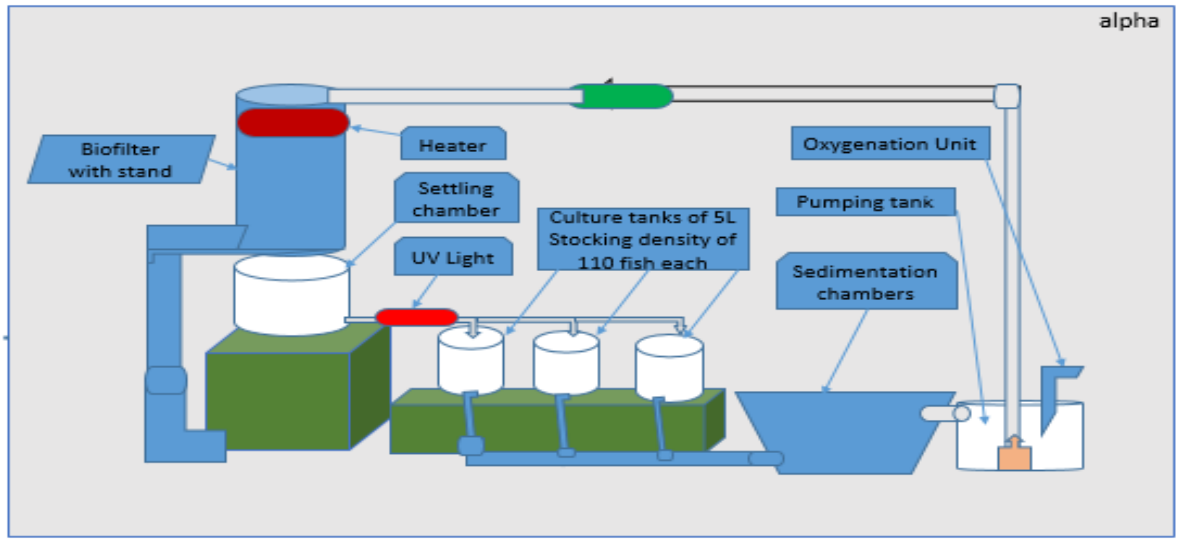

Figure 18: Design A, with UV filter.

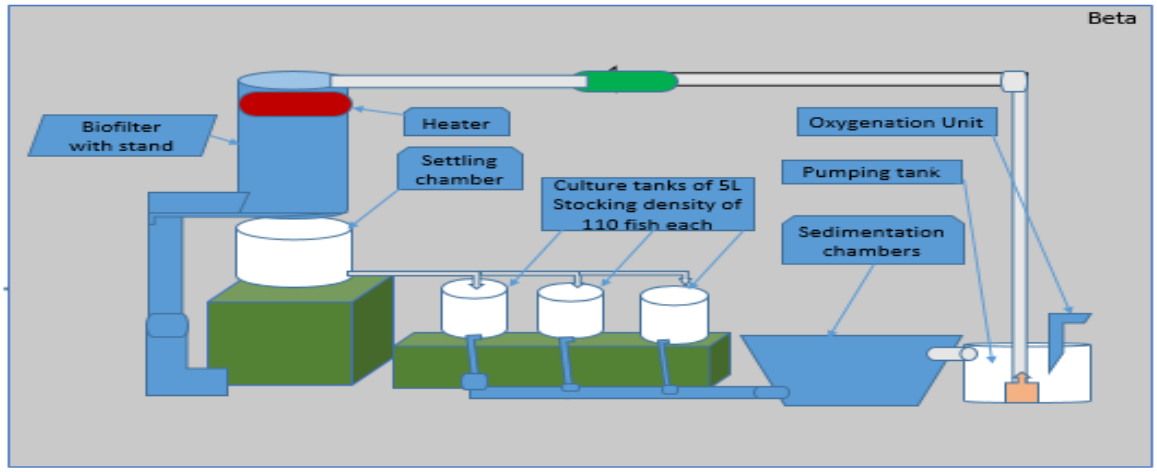

Figure 19: Design B, without UV filter.

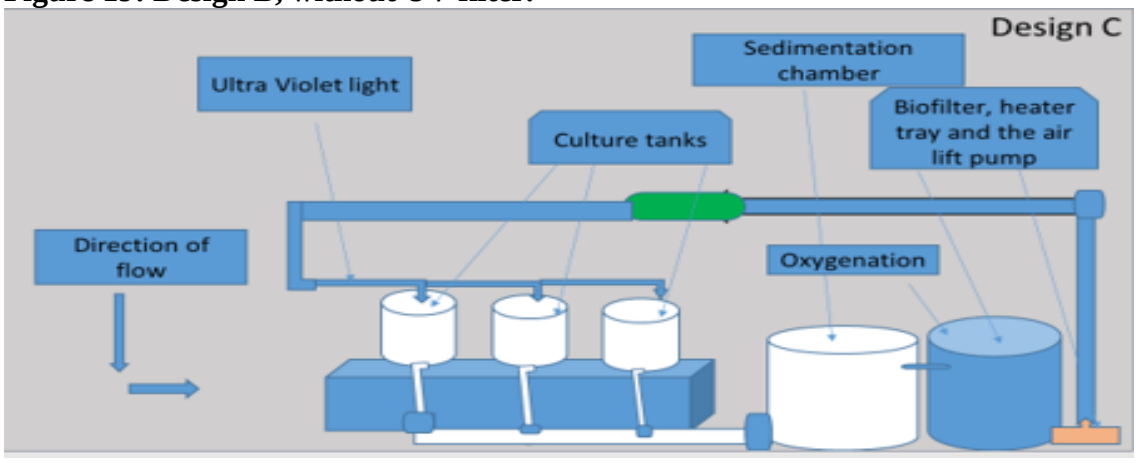

Figure 20: Design C, with air lift pump.

Construction phases

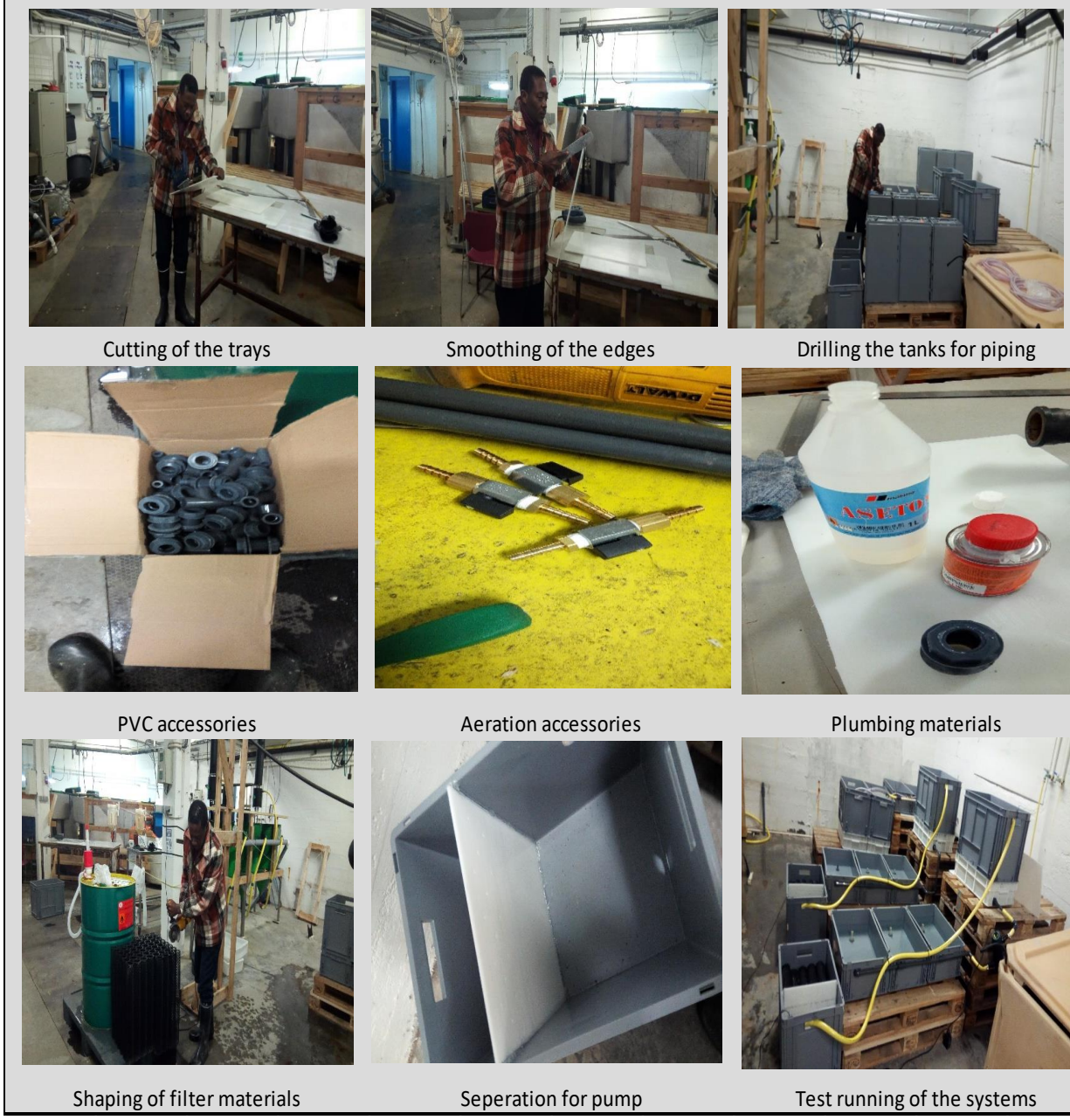

Figure 21: Materials for construction.