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Review

# Prospect and potentials of water re-circulating system in catfish production in Nigeria

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**Aquaculture is mostly undertaken in earthen ponds or large tanks with water. Earthen ponds require large areas of land and significant quantities of clean groundwater. Flow-through tank aquaculture requires less land but needs more water per kilogram of fish produced to maintain good growing conditions within the tank. Furthermore, there has been a serious concern regarding detrimental impacts of aquaculture production on the environment, increased regulations on aquaculture effluents and the need to conserve water resources and energy. In view of these, the aquaculture industry has identified the use of water re-circulating system technology in production as promising, with its ability to allow for high stocking density on the forefront. However, the adoption of this technology is low in Nigeria owing to the dearth of knowledge on its principles of operation as well as high cost of setup and maintenance.**

**Key words;** Potentials, aquaculture, water re-circulating system**,** catfish production, Nigeria

## INTRODUCTION

Water Re-circulating System (WRS) has been in existence, in one form or another, since the mid 1950's. However, only in the past few years has its potential to grow fish on a commercial scale been realized (Louis and George, 2005).

Recently, several factors have changed the practices of aquaculture drastically from small scale homestead activities to large scale commercial farming (Khudadad, 2012). Large proportion of finfish and shellfish for research and food are produced by aquaculture, with the majority being produced for food (Youngs and Timmons, 1991). Due to concerns regarding detrimental impacts of aquaculture production on the environment, increased regulations on aquaculture effluents, and the need to conserve water resources and energy, the aquaculture industry is focusing on development and refinement of water recycling technologies.

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The renewed interest in re-circulating systems is due to their perceived advantages such as greatly reduced land and water requirements; reduced production costs by retaining energy if the culture species require the maintenance of a specific water temperature, the feasibility of locating production in close proximity to prime markets (Dunning *et al.*, 1998) and the possibility of producing fish even in high profile part of our cities. The water quality in WRS depends on different factors most importantly the source, the level of recirculation, the species being cultured and the waste water treatment process within the system (Sanni and Forsberg, 1996 and Losordo *et al.*, 1999). Water re-circulating System technology was first introduced in Nigeria by Nigerian Farms Ltd. Patani, Delta State in 1978 by some German entrepreneurs. Other farms such as Chi farms Nigeria. Ltd, Lagos, Zartech and Durante farms in Ibadan followed as from 1996 (Anyanwu and Ezenwa, 2003).

This paper reviewed the concept of water re-circulating system and its applicability in aquaculture towards boosting production of fish in Nigeria. It is hoped that,

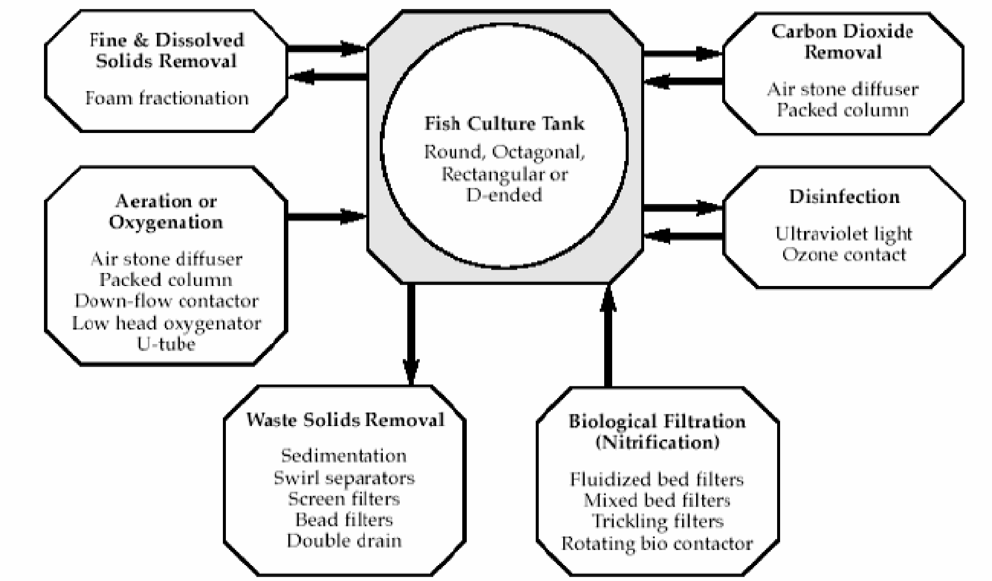



**Figure 1:** Required unit processes and typical components used in re-circulating aquaculture production systems (Source: Losordo, *et al.*, 1998).

even a homestead farm will employ a WRS technology having understood the basic principles involved in re-circulating aquaculture production systems.

**Concept of Water Re-circulating System in Aquaculture**

Water Recirculating systems (WRS) consist of an organized set of complementary processes that allow at least a portion of the water leaving a fish culture tank to be reconditioned and then reused in the same fish culture tank or other fish culture tanks (Timmons *et al.,* 2002).

**Principles of WRS in Aquaculture**

Libey (1993) and Jared *et al.* (2006), discussed the operational principles of WRS as an assemblage of parts used for the culture of aquatic organisms where water is continuously cleaned and reused. Water is cleaned via mechanical and biological filtration. Mechanical filtration removes particulate wastes, while biological filtration removes dissolved wastes via biochemical reactions that occur during bacterial metabolism. These processes allow water to be cleaned and reused several times prior to discharge. These processes also conserve water by reducing the amount of water needed (from an external source) to maintain a biologically suitable culture environment for the crop or fish. Water recycling allows the majority of re-circulating systems to exchange approximately 10 % of total system volume per day while recycling 90 % of the culture water. The most important consideration in re-circulating systems design is the development of an efficient water treatment system. Re-circulating production systems must be designed with a number of fundamental waste treatment processes. These processes, referred to as "unit processes," include the removal of waste solids (both feces and uneaten feed), the conversion of ammonia and nitrite-nitrogen (a non-toxic form of dissolved nitrogen), the addition of dissolved oxygen to the water, and the removal of carbon dioxide from the water. With less robust species, and depending upon the volume of new water used, a process to remove fine and dissolved solids, as well as a process to control bacterial populations, may need to be applied. Figure 1 shows these unit processes.

There could be different designs for WRS and most will work effectively if they accomplish: aeration, removal of particulate matter, biological filtration to remove waste ammonia and nitrite, and buffering the pH. These processes could be achieved by a simple composite unit such as an aquarium filter or in larger systems, by several interconnected components (Michael and Charles, 2000).

**Benefits of WRS in Aquaculture**

WRS offer fish producers a variety of important advantages over earthen pond culture. These include:

A method to maximize production on a limited supply of water and land.

Nearly complete environmental control to maximize fish growth year-round.

The flexibility to locate production facilities near large markets.

Complete and convenient harvesting.

Quick and effective disease control.

**Water Treatment Processes**

Waste water treatment options are numerous. These could be categorized under physical, chemical and biological treatments.

**Physical Treatment**

Solids can be removed from aquaculture systems using physical methods and processes. These processes include trapping of particulates and gravity separation.

**Chemical Treatment**

Some chemical filtration methods which are useful in large commercial WRS include:

**Activated Carbon**

Activated carbon is prepared by first making char from coal, pecan, coconut or walnut shells: wood or the bones of animals by heating the material in the absence of air at about 900$^{o}$C the charred material is than activated by exposing it to an oxidizing gas at high temperature. The gas creates a highly porous large internal surface area (Wheaton, 1977). It is then referred to as activated carbon.

**Ion Exchange**

It is a unit process within which certain ions are displaced from an insoluble exchange material (resin) by ions of a different species dissolved in the waste water. Ion exchange resins are manufactured in the form of tiny porous beads about 1mm in diameter (Thomas, 1997).

**Foam Fractionation**

Foam fractionation is a process that removes dissolved organic carbon (DOC) and particulate organic carbon (POC) from fish culture water by absorbing them onto the surfaces of air bubbles rising in a closed contact column. According to Thomas (1997), the bubbles create foam at the top of the liquid column, and accumulated organic wastes are thus discarded along with the foam produced.

**Biological Treatment**

This refers to filtration techniques that utilize living organisms to remove a substance from a liquid medium. It includes systems using algae and higher green plants to filter the water, commonly referred to as hydroponics. In WRS, biological filtration refers to the removal of ammonia and nitrite by bacteria.

According to Pillay and Kutty (2005), there are several systems and designs employed in waste water treatment for hatchery use as well as for intensive aquaculture. The most commonly used and relatively more economical would appear to be Biofiltration. Several types of filter media are normally used. These include sand, gravel, oyster shells, plastics, anthracite, diatomaceous earth and their combinations.

**Nitrification**

Louis and George (2005) noted that, Ammonia is a poisonous waste product excreted by fish. Since fish cannot tolerate this poison, detoxifying ammonia is fundamental to good water quality, healthy fish, and high production. Detoxification of ammonia occurs on the biofilter through the process of nitrification. Nitrification refers to the bacterial conversion of ammonia ($NH_3$) to less toxic nitrite ($NO_2$), and finally to non-toxic nitrate ($NO_3$). The process requires a suitable surface on which the bacteria can grow (biofilter media), pumping a continuous flow of tank water through the biofilter, and maintaining normal water temperatures and good water quality. Two groups of aerobic, nitrifying bacteria are needed for this job. Nitrosomonas bacteria convert $NH_3$ to $NO_2$; the Nitrobacter bacteria convert $NO_2$ to $NO_3$ (Michael and Charles, 2000). The equations for these reactions are as follows:

$$NH_4^+ + 1.5O_2 \longrightarrow NO_2 + H^+ + H_2O \text{ (nitrosomonas)}$$

$$NO_2^- + 0.5O_2 \longrightarrow NO_3^- \text{ (nitrobacter)}$$

Total equation: $NH_4^+ + 2O_2 \longrightarrow NO_3^- + H^+ + H_2O$

The rate of ammonia oxidation in biofilter can be described by Monod equation.

$$\text{Monod equation } (\mu) = \mu m \times \frac{S}{Ks + S}$$

Where µ= specific growth rate of nitrifying bacteria (l/day)

µm = max. specific growth rate of nitrifiers (l/day)

S = residual growth-limiting substrate concentration (g/m3)

Ks = saturation constant (substrate conc. at which µ = µ/2)

**Design of WRS for Aquaculture**

A key to successful WRS is the use of cost-effective water treatment system components. Water treatment components must be designed to eliminate the adverse effects of waste products (Losordo *et al.* 1998). In re-circulating tank systems, proper water quality is maintained by pumping tank water through special filtration and aeration and/or oxygenation equipment. Each component must be designed to work in conjunction with other components of the system. To provide a suitable environment for intensive fish production, re-circulating systems must maintain uniform flow rates (water and air/oxygen), fixed water levels, and uninterrupted power supply for efficient operation (Fivelstad and Smith, 2003).

The most important functional parts of a WRS include the following:

**Fish Culture Tanks**

Fish can be grown in tanks of nearly every shape and size. Fish tanks are typically rectangular, Circular or oval in shape. Circular or oval tanks with central drains are somewhat easier to clean and circulate water through than rectangular ones. The size of the tank depends on a variety of factors including: stocking rate, water quality economic considerations The tank must be designed to correspond with the capacity of other components of the system, particularly size of the bio -filter and sump so that all parts of the system are synchronized(Louis and George, 2005).

**Sedimentation Tank/Particulate Removal Device (Sump)**

According to Louis and George (2005), the clarifier tank is designed as a settling basin (large volume tank with a slow flow rate to increase sedimentation). Its purpose is to concentrate and remove suspended solids (fish feces, uneaten feed particles) before they clog the bio-filter or consume valuable oxygen supplies. The clarifier should be a separate tank, isolated from the fish and the bio-filter, so that it be cleansed periodically. To increase the efficiency of the clarifier, various filters (plastic filters, sand filters metal screens) can be inserted into the sedimentation tank.

**Water Circulating Pump**

This element is also known as the air lift pump whose function is achieved by using air to move water. Air lift pumps exploit the physical properties of a two-phase mixture of air and water which creates an upward flow in a standpipe while contacting air and water for gas exchange. This flow is a result of the reduced density of the air/water mixture below the water line (Neil, 1997).

**Biofilter**

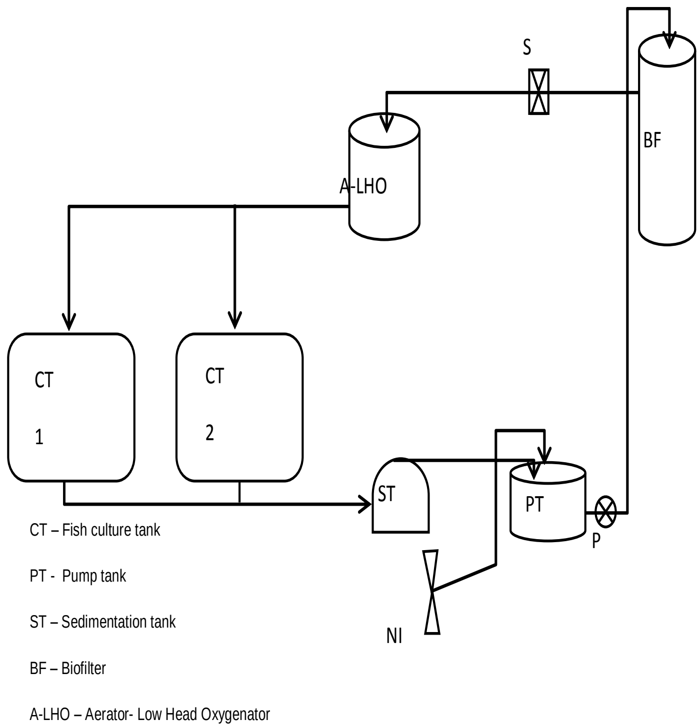
As described by Louis and George (2005), a biofilter, in its simplest form, is a wheel, barrel, or box that is filled with a media that provides a large surface area on which nitrifying bacteria can grow. This biofilter container can be constructed of a variety of materials, including plastic, wood, glass, metal, concrete, or any other nontoxic substance. In small-scale systems, some growers have used plastic garbage cans or septic tanks. The size of the biofilter directly determines the carrying capacity of fish in the system. Several types of biofilters have been developed for use in the aquaculture industry, each with its own design and operational characteristics.

**Sterilizer (Ultraviolet light/Ozone)**

Diseases can spread quickly because of the density of fish in re-circulating systems. Some chemicals used to treat diseases have a devastating effect on the nitrifying bacteria within the biofilter and culture system. Alternatives to traditional chemical or antibiotic treatments include the continuous disinfection of the recycled water ozone or ultraviolet irradiation (Losordo *et al.*, 1999). Ozone and ultraviolet light are powerful sterilants. Ozone must be used with caution since it is directly toxic to aquatic life and may form harmful by-products (hypochlorite, hypobromite) (Louis and George, 2005). Microorganisms (including disease-causing bacteria) are killed when exposed to the proper amount of ultraviolet (UV) radiation. Spotte (1979) noted that the effectiveness of UV sterilization depends upon the size of the organism, the amount of UV radiation, and the level of penetration of the radiation into the water.

**Oxygen Diffuser**

The multi-staged low head oxygenator (LHO) as illustrated in this paper oxygenates flowing water where there is only a small elevation difference between the source of the water and the culture tank. Pure gaseous oxygen enters one end contact chamber and oxygen with off gases (nitrogen and $CO_2$) exits the adjacent contact chamber. The oxygen transfer capability of this system is determined by the length of water fall, gas and water flow rates, the DO concentration of the influent water, and the number of contact chambers (Losordo, *et al.,* 1999)




**States of power generation in Nigeria**

Nigeria is at present generating 3106.4Mw compared to 2000Mw as was recorded in the year 2012 this is an improvement that requires investment in areas where investment such as fish production using re-circulating system, a production system that is power dependent is very important for improvement in protein availability.

**Water Quality in Water Recirculating System**

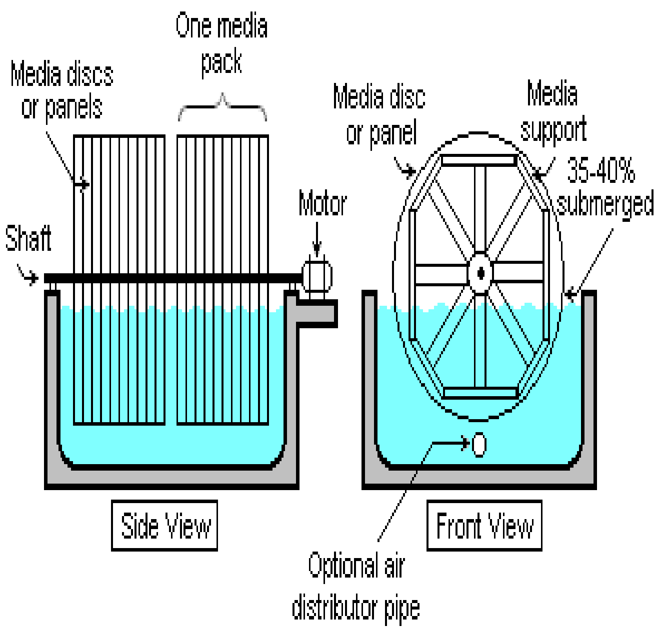
As fish live and breathe within water it is important that optimum water quality conditions are maintained within the recirculating system especially when fish are stocked at high densities. Maintaining temperature, oxygen, carbon dioxide alkalinity and hardness at optimal range ensures good growth to make the cultured fish less prone

**Table 1:** States of power generation in Nigeria

| Station | Location | Power output (Mw) |
|---|---|---|
| Kanji | Niger | 140 |
| Jebba | Kwara | 242.0 |
| Shiroro | Niger | 440 |
| Egbin | Edo | 541 |
| Delta | Delta | 203 |
| Afam 4 | Akwa ibom | 65 |
| Afam 6 | Akwa ibom | 434 |
| Sapele speam | Delta | 75 |
| Sapele NIPP | Delta | 9 |
| Okpal | | Nil |
| Geregu 1 | Kogi | 110 |
| Geregu 2 | Kogi | 115 |
| Olorunshogo | Ogun | 40.7 |
| Olorunshogo NIPP | Ogun | 77.5 |
| Omotosho 1 | Ondo | 57.5 |
| Omotosho NIPP | Ondo | 108.3 |
| Ihodu | Benin | 109.5 |
| Rivers NIPP | Rivers | 140.0 |
| AES (NIPP) | | 198.9 |
| Total | | 3106.4 |

**Source**: Ministry of Power Bulletin, August, 2013

**Figure 2**: General Diagram of WRS in Fish Culture




to diseases. (Aquaculture SA, 2003, Pillay and Kutty 2005 and Boyd 2005). Alkalinity and water hardness, the concentration of calcium and magnesium are often categorized thus;
0 – 75 mg/l soft
75 – 150 mg/l moderately hard
150 – 300 mg/l hard
over 300 mg/l very hard
A fish creates and expels various nitrogenous waste products through gill diffusion, gill cation exchange, and urine and feces excretion; in addition some nitrogenous wastes are accumulated from the organic debris of dead and dying organisms, uneaten feed, and from nitrogen gas in the atmosphere (Timmons *et al.*, 2002).
Exposure to extreme pH values can be stressful or lethal for aquatic species, but it is the indirect effects resulting from the interactions of pH with other variables that depend on the water acid-base equilibrium such as dissolved $CO_2$, the relationship between $NH_3$-N and $NH_4^+$-N levels and $NO_2$-N levels, that an increase of their concentrations depresses the pH values in water (Pillay and Kutty, 2005). Low pH values increase the water solubility of some heavy metals such as aluminium, copper, cadmium and zinc, their high concentrations in water cause toxic effects on fish, and also increase the toxicity of hydrogen sulphide on fish (Fivelstad and Smith, 2003).

## Role of WRS in Fish Production in Nigeria

Despite the popularity of catfish and its great market potentials, the production is still basically at subsistence level due to inadequate supply of seed for stocking, absence of reliable production techniques for the mass production and rearing of the species under practical farming conditions (Adeyemo and Falaye(2009). According to Adeyemo *et al*.(2011) a major proportion of public sector research and development effort has been directed towards increasing the productivity of pond systems. In contrast, very little public sector research and development has been geared towards improving and understanding of other production systems. In order to increase the production potential of aquaculture in Nigeria, research and development should focus on a wider range of production systems for fish farming and on increasing the intensity of production in fish ponds to help farmers achieve higher yields (Hecht, 2000). However, the poor state of electric power supply in Nigeria could stand as a single factor capable of militating against its wide adoption. In any case, there is the need for enlightenment about the advantages that abound in using such systems as water re-circulating system.
In a recent study by Adeyemo *et al.* (2011), it was seen that the cost of raising fry in a recirculating system (₦34,000) was twice that needed for earthen pond (₦17,000), but this was more than made up for in the profit from sales, which was ₦311,360 and ₦99,156 respectively. This was as a result of the high survival rates of the fry in the recirculating system.
The development of a reliable method for the mass production of *Clarias gariepinus* fingerlings for constant supply is important. In Europe, about 75% of Clarias fingerling demands are supplied by few producers. In Nigeria however, the fingerlings supplied from both the government and privately owned hatcheries are not

**Figure 3**: Schematic diagram of a rotating biological contactor (RBC) filter (Wheaton et al., 1994).

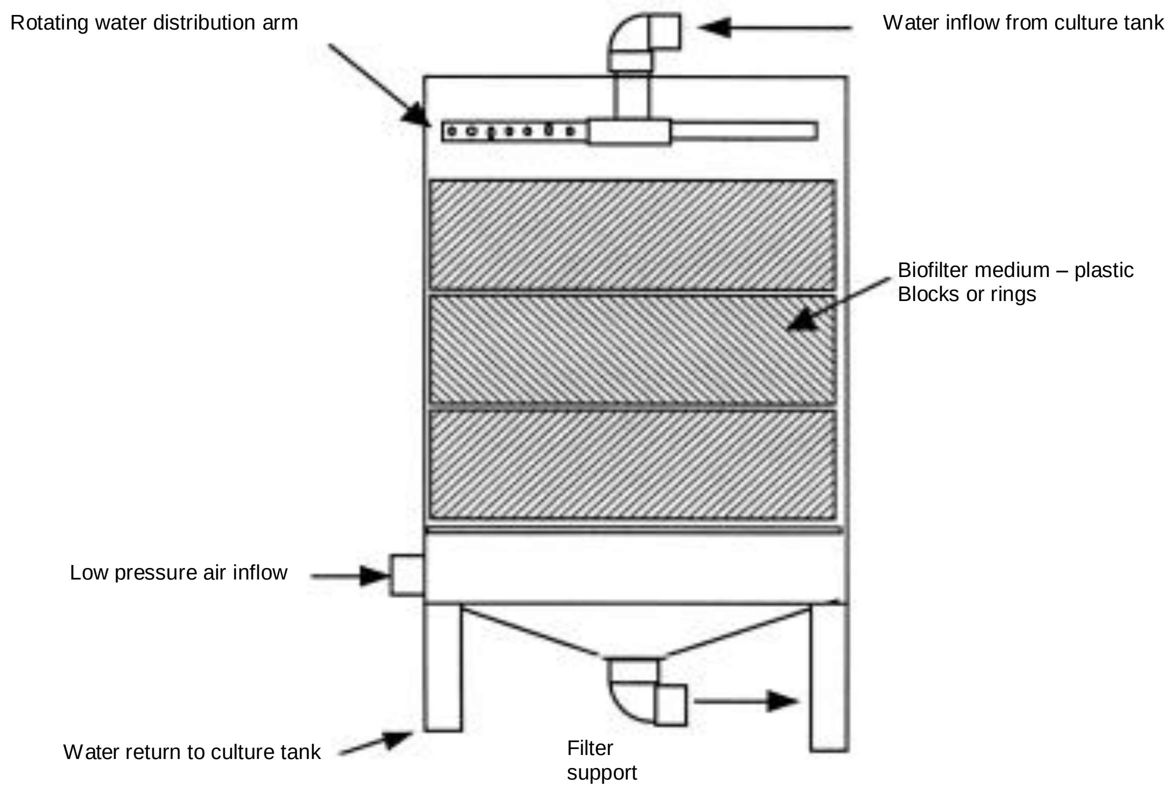



**Figure 4**: Schematic diagram of a packed tower trickling

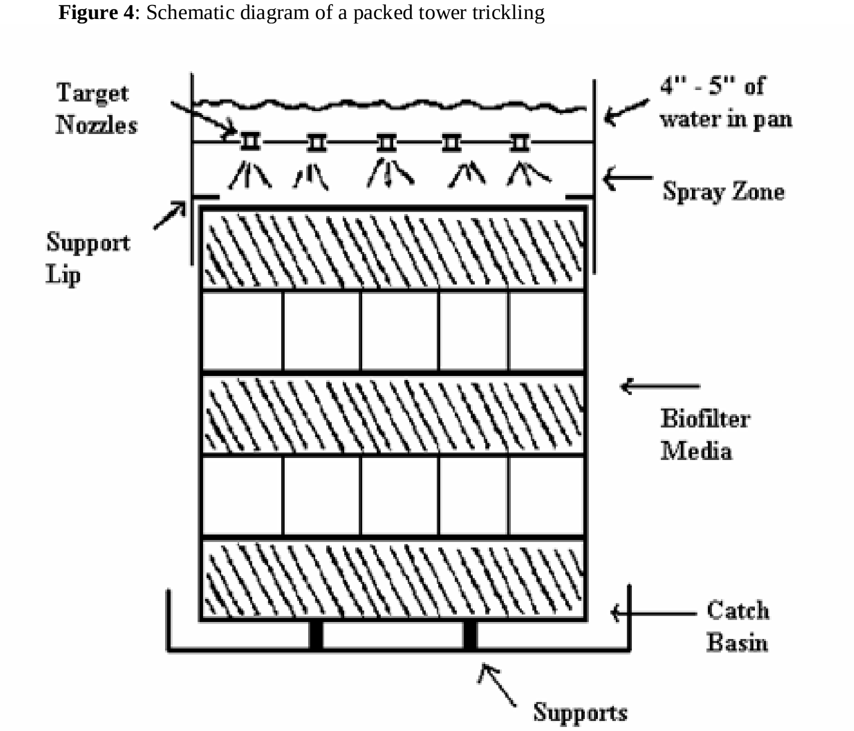


**Table 2**: Lethal levels of $NH_3$-N (concentration of nitrogen bound as $NH_3$) for some aquaculture species.

| Specie | $NH_3$-N (mg/L) | Reference |
|---|---|---|
| Rainbow trout | 0.32 | Timmons et al., 2002 |
| Arctic charr | 0.03 | Aquafarmer, 2004 |
| Common carp | 2.2 | Summerfelt et al (2004) |
| Catfish | 3.10 | Summerfelt et al (2004) |

enough to meet the catfish farmers' fingerling demands (Olaleye, 2005). According to Jamu and Ayinla, (2003), one way of achieving high production intensities is through the use of recirculating aquaculture tank systems.

Here, unlike fisheries, inputs, production processes and quality of output can be at least partially controlled, and ownership, care and environmental responsibility might be more easily established (Adeyemo *et al.*, 2011).

## CONCLUSION

If the WRS Technology is domesticated through use of local raw materials and fabrications to reduce production costs, more farmers will be attracted to adopt the technology and more fish will be produced in Nigeria. This will ensure self-sufficiency and food security as well as creation of employment opportunities thereby alleviating poverty.

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