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Recirculating Aquaculture Systems in China-Current Application and Prospects

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For the past 20 years, aquaculture has seen a worldwide expansion and is the fastest growing food-producing sector in the world, with an average annual growth rate of 6-8%. World aquaculture has grown tremendously during the last sixty years from a production of less than a million tonne in the early 1950s to 90.43 million tonnes by 2012. Of this production, 66.63 million tonnes, or 73.68%, was fish. Aquaculture is now fully comparable to marine capture fisheries when measured by volume of output on global scale. The contribution from aquaculture to the world total fish production of capture and aquaculture in 2012 reached 42.2%, up from 25.7% in 2000.

China is one of the most important contributors to world aquaculture production. Since 1993, aquaculture has accounted for more than half of the country's aquatic production, making China the largest producer of aquatic products in the world. In 2012, the farming fish production in China was 41.11 million tons, which occupied 61.7% of the world total aquaculture production. Being a developing country, the economical expansion of industrialization in China had made great impact on the traditional fish farming industry. Therefore, aquaculture is expanding into new directions, healthy and sustainability, calling for developing high-efficient ecological aquaculture.

The Status of Intensification Aquaculture in China

Over the past 30 years, the Chinese aquaculture has gradually established the intensive breeding technological system and obtained the quite successful experience. Up till now, there are about 3 million square meters total area of industrial aquaculture in China, including three kinds of main models of flow-through system, semi-closed recirculating system and recirculating aquaculture system (RAS). Among that, the flow-through system was the major area, followed by the semi-closed recirculating system and RAS, accounting for 85~90%, ~10% and < 5.0% of the total amount industrial aquaculture area, respectively. Indeed, most of the RAS areas were used for marine fish aquaculture and the RAS area is nearly 1 200 000 m^2.

The Development Course of RAS in China

The development of marine recirculating aquaculture industry has experienced nearly 30 years, and can be divided into 4 stages:

Pioneer stage (1980s): Marine RAS begun in the 1980s in China; in the meantime, 9 RASs were first introduced from Denmark for culturing eel fish. Because of the high investment and running enery cost, the above facilities were soon fell into disuse. After that, with the support of national science projects, some RAS facilities and equipment have been researched and developed, such as microfiltration machine, foam fraction and ozone generator independently, and these technologies were proved to be suitable for China's national social and economic conditions.

Exploratory stage (1999~2006): With the increasing investment of scientific research, enterprises in China pay great attention to scientific research to improve academic level. Based on this, the culture and water treatment process were initially established, and some enterprises began to carry out this aquaculture model. This work marks that the RAS with independent intellectual property rights achieved from the experimental stage gradually turns to industrialization, large-scale popularization and application.

Integrative stage (2007~2011): China has made considerable progress in research and application of marine industrial aquaculture, and established the suitable development mode of China's RAS. During this period, many species, such as grouper, half-smooth tongue sole, fugu, abalone, and sea cucumber were firstly cultured in RAS. Turbot, Atlantic salmon, grouper and scallop were also bred in RAS successfully. The successful application of RAS has improved the efficiency of the aquaculture, protected the ecological environment, and promoted the development of marine economy.

Rapid growth stage (2012): Since 2012, the aquatic enterprises are paying more attention to RAS for its high efficiency and low-cost superiority on natural resource（including land and water resource. Meanwhile, Chinese government is also supporting the application of RAS, as one incentive policy for aquaculture sustainable development. We can optimistically forecast that all-season aquaculture product can be widely realized in the next 5 years in RAS, and the breeding standard of some typical species can also be established.

The Main Problems of RAS in China

The basic technology RAS has developed rapidly in recent years, yet, there are many technical innovations needed to enable the systems performing well for a broader range of aquatic species and culture conditions.

Late beginning, small scale

Since large-scale application of the RAS began in 2006, many companies are still at the stage of adaptation of this technique. On the other hand, China's aquaculture enterprises are mainly small and medium-sized, thus the RAS application has obvious features of large quantity and small scale..

Lag in technology, waste resources

Owing to the imperfect system and lack of professional technicians, the breeding efficiency for RAS technology is far from standard, causing the waste of resources.

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High running cost

The cost of domestic RAS is generally high. An investigation showed that diesel, electricity and coral account for 0.2%, 16.51% and 10.52% of total cost in turbot farm respectively, while average energy cost in turbot in Europe the is less than 11% (mainly electricity). The low efficiency of energy utilization limits the profits of enterprise to a large extent.

Poor practicability and reliability of equipment

Due to the pursuit of low input, the practicability and reliability of equipment is poor. Certainly, lack of professional technicians is also the main cause of the dysfunctional system.

Low intelligent and automatic level

At present, most of the RAS are simple, with the characters of low cost, simple management and well applicability. But these culturing systems are still with hand feeding, simple water treatment equipment and more space utilization, in addition， the water treatment units did not achieve real-time monitoring. In a word, the intelligent and automatic level is still low.

Serious pollution

China is confronting with great pressures and challenge with the environmental pollution. Since the development of urbanization and industrialization, coastal water quality was getting worse, which could not be used for RAS directly. In addition, decreased groundwater resources and reduced water quality also have a negative impact on the development of the RAS.

Some Typical RASs of Marine Aquaculture

The RAS enterprises were throughout China's coastal areas (Figure 1), and the main farmed species are flatfish, salmonids, groupers, fugu, shellfish and shrimps.

Typical RAS for Turbot

Turbot is one of aquaculture species for industrialized farming in the northern coastal areas of China with great superiority for high stocking density. The RAS for turbot is the basic type, consisting of greenhouse, pond, foam fraction, biofilter, filtration, sterilization and monitoring system (Figures 2 and 3). Generally, the stocking density of turbot could reach about 60 kg/m^3.

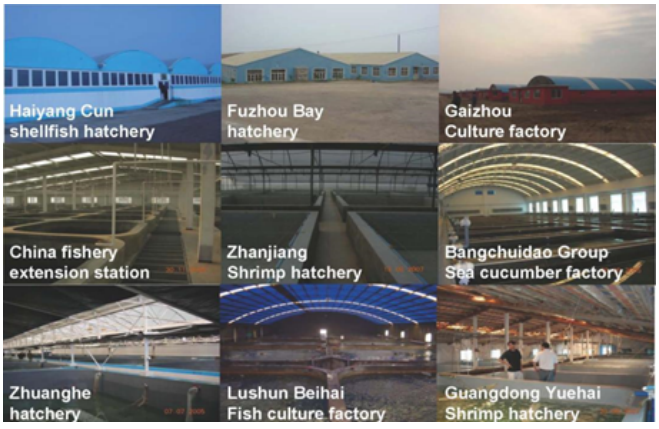

Figure 1: Some RAS enterprises of marine aquaculture in China.

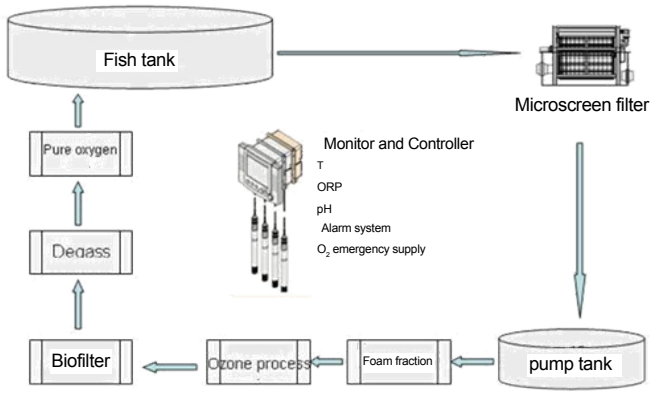

Figure 2: The frame of RAS for turbot.

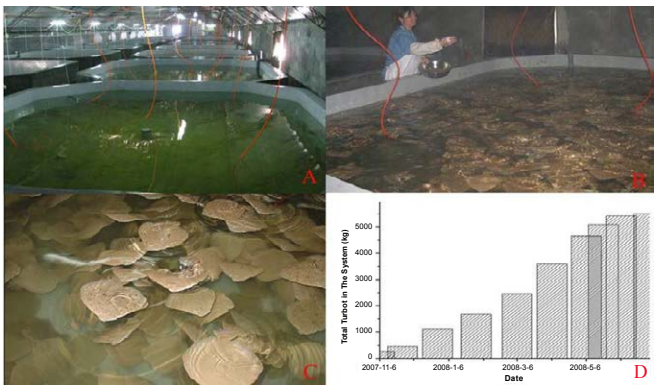

Figure 3: RAS for turbot. A: green house; B and C: the turbot; D: turbot capacity in RAS.

Typical RAS for Atlantic Salmon

Atlantic salmon was first introduced to China for RAS culture in 2010. Until now, 78 RASs are running, with the scale of 100000 m^2 and 36800 m^3 water spaces totally. This farm could produce 1000 tons of salmon every year, and is the largest RAS base of Atlantic salmon in the world. All the systems are designed and built independently, with high degree of automation and well stability. In addition, the technology of automatic feeding and internet of things were also successfully introduced, to some extent, this system representes the top level of land based marine aquaculture in China. Generally, the stocking density of Atlantic salmon could reach about 45 kg/m^3 (Figures 4 and 5).

Technical Analyses of Chinese RAS

Nowadays all units of RAS can be produced domestically. There are more than 50 RAS manufacturing enterprises in China and all the key units of RAS can be batch produced. Some devices with independent intelligent property right are also developed, such as fish counter, automatic feeder and flesh color evaluation software. The performance of some home-made units are quite close to import commodities and with much lower price. Recently, RAS is becoming more and more automatic, and seacage aquaculture has a potential starting to move to land-based RAS for the demand of environmental policy and food safety. Overall, there are still gaps between Chinese RAS and international standard, including engineering design, production

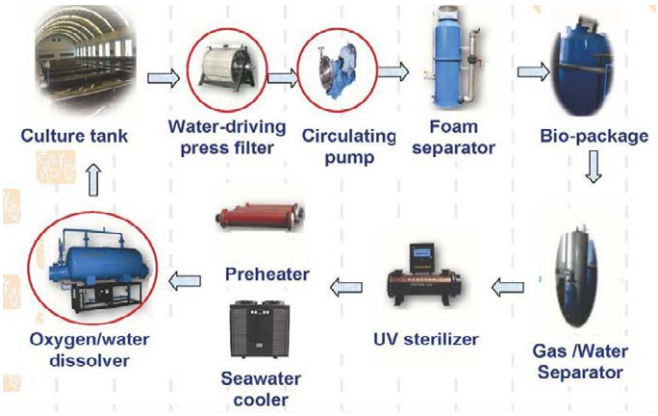

Figure 4: The frame of RAS for turbot.

Figure 5: RAS for turbot. A: The RAS aquaculture workshop of salmon; B: Inside of the workshop; C: Automatic feeding equipment; D: Internet of things system.

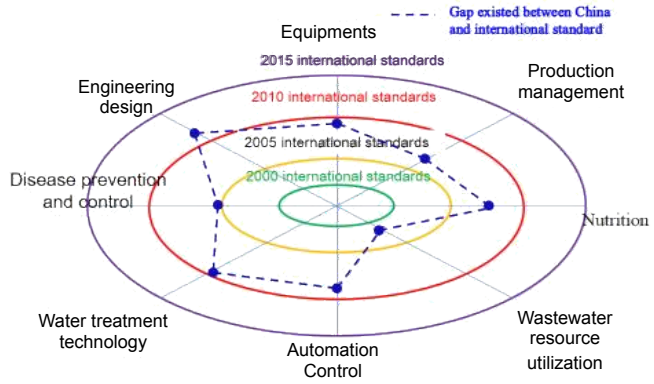

Figure 6: Gaps between Chinese RAS and international standard.

management, automaticity and the wastewater treatment technology (Figure 6).

Outlook

Overall, the prospect of Chinese RAS is hopeful for the next 10 years. It can be predicted that reliable RAS units can be produced by Chinese enterprise before long, and partly meet the international standard. The national manufacture technical standards for RAS will be established, and RAS will be used for hatchery in production. The area of RAS will probably exceed 5 000 000 m^2. RAS application will be more reliable, profitable, and meet the demand of aquatic enterprise.