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Performance evaluation of foxtail amaranth (*Amaranthus gangeticus*) and GIFT tilapia grown in a recirculating aquaponics system

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ABSTRACT : This paper deals with the development and performance evaluation of aquaponics system. In the present study GIFT tilapia fingerlings and foxtail amaranth (*Amaranthus gangeticus*) seeds were procured and grown in fish culture tank and plant bed, respectively in aquaponics unit. This study demonstrates and evaluated the growth of GIFT tilapia and foxtail amaranth (*Amaranthus gangeticus*) grown in aquaponics system and normal culture system. The fish fingerlings of average weight 0.70 g were procured from a fish farmer. The fish weight was recorded in aquaponics and glass tank and was found to be 83.20 and 78.10 g, respectively after 160 days of culture. Plant height observed in aquaponics system and normal culture system which was recorded as 18.10 cm and 20.20 cm, respectively. The recirculation flow rate in aquaponics was maintained 0.43 L/ throughout the culture and the average biofiltration efficacy was found to 23 per cent. Fish were fed at the rate of 12 per cent of body weight with commercially available feed.

KEY WORDS : Aquaponics system, GIFT tilapia, Foxtail Amaranth (*Amaranthus gangeticus*); Recirculation flow rate

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Aquaculture is one of the important sources of protein production and accounts for almost one-half of the fish eaten globally. It has emerged as a major food producing sector, and presently a major global food industry with total annual production exceeding 63.6 million tons (FAO, 2012). Aquaculture has the potential to decrease the pressure on the world's fisheries and to significantly reduce the footprint of less-sustainable terrestrial animal farming systems in supplying humans with animal protein. Water quality Management is one of the important issues in any aquaculture operation. Aquaculture practice generates lots of effluent and to treat or dispose of the effluent can be both expensive and environmentally harmful. Without treatment, the release of effluent directly to the environment or any natural water body may lead to eutrophication and other ecological and economical imbalance. Water reuse systems have become popular in small capacity systems due to high initial capital investments required by recirculating aquaculture system (Schneider *et al.*, 2006). High stocking densities and productions are required to cover investment costs; which may also lead to accumulation of minerals, drug residues, hazardous feed compounds and metabolites affecting the health, quality and safety of the cultured species (Martins *et al.*, 2009 a and b). Therefore, an aquaponic system can benefit the aquaculture operation by improving the quality of recirculated water or by reducing costs associated with treating effluent from flow-through raceways (Rakocy *et al.*, 2006). There is no requirement of fertilizers and extra labour input in hydroponic culture system to maintain adequate moisture levels. Thus, the marriage of fish culture with plant culture in aquaponics system allows both operations to reduce inputs and makes the enterprise more sustainable (Tyson *et al.*, 2008). Therefore, an aquaponics system will serve the purpose of producing food for a sustainable future without much degradation to the environment. Aquaponics is a combination of conventional aquaculture systems *viz*., raising fish, crayfish or prawns in tanks or ponds with hydroponics *i.e.* cultivating plants in water in a controlled environmental condition. The field of aquaponics has grown dramatically in the past few years (Love *et al.*, 2014). However, data gaps exist on the resource use, cost–benefit analysis, and life cycle assessment of aquaponics. Basically, aquaponics systems are nothing but recirculating aquaculture systems where water is continuously recycled through an interconnected series of fish tanks and waste treatment systems (Timmons *et al.*, 2002). A potentially toxic by-product of fish waste is ammonia and which needs to removed from fish culture water. Hence, to remove toxic nitrogenous compounds and improve water quality, biofilters were used. Francis *et al.* (2003) reported that sustainable agricultural production can be achieved similar to natural ecosystems like aquaponics system. Although preliminary research has shown that developed aquaponic system components are not yet fully realized in view of either cost effectiveness or technical capabilities (Rakocy, 2012; Vermeulen and Kamstra, 2013). The linking of fish culture with plant culture allows both operations to reduce inputs and makes the enterprise more sustainable (Tyson *et al.*, 2008). The aquaponic concept is promising to contribute to both global and urban sustainable food production and should at the same time minimize pollution and urgent need for natural resources.

The objective of this research was to develop aquaponics system and evaluate the performance of GIFT tilapia reared and foxtail amaranth (*Amaranthus gangeticus*) cultured in the developed aquaponics system.

■ METHODOLOGY

In the present study aquaponics system set-up was installed in College of Fisheries Engineering, Tamil Nadu Fisheries University Nagapattinam. A typical schematic diagram showing all the components of aquaponics system is presented in Fig. A. The details of the individual components are described in brief.

Specification:

The installed set –up consists of

- Fish rearing tank of dimension (90×60×60) cm^3
- Plant culture tank of dimension (90×60×60) cm^3
- Nylon pot scrubber as plant growth bed 500 nos and construction gravel
- Wooden rack of dimesion (120cm×110cm× 90cm)
- Submersible pump (Make: SUNSUN, Power consumption: 18W, Height:1.85m, Output: 1800 L/h).

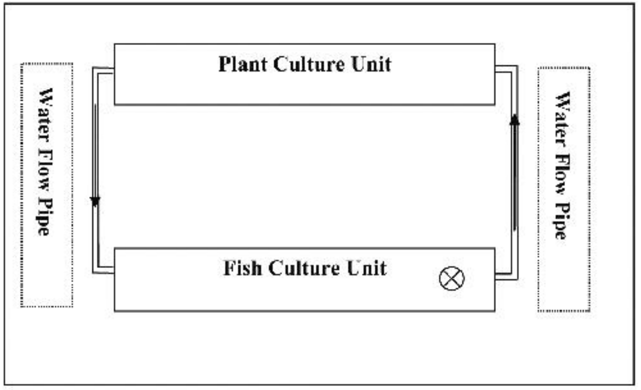

Fig. A : Aquaponics system showing individual components

Fish rearing unit :

An FRP tank of inner dimensions 2.5 x 2 x 1.4 m^3 was installed to rear fish under controlled condition. Six pipes joined with five elbows were fitted to rearing tank for outgoing of recirculated water to the plant rearing tank. One gate valve was also fitted in the pipe to regulate the flow of water from fish rearing tank to plant culture tank. Water from the fish rearing tank was pumped with the use of a submersible pump.

Plant culture unit :

An FRP tank was used as a plant culture unit. Nylon pot scrubber was used as plant culture media. 500 numbers of nylon pot scrubbers were placed in the plant culture unit and over it construction gravel was used and both were used as a plant bed. 25 numbers of foxtail amaranth (*Amaranthus gangeticus*) seeds were spreaded on the entire plant culture bed and the system was run for continuous operation the flow rate was maintained as 0.43 l/minute throughout the culture period.

Water quality analysis :

Water quality variables were analyzed during the experiment at 07 d intervals. Sampling was conducted between 08:30 and 09:30 at each sampling date, and samples were kept in a refrigerator at 4^0 C in labeled polythene bottles for chemical analysis. Water temperature was measured by thermometer, and pH was measured using universal pH indicator. Dissolved oxygen, free CO_2, hardness, alkalinity, ammonia, nitrite, and nitrate were analyzed by standard methods outlined in APHA (1998). Phosphate, magnesium, iron, and zinc were analyzed by chemical analysis using Supra Pure concentrated acids (Merck, Darmstadt, Germany).

Fish and plant sampling :

Fish sampling and plant growth were assessed at 07 day intervals. Fish growth was assessed by measuring its length, width and weight. Plant growth was monitored by measuring the plant height, leaf length, and leaf width. After 60 days, foxtail amaranth (*Amaranthus gangeticus*) plants were harvested.Fish were reared for the period of 160 days.

Feed :

In the present study, GIFT tilapia were provided brand pelleted feed containing brown coloured pellets. The ingredients of the feed are presented as follows:

– White fish meal, wheat flour, shrimp meal, dried yeast, soybean meal, wheat germ meal and dehydrated alfalfa meal.

– Vitamin A, C, D, E, K, B_1, B_2, B_6, B_{12}, inositol, nicotinic acid, Ca- pantothenate choline, biotion carotenoid, para–amino benzoic acid and folic acid.

– Minerals: Iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), cobalt (Co), phosphorus (P), magnesium (Mg) and P–amino benzoic acid (Paba).

– Carotenoids, NS germ and chlorophyll.

The percentage of proximate composition of the GIFT tilapia feed is shown in Table A. The GIFT tilapia were fed at the rate of 2.5, 4.5, 7, 10 and 12.5 per cent of fish biomass consecutively for 30, 60, 90, 120 and 160 days, respectively. Feeding was done thrice a day to enhance easy digestibility of feed by fish (Penry and Jumars, 1986).

Table A : Percentage of proximate composition in GIFT tilapia feed

Sr. No.	Composition	Percentage
1.	Crude protein	40
2.	Crude fat	8
3.	Crude fibre	6
4.	Crude ash	16
5.	Moisture	11
6.	Nitrogen free extract	32

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Fish growth :

The average initial weight of fishes was recorded as 0.70 g. With the initial value of weight, time-temperature data, fish weight was recorded on 07 day interval basis. The plot showing weight and specific growth rate during culture for the period of 160 days is shown in Fig. 1 and 2.

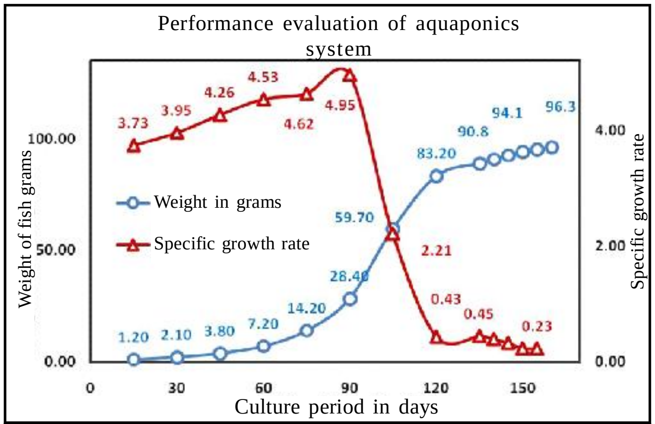

Fig. 1 : Specific growth rate and weight of GIFT in aquaponics system

From Fig. 1 and 2 it can be inferred that the specific growth rate followed a reducing trend after 60 days of culture. This was because the growth was faster at the initial stage and then growth slows down. The growth rate was found almost same for over initial 30 days. This may be due to the time taken by the fishes to acclimatize to the new culture environment. The length of fish was

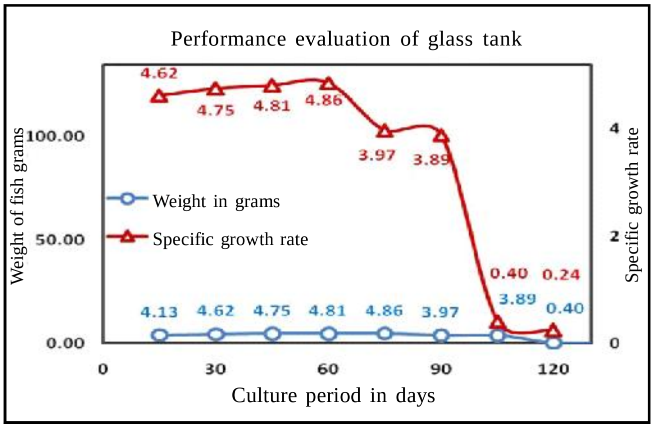

Fig. 2 : Specific growth rate and weight of gift in glass tank system

continuously increasing throughout the culture both in aquaponics and normal culture (glass tank) unit as shown in Fig. 3. The growth of fish in this manner indicated that the fish were adequately fed and were all well nourished.

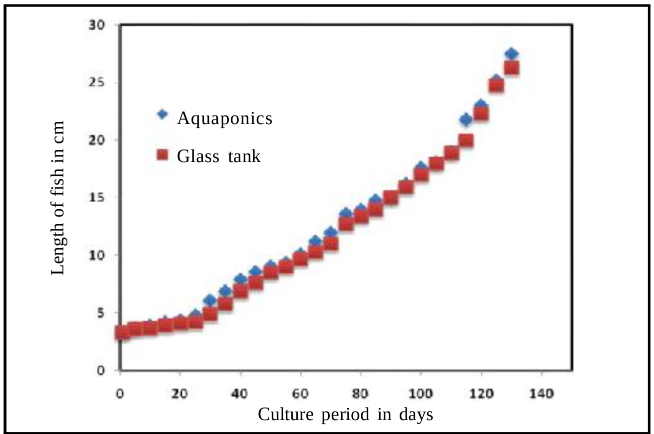

Fig. 3 : Length of fish observed in aquaponics and glass tank culture system

Plant growth :

The foxtail amaranth (*Amaranthus gangeticus*) seeds were spreaded over the plant bed and growth of plant was observed at every seven day interval. At the end of 60 days plants were harvested.

Table 1 : Plant height with duration

Date	Height(cm) aquaponics system	Height(cm) normal culture system
10.2.17	0	0
17.2.17	3.3	3.8
24.2.17	4.5	5.0
3.3.17	6.1	7.0
10.3.17	8.7	9.2
17.3.17	11.0	11.7
24.3.17	12.8	13.4
31.3.17	14.3	15.0
1.4.17	16.2	16.9
8.4.17	18.1	20.2

It can be clearly observed form Table 1 that plant were grown and finally average height of the plants were measured as 18.1 cm. Though the average height of plant cultured in normal culture system on the ground was quiet higher *i.e.* 20.2 cm than the plant grown in aquaponics system but it requires additional space and water. Therefore, It can be inferred that plants adequately utilized the nutrients available in recirculated fish culture water and well nourished.

Water quality data :

TAN concentration :

TAN concentrations of water in fish rearing tank and glass tank were measured on a weekly basis and the plot of observed values in aquaponics system and glass tank are shown in Fig. 4.

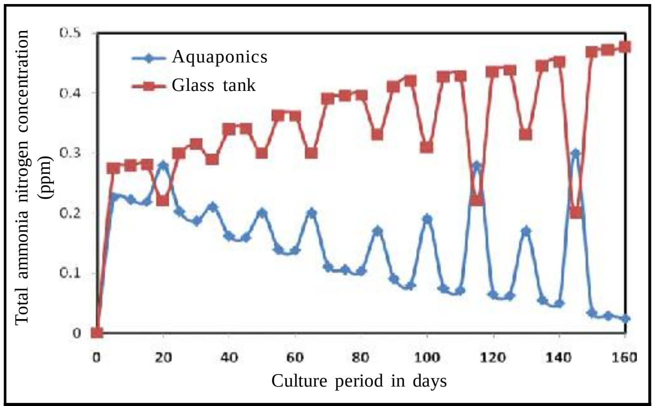

Fig. 4 : Comparison of TAN concentration (mg/l) of fish culture water in aquaponics system and glass tank

It can be seen from Fig. 4 that the TAN concentration fluctuated throughout the culture period and follows the same trend both in aquaponics and glass tank system, respectively. TAN concentration depends on many factors like amount of feed, individual weight of fish, number of fish and biofiltration efficiency. Thus, before the TAN concentration becomes lethal necessary water exchange was performed.

Nitrite-N Concentration (ppm) :

The nitrate concentration was observed and recoreded both in glass tank and aquaponics system as shown in Fig. 5.

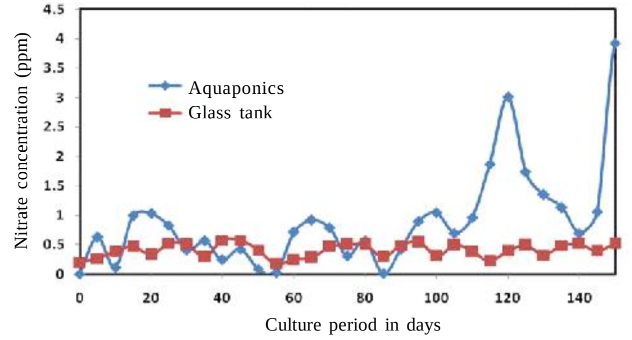

Fig. 5 : **Comparison of nitrate concentration (mg/l) of fish culture water in aquaponics system and glass tank**

It can be clearly observed from the Fig. 5 that nitrate concentration does not increase beyond 5 mg/l in case of glass tank culture. This happened due to a regular water exchange. However, the NO_3-N concentration was found to be drastically increased in case of aquaponics fish culture tank due to very limited time water exchange as shown in following Fig. 6. Though it does not go beyond the permissible limit of 90 mg/l and fish were found to be healthy in aquaponics fish rearing tank. Therefore, it can be inferred that NO_3-N concentration in GIFT tilapia culture is not very much sensitive upto the permissible limit which is very high compared to NO_2-N concentration.

Nitrate-N (NO_3-N) concentration :

NO_3-N concentration of water in rearing measured on a 05 day basis. The observed values of NO_3-N concentration in glass tank and aquaponics system fish culture tank are presented in Fig. 6.

The observed NO_3-N concentration of water from fish rearing tank is presented in Fig. 6. In the present study as water exchange was performed in glass tanks and aquaponics system whenever NO_3-N concentration reached its permissible limit; the NO_3-N concentration never exceeded the permissible limit of 90 mg/L. It can be seen from the fig. NO_3-N concentration never exceeded 5 mg/l which that it can be further seen from the above fig. that the NO_2-N did not reach the maximum permissible value. Therefore, it can be inferred that nitrite concentration was in control.

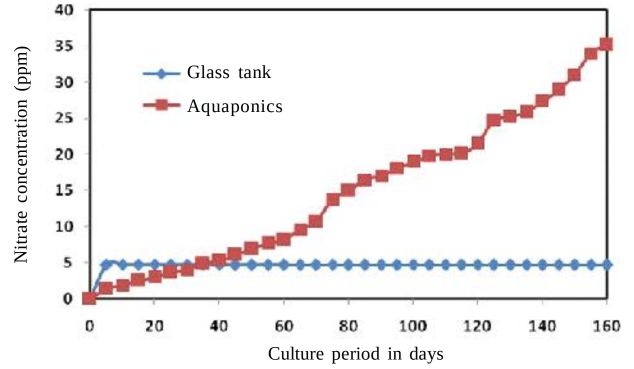

Fig. 6 : **Nitrate concentration (mg/l) of fish culture water in aquaponics system**

DO concentration :

The DO concentration in rearing tank was monitored regularly on a daily basis and a plot between observed and predicted values of DO with line plot is shown in Fig. 7.

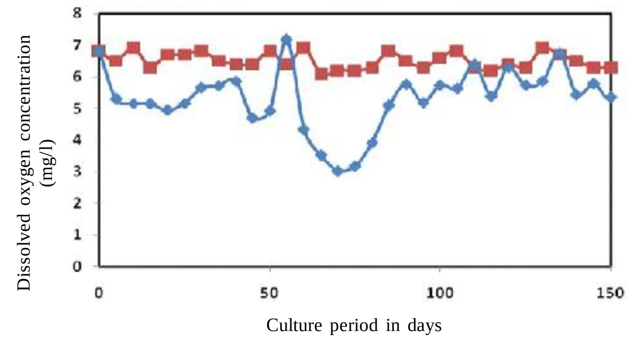

Fig. 7 : **Comparison of dissolved oxygen concentration (mg/ l) of fish culture water in aquaponics and glass tank system**

pH :

The pH is a measure of acid base status of the environment and serves as an indicator of productivity. The gills of fish are highly sensitive to acid and alkaline media water pH values ranging from 6.5 to 9.0 are reported to be most suitable for fish culture and those with more than 9.5 are unsuitable owing to the non-availability of carbonates. Meade (1989) recommended the pH range of 6.5 - 8.5 for good growth of fish whereas in the present study, the water pH was recorded within its ideal range (7-8.5) in glass tank and aquaponics culture system as shown in Fig. 8.

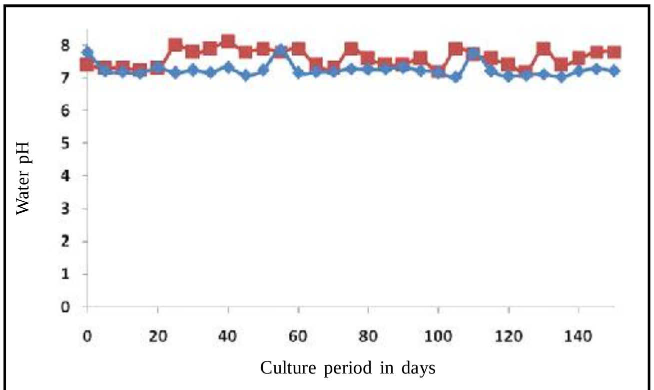

Fig. 8 : **Comparison of pH of fish culture water in aquaponics and glass tank system**

Total suspended solids :

Total suspended solids consist of planktons, uneaten food grains, suspended particles of clay etc. The suspended clay particles are the extremely undesirable (Boyd, 1982) and a serious concern in intensive farming system.

The total suspended solids were found to be more in aquaponics culture system compared to glass tank system. In the present study, the aquaponics system was kept in an open outdoor environment. Therefore, dust particles might have fallen in the water body and thus increasing the TSS concentration. The glass tank fish culture system was placed in an indoor environment (Fig. 9).

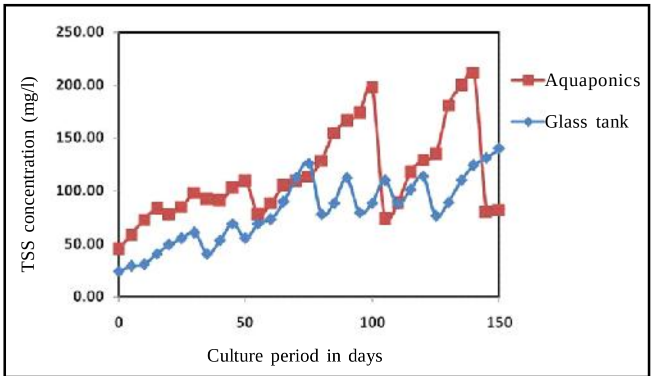

Fig. 9 : **Comparison of TSS of fish culture water in aquaponics and glass tank system**

Biofiltration efficiency :

The biofiltration efficiency was calculated by considering TAN concentration in water in aquaponics fish rearing tank and TAN concentration in water out form the plant culture tank. The average biofiltration efficiency of the developed system was found to be 23 per cent (Fig.10).

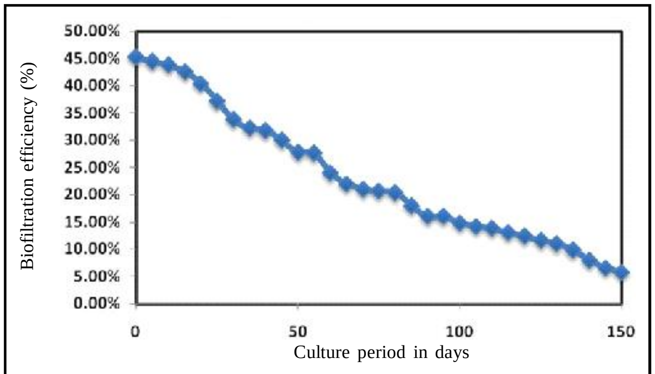

Fig. 10 : **Biofiltration efficiency in aquaponics system**

Conclusion :

The following conclusions are drawn from the study:

– The developed desktop based aquaponics system in the study is applicable to any fish species and leafy plant variety.

– Unlike in usual aquaculture system where daily partial exchange of water in fish culture tank is performed, the system is developed to overcome the difficulty of daily water exchange and thereby saving pumping and labour costs.

Future scope of the study :

– Nutrient supplements can be made for better growth of plants and fish.

– Amount of nitrogen available can be calculated by amount of protein present in the feed and hence, the plant growth can be predicted.

– Growing aquatic animals and greens can be commercialized all over the country.

– Hydraulic loading rate can be varied and optimum hydraulic loading rate can be fixed to get the maximum rate of increment in size of plant and fish species.

– The mathematical model can be developed with solid removal and nitrification units. The model can predict concentrations of total-ammonia nitrogen, nitrate-nitrogen, dissolved oxygen in the culture tank and biofiltration efficiency and suspended solids at the outlet of plant culture unit for any recirculating aquaponics system.

– In the present study it was assumed that water of the rearing tank is homogeneously mixed; it does not take into consideration the variation of concentrations of water quality parameters with depth. Further study may be carried out to characterize water quality parameters with depth and then model the concentrations of water quality parameters at finite element level.

– The influences of metal ions, which may be present in water, were not accounted for on the functioning of nitrifying biofilters. Therefore, sub-models may be coupled to take care of metal ions throughout the developed system.

The fishes and plants were assumed to be healthy and the present study does not take into count the diseases that may arise due to increase in temperature and continuous variation in pH. Sub-models may be coupled to take care of the disease aspect and thus, the reduction of growth of fish and plants.

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