Concept of indigenous recirculatory aquaculture system executed in West Bengal, India and other places

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In pursuit to modernise fish culture practices, instead of the conventional method of rearing fish in open earthen ponds in rural areas, novel recirculatory aquaculture systems (RAS) have been introduced in semi-urban areas in West Bengal and other parts of India. A feature of RAS 'clear water culture' is that materials normally considered essential in the pond environment such as plankton, fertile soil base, sunlight, fertilisers and nutrients, lime and common water treatments are not required.

Quite a few progressive fish farmers in India have adopted 'high profile' advanced-type, intensive and imported versions of RAS featuring huge plant, while other farmers adopted small and indigenous version of RAS, where the investment is comparatively low. This article upholds the design, principles, state-of-the-art and associated practical aspects of indigenous model, i.e., low-cost version of 'water-smart' RAS technology presently executed commercially by some RAS practitioners and experts in West Bengal and other places.

Basic features of recirculating aquaculture systems

Aquaculture technologies such as RAS, super-intensive raceways, aquaponics, and integrated multi-trophic aquaculture are likely to make a significant contribution to future global fish production and supply[1]. Countries such as Germany, Israel, Egypt, and others have adopted intensive aquaculture and one of the methods is to use fully closed water systems based on biofiltration units that can produce fish at over 100kg/cubic metre[2]. RAS are fully controlled systems and can limit water consumption, which is important in regions of water scarcity. With fresh water supplies increasingly under pressure in India, there is a growing requirement to produce higher volumes of fish from limited supplies[3]. Water leaving fish culture tanks from centrally positioned outlets is constantly filtered and cleaned for recycling back into the culture tanks for reuse. Treated water is saturated with dissolved oxygen to optimise fish growth; the concentration of carbon dioxide, ammonia (both its non-ionised and ionised forms), and nitrite are reduced to nil while that of nitrate remains within safe limits. High-valued edible indigenous freshwater fishes of West Bengal and tilapia are farmed; water quality in well run RAS tanks is of better quality when compared to earthen ponds.

Utility and merits of RAS

Since access to good quality water for aquaculture is becoming more limited, the adoption of high-tech fish farming systems becoming necessary to sustain fish productivity level[4]. Better food conversion ratios are achievable with RAS[5]. In circular tanks in RAS, fry-staged fish are stocked at a higher density in comparison to conventional and familiar earthen pond aquaculture systems. Problems such as slow growth, fish mortality and unhygienic bottom soil can be avoided in RAS.

According to progressive fish farmers in West Bengal, there are many issues impeding the development of both commercial and rural inland pond aquaculture. These include:

- Insufficient availability of quality water for fish culture in rural areas, and reduced pond water resources.

Indigenous RAS biofilter design.

Indigenous filter design.

- Deteriorating physico-chemical parameters of pond water and soil.
- Water discharged from ponds being mixed with natural open freshwater resources, which may be redrawn for supply.
- Shortages of suitable land and the cost of new pond excavation for fish culture, which often have low water retention capacity.
- The cost of periodically drain ponds to remove silt/ sediment deposits from farming operations.
- The high cost of repairs to dyke of earthen ponds, particularly in new ponds which may need repair every year.
- Escape (loss) of crop during heavy rain and flood events.
- Harvest size is falling despite stocking levels remaining the same.
- The cost of labour to seine and maintain the pond.
- The spread of pathogenic microorganisms.

Issues such as these are helping to make RAS a viable alternative, as it can overcome or avoid such impediments. More fish can be produced in less space, without fear of poaching. Normally in RAS, 1kg of fish can be produced from every 16-25 litres of water, which is much more efficient compared to the water required for an equivalent yield in a pond. Mortalities are generally lower, and less labour is required - only one or two employees to monitor an entire RAS system and check the water quality parameters. Market-sized fishes can be easily harvested at the proper time, quantity and even size, creating produce that is more acceptable to consumers as being antibiotic- and chemical-free. According to officers at the Indoor Fish Farming Project under BCSIR, Dhaka: From every 1,000 litres of water, 100 kg of fish may be produced from a typical RAS compared to 10 kg of fish from an earthen pond, or 20 kg in ponds when paddle-wheel aerators used.

Mechanical and biological filtration systems

Mechanical filtration

In RAS, used water is purified by a combination of mechanical and biological filter systems. The former removes suspended solid waste originating from uneaten fish feed, fish faeces and bacterial biofilms from continuously flowing used water. Firstly, water passes from the fish rearing tanks and enters into a drum filter, where water passes through a filter microscreen of 40-100 micron mesh size. Rotation of the drum causes solid wastes to be trapped on a filter screen, which are retained within, rejected and lifted to a backwash area which accumulates filtered particles into a sludge tray for disposal. Clear water, devoid of organic particles, ejects out of the filter screen.

Biological filtration

Primarily treated water passes into a biofilter or biological purification system; aiming to eliminate and convert toxic ammonia nitrogen and dissolved nitrates in an aerobic environment. This is effected by a community of beneficial nitrifying bacteria. Application of beneficial microorganisms to degrade waste materials of fish rearing tanks into less toxic forms is bioremediation; it can lead to a good harvest by increasing survival and growth rate of desired culture species[6]. Nitrifying bacteria grow on the surface of beads that provide a large substrate for formation of biofilms, while allowing water flow through the media bed. A moving bed filter (MBF) consists of a rectangular tank with an aeration device, filled with filter beads that are light in weight and have a high surface area. Hundreds of closely-packed plastic media, also termed moving bed biofilm reactor media, move around in the water due to air currents created by a pump inside the MBF tank. Microscopic organic material from used water is removed. Water flowing out of the biofilter is treated with antimicrobial UV-C light (having short wavelength 200-280 nm), to reduces potential pathogen load before water is recirculated back into the culture tanks[7].

Bacteriological nitrification, a practical method of removal of ammonia from closed aquaculture systems, is also commonly achieved by setting up sand and gravel biofilters, through which water circulates. Biofilters are readily designed and constructed in modular form, making them useful for water quality management in aquaculture[8].

Simple design of RAS

Structure of filter system

High-tech RAS involve high capital outlay and running cost. To reduce expenses and maintain production, simplified RAS have been designed for small-scale fish farmers, which require only small investment, using drum filters constructed from blue plastic water barrels (220-300 litre capacity) (courtesy: Sri Rajkumar Jha, Radio Madhubani, Mithila, Bihar). In each 10,000-litre fish rearing tank, 500 seed are stocked. Used water enters the first drum filter from below. After moving in a circular motion, water passes upwards through a sponge-type filter or fine-meshed net and thereafter via thick bed of gravel (separate beds of small- and large-sized gravel). As water moves into a second drum filter from above, it passes down through three layers; the first and third comprise thick beds of gravel and the middle layer is a bed of sand of equal thickness. The gravel reduces turbidity by trapping and removing particulate matter from suspension[9]. Purification of water occurs in outer few centimetres of the sand layer. Undesirable bacteria and other microorganisms are captured by the sand grains as water passes through the layer.

As water leaves the second drum filter it is treated with UV light before entering a third drum filter consisting of biomedia, i.e., small pieces of plastic that provide a large surface area to facilitate attachment and growth of nitrifying bacteria. Materials used to wash kitchen utensils (some utensil scrubbers, Scotch Brite), micro-sponge (sponge filter), bio-balls, pumice stone (*jhama pathar* in Bengali) and even-sized stones may be used while preparing the biofilter tank. Oxygen levels are maintained in this filter via an air blower/aerator. After passing through the biofiltration drum, water is returned to the fish culture tanks. In indigenous design, plastic black-coloured K-1 media in moving bed filters are used as media to grow nitrifying bacterial colonies; K-5, K-6 media and black bioballs also used in RAS biofilter tanks.

Sri Samar Mondal's RAS

Wise RAS practitioner and expert Sri Samar Mondal at Patikabari Village, Murshidabad District, West Bengal, has constructed an indigenous rotary automatic mechanical drum filter (RDF) using a plastic drum, shaft, iron frame and other accessories and installed it inside a rectangular cement cistern. Water is lifted into the RDF from fish culture tanks via a pipeline and motor. Screen printing mesh cloth (micron net) is used to construct the RDF to filter out uneaten feed particles and faeces. Wastewater is drained via a pipeline outside the RDF container. Filtered water is stored inside a cement cistern beneath the RDF and passed into sedimentation tank, and thereafter into a rectangular cement tank (first biofilter) consisting of moving and self-cleaning plastic media, ie. a moving bed filter. Sri S. Mondal uses small, home-cut pieces of corrugated black flexible pipe as media. K-1 media packed quite densely moves freely in the biofilter tank. The constant chaotic movement of air from the pump causes media to self-clean. In Sri S. Mondal's set-up, treated water from the first biofilter tank enters the second, which is occupied by a thick bed of activated charcoal and gravel placed within the water column. Fine impurities in the water, not screened by the RDF, are separated here.

Next, water is passed into a UV filter tank, where it is treated before being returned to fish tanks of around 1 metre depth. Initially the water level is maintained at 45-60 cm but is increased with advancement in fish growth. According to him, for each of 1,000 litre RAS fish tank, and indigenous biofilter of 300 litre capacity must be set up consisting of 150 litres each of water and biomedia. To enhance populations of nitrifying bacteria and to eliminate ammonia and nitrate, the product 'Bacteria-Push Microlife-S2' (liquid bacterial suspension) may be applied in the moving bed filter, seeding the bed. Bacteria become active within 3-8 hours and begin functioning. In this RAS, the air blower produces 21,000 litres of air every hour to maintain oxygen levels in the fish culture and moving bed filter tanks.

According to Sri S. Mondal, a RAS of 5,000 litre capacity will cost approximately Rs 55,000/-, with expenditure break-up as follows: Rs 30,000/- for single cement tank construction; Rs 10,000/- for RDF (self-made); Rs 5,000/- for biofilter; Rs 4,000-5,000/- for good quality air pumps suitable to treat 5,000 litres of water; Rs 2,000/- for UV light and Rs 3,000/- for a quality water pump. From the culture tanks, water first passes into the RDF; clear water thereafter successively passes through the moving bed filter tank (cement construction with air pump), normal bed biofilter tank (with small rocks and charcoal), UV tank (18 w UV light), before treated water recirculates back to the fish rearing tanks. Two biofilter tanks and the UV tank are made of cement, rectangular and almost equal in size. He has two cement fish tanks, each 2.44 m in diameter, height 1.2 m (water column: 1.05 m) and approximately 6,000 litres in capacity, where 3,000 advanced *H. fossilis* fry (7.6-8.9 cm) are stocked in every 3, 000 litres of water.

Second author's RAS filter design

According to second author, construction cost of an indigenous small backyard RAS costs around Rs 300,000-400,000/-. Two RAS tanks of 10,000 litre capacity each for *H. fossilis* culture, with 3,000 fish in each tank, are maintained with greenhouse netting as an overhead shade. Fish attain 8.9-11.4 cm in length 35 days after stocking and are sold within the next two to three months. Three diffuser-type aerators are used in each tank.

In another small-scale RAS set up, two circular brick-walled fish tanks 1.50-1.75 m in diameter (water level: 1.0-1.2 m) are constructed for rearing *O. pabda* and *M. vittatus*. Mild water flow is created in tanks with the force of water inlets positioned above the rim of tanks. Three blue plastic barrel-based drum filters are employed, including a biofilter. Used water from fish tanks is first lifted and filtered through stainless steel wire nets from above before entering the first filter tank. Here, water is sieved using two kinds (double filter) of high-quality sponge filter and plastic chubri (round rim flexible plastic baskets used in the kitchen). In the second filter, the bioflter tank, many plastic bioballs placed in the water and an activated carbon system set up with intensive oxygenation. Treated water finally enters the third filter tank, consisting many home-made K-1 media in a submerged and continuously moving state due to the action of bubbles. Treated water is finally lifted back to the fish culture tanks using a 0.5 HP motor. A home-made iron filter constructed in this RAS complex comprises gravel and sand beds, which are essential if ground water is used. Rainwater harvested from the roof top is used in fish tanks and recirculated. After three years of thorough experimentation, the second author became a pioneer in introduction of indigenous RAS technology in West Bengal in 2016.

Two RAS fish tanks under shade.

Water inlet generating circular flow in RAS cement fish tank.

Mystus vittatus

RAS set-up of Janab Malekh Sekh

Progressive fish farmer Janab Malekh Sekh at Gadisahebnagar Village, PS Sagardighi, Murshidabad District, has set up 5,000-10,000 litre concrete RAS fish tanks on a home terrace for *O. niloticus*, *O. pabda* and *M. cavasius*. He has found FCR to be in the range 1.5-2.0 and 0.7-1.0 (beneficial) in pond conditions and RAS tanks respectively. In a RAS tank of 3.65 m x 3.95 m (45-60 cm water depth) with oxygenation system, Janab Sekh stocked 10,000 advanced *C. batrachus* fry and will harvest 1,000 kg of fish after four months. Fishes grow from 5 g at stocking to 20 g in three weeks. He has constructed an indigenous water filter system that removes ammonia (Courtesy: Biofloc fish farming murshidabad com).

RAS at ICAR-CMFRI, Visakhapatnam

It is possible to reduce the initial investment in RAS if a rapid sand filter (RSF) of indigneous design is used as an alternative to expensive RDF in advanced-type RAS. 350kg of white sand with a 2 mm particle size is kept in each of two RSFs. In an indigenous biofilter model of 2,000 litre capacity and cement structure, dead oyster shells or those of freshwater mussels and bioballs (4,000 pieces) are used, providing substratum for growth of nitrifying bacteria biofilms. Oyster shells with sufficient surface area used for attachment of nitrifying bacteria and maximising contact with passing water for ammonia removal. The cost is around Rs 130,000/- and Rs 20,000/- to set up two RSF units and one biofilter tank respectively, with a total establishment cost of around Rs 1,403,000/-[10]. Water requirements are reduced, since recirculation aquaculture systems can be adopted in salinity varying from 0-30 ppt[11].

Indigenous RAS in Bangladesh

RAS systems are also in use in Bangladesh; some examples include:

- At Hobigonj Town in Sylhet District, Sri Uttam Bhai is running RAS in six fish tanks, each of 1,000 litre capacity with 2,000 *H. fossilis* fry stocked in each. Fish attain 15-20 individuals/kg (50-66 g) in four to five months and are harvested and sold in the market (Courtesy: Agro fish farming channel 'fishmarketbd', Bangladesh).

- A home-based RAS has been set up at Dighirchala Village in Gazipur District for farming *H. fossilis* where approximately 8,000 fish are reared in three well-oxygenated rectangular tanks of 800 litre capacity each.

- In Shimultoli Village in Gazipur District, RAS-based rectangular cement tanks for *H. fossilis* have been established with 5,000 fish stocked in each tank.

- At Manikganj, *H. fossilis* is reared in four circular RAS tanks (12,000 fish stocked in each 8,000 tank) with plastic barrel-based biofilter tanks positioned on the boundary wall of cement tanks (Courtesy: 'bd ras' fish farming video).

- At Gachirhata Village in Kishoreganj District, a RAS project has been established with four circular concrete tanks for *O. niloticus*. In some RAS, in addition to other filter elements, used water is treated in tanks containing masses of naturally-grown *Eichhornia crassipes* and *Ipomoea aquatica*, which help in ammonia removal.

- At Mauna town in Gazipur District, a cement tank (4.58 x 6.10) m^2 in area (1.5 m high) is functioning as RAS, where 11,000 *H. fossilis* are propagated.

Mystus cavasius.

Anabas testudineus.

Additional information on RAS

According to Sri Pawan Phogat at Wazirpur Village near Dehri in Bihar, the construction cost of a 10,000 litre tank (4 m diameter, 1.22 m deep) made of square iron mesh support frame and tarpaulin (650-700 GSM) is around Rs 18,000/-, including tarpaulin, air stone and other aeration devices. Circular fish tanks made of zinc-aluminium alloy sheets are used in intensive RAS. Due to their dual respiration habit, *H. fossilis* is ideally suited for RAS and will survive an electricity (aeration) failure. Air-breathing catfishes *Clarius batrachus* and *H. fossilis* grow faster than *O. pabda* and *M. cavasius*. Nutritionally balanced pellet-type floating supplementary feed (Rs 45-75/-/kg) is fed to growing fishes daily. Excess feeding and sinking-type pelleted feed should be avoided as it will hamper water recirculation and working of RAS. Fish tanks are saturated with dissolved oxygen (8-11ppm), and a proper dosage of feed maintained. Stable bioavailable vitamin C is sometimes added to feed before use; growth promoters, chemicals, and medicines (antibiotics) completely avoided.

Oxygen generators and air blower are important components in indigenous RAS models; dissolved oxygen content must be maintained throughout the whole system. An oxygen supply outage of more than four hours in the biofilter tank may kill nitrifying bacteria colonies formed over a moving bed filter. A constant and sufficient oxygen supply is required for proper functioning of nitrifying bacteria. Two to three bubble diffuser-type aerators are used in each fish tank (more in tanks containing larger fishes); adequate dissolved oxygen levels and correct pH encourages fast growth of fishes.

Under the initiative and advice of second author, four RAS tanks, each of 13,000 litre capacity and 2.14 m in height are under reconstruction in North 24 Parganas, West Bengal with provision of a K-1 media filter and mechanical filter. Another project has started at Ranaghat, District, Nadia, with four cement tanks of 10,000 litre capacity each. Concrete circular breeding pools (components of Chinese hatchery design used in induced breeding and spawn production of major carps), smaller in size, may function as RAS fish tanks but contact of water with cement layer on its inner walls and inherent chemical reactions must be prevented. RAS expert Sri Viswanadha Raju Bh. R. in Hyderabad, Telangana State constructed cement RAS tanks with a coat of epoxy paint.

Circular RAS fish tanks are most convenient as suspended solids move out rapidly via the central drain with a pipe diameter of around 10 cm. In RAS tanks made of cement exclusively, alkalinity increases, and water pH can become uncontrollable, although cement tanks have more longevity than tarpaulin tanks. The diameter of the former should be about 4.5 m with a slope of around 15 cm towards the centre and a wall thickness 15-25 cm.

End note

Besides commercially-important major carps, there are high-value freshwater (warm water) fishes in West Bengal such as *H. fossilis*, *C. batrachus*, *Puntius sarana*, *Labeo gonius*, *A. testudineus*, *M. vittatus*, *M. cavasius*, *O. pabda*, *O. niloticus* that are cultivable in confined systems under control. Diversification of freshwater fish culture in West Bengal and other places can be achieved by incorporating these species, which are mostly small and indigenous; are nutritious, and have higher commercial value and market price in comparison to major carps. Their propagation from fry/advanced fry up to marketable size is advantageous in RAS when compared to earthen pond conditions.

It is necessary to convert 10-15% of aquafarms in India to intensive aquaculture systems such as raceway culture, running water culture, and recirculatory aquaculture which, are feed-based systems (Courtesy: ICAR-CIFA Vision 2050). The average freshwater fish farmer in India are able to produce 2,000-3,000kg/ha/year while progressive farmers may achieve 8,000-10,000kg/ha/year. Contrary to this,

Ompak pabda.

RAS may be able to produce up to 60,000kg fish/year. It is expected that RAS will gain an increasingly strong foothold in Indian aquaculture production soon[12]. In the near future, both imported and indigenous versions of RAS will be promoted widely; more fish farmers in different parts of India are expected to adopt this modern technology.

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