New mode of Shrimp breeding by novel Nano-bubbles water treatment technology

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1. Industry background

In the past, shrimp remained as a luxury commodity because of its high popularity and cost. It was hence considered as a type of favorite food for the high society people. In recent decades, due to the high protein contents in shrimps, and the grown market demands for shrimps, the shrimp breeding attracts a huge international market. Generally, shrimp aquaculture plays an important role in the fisheries sector globally. The rapid development of the shrimp farming industry throughout the world was largely due to the following reasons: the successful breeding and propagation technique of tiger shrimp, Penaeus monodon, first achieved in 1968 *(Liao et al., 1969)*, followed by a large number of commercial hatcheries set up to supply high quantities of shrimp seed to the industry.

Moreover, there has been a rapid expansion in the culture of shrimps over the last 20 years in southern and eastern Asia, Latin America and other tropical regions. In south-east Asia, the production of cultured crustaceans increased by over 500% between 1984 and 1995. By 1998, the total shrimp aquaculture production in this region was 580 000 tonnes, i.e. slightly more than the quantity of shrimps caught in the wild. The value of shrimp exports not discriminating between cultured and wild-caught shrimps. From the south-east Asian countries was approximately US $4 billion the same year. There is no doubt that the marine shrimp culture is a very important economic factor for many of these countries.

The countries dominating the production of cultured marine shrimp in south-east Asia are Thailand, Indonesia, Vietnam, Philippines and Malaysia. The most important markets for south-east Asian farmed shrimps are Japan, the United States and Europe. Smaller volumes are exported to other Asian countries, e.g. South Korea, Malaysia, Taiwan, China and Singapore, and some is consumed within the producing countries. Part of the trade is not official, indicates that France is the largest importer of Malaysia Penaeus monodon. The species dominating the marine shrimp culture in south-east Asia are penaeid shrimp, especially Penaeus monodon, commonly known as the black tiger shrimp, or the giant tiger shrimp.

The management systems used in marine shrimp farming can be separated generally into three types: extensive, semi-intensive and intensive. The extensive farming system has low shrimp densities in the ponds; usually juveniles from wild populations brought into the ponds with the inlet water. In the extensive method, either no chemicals are used at all, or fertilizers are added to promote the growth of algae as a natural food. Semi-intensive farms have medium-sized ponds and stocking densities, the juveniles are either from the wild or from hatcheries, and natural food is used and/or artificial feed is added. Intensive farms are typically small and have high densities of hatchery produced juveniles. The production relies on heavy feeding and aeration. Primarily intensive farms, but also semi-intensive farms use a wide array of chemicals and biological products to enhance the production.

2. **Problems encountering in shrimp farming**

In the shadow of the value of the shrimp farming sector, much attention has been paid to several negative environmental and socio-economic impacts of the industry. The main concerns have been the destruction of mangroves and other wetlands for the construction of shrimp farms, salinization of the soil, biological pollution of native shrimp stocks, depletion of wild fish populations through large inputs of fish meal and fish oil in commercial shrimp feed, eutrophication; and the dispersion of chemicals in the environment.

Shrimp farming in Malaysia in particular, has been expanded rapidly following huge demand in the international market. This fast development is however accompanied by lack of adequate planning and regulation at the national policy level. This unplanned and haphazard shrimp farming is gathering considerable debate due to its negative environmental and socio-economic consequences.

Farm-raised production of shrimp has been, however, sharply dropping in Malaysia over the past few years, mainly due to serious viral disease problems. Since 1992, White Spot Syndrome Virus (WSSV) has caused high mortalities and serious damage to the shrimp culture industry of China and other Asian countries. It also occurred in cultured shrimp in the southern US, resulting in mass mortality in 1995 *(Wang et al., 1998)*. In addition, Lightner (1995) reported that Taura Syndrome Virus (TSV) devastated Western Hemisphere shrimp farms, producing economic losses in excess of US$1 billion. TSV has also already invaded the Eastern Hemisphere *(Tu et al., 1999*). Exports of block frozen black tiger shrimp (P. monodon) had been rejected from Malaysia due to the presence of *V. parahaemolyticus* by some

EU countries, especially France *(Mohammad, Hashim, Gunasalam, & Radu, 2005)*.

Since 1980s, researches have been done on the different types of viruses which affect the shrimp; reports of new viruses have increased in parallel with the rapid development of shrimp farming globally and, to date; more than 20 viruses have been reported in shrimp as shown in the Table below.

Genome	*Virus family*[a]	*Acronym*	*Virus name*	*Host*	*Genomic data*
ssRNA	*Dicistroviridae*	TSV	Taura syndrome virus	*P. vannamei*	Complete
	Roniviridae	YHV	Yellow head virus	*P. monodon*	Complete
		GAV	Gill-associated virus		Complete
	Bunyaviridae	MoV	Mourilyan virus	*P. monodon*	Partial
				P. japonicus	
	Totiviridae	IMNV	Infectious myonecrosis virus	*P. vannamei*	Complete
	Rhabdoviridae	RPS		*P. stylirostris*	n.d.
				P. vannamei	
	Togaviridae	LOVV	Lymphoid organ vacuolisation virus	*P. vannamei*	n.d.
	Nodaviridae	MrNV/XSV	Macrobrachium rosenbergii nodavirus/extra small virus	*M. rosenbergii*	Complete
		LSNV		*P. monodon*	n.d.
dsRNA	*Birnaviridae*	IPN-like virus	Infectious pancreatic necrosis-like virus	*P. japonicus*	n.d.
	Reoviridae	Reo-Pj		*P. japonicus*	n.d.
		Reo-Pm		*P. monodon*	n.d.
		Reo-Pv		P. vannamei	n.d.
		PBRV		*Palaemon* sp.	n.d.
ssDNA	*Parvoviridae*	IHHNV	Infectious hemocytic and hematopoietic virus	*P. stylirostris*	Complete
		HPV	Hepatopancreatic parvovirus	*P. semisulcatus*	Complete
		HPV-like		*P. merguiensis*	n.d.
				M. rosenbergii	n.d.
					n.d.
		SMV		*P. monodon*	n.d.
		LPV		*P. monodon*	n.d.
				F. merguiensis	n.d.
				P. esculentus	n.d.
dsDNA	*Iridoviridae*			*Protrachypene precipua*	n.d.
	Nonoccluded bacilliform virus	BMNV or (PjNOB)	Baculoviral midgut gland necrosis virus	*P. japonicus*	Partial
		PHRV			n.d.
		CcBV		*Crangon crangon*	n.d.
	Baculoviridae	PvNPV or (BP-type)	Single-nucleocapsid polyedrosis virus	*P. duorarum*	n.d.
		PmNPV or (MBV-type)	Single-nucleocapsid polyedrosis virus	*P. vannamei*	Partial
		MbNPV	Single-nucleocapsid polyedrosis virus	*P. monodon*	Partial
				Metapenaeus bennettae	n.d.
	Nimaviridae	WSSV	White spot syndrome virus	Penaeids and numerous other crustaceans	Complete

[a]Only TSV, GAV, YHV, IHHNV, and WSSV have been formally classified to date.

Some of these issues, including the virus issues, have given the shrimp farming industry a negative image in countries that import shrimps, and among environmentalists within the producing countries. There is an increasing interest in an environmentally friendly shrimp culture within the shrimp farming industry, and efforts to reach a sustainable production are being made.

A survey of the biggest shrimp farm in Kuala Selonger, Malaysia was performed recently. This shrimp farm covers an area of around 400 ha. , separated into more than 200 shrimp ponds. Based on the survey, around more than 90% of the total shrimp breeding ponds are currently not functioning, with these ponds only exposed for insolation, further for disinfection. The following photos taken from the shrimp farm show the sundried ponds' status.


Shrimp farming ponds in Kuala Selonger, Malaysia; 2016.01.10

According to our survey, shrimp farming in the Malaysia is dominated by intensive and semi-intensive systems. The most recent figures show that semi-intensive systems are becoming more frequent while the proportion of intensively managed farms is decreasing, possibly as a response to the disease and water quality problems often associated with a farm's level of intensity. In intensively managed shrimp ponds, there is a high risk of disease outbreaks caused by virus, bacteria, fungi and other pathogens. Intensively/semi-intensively farmed shrimp ponds are often abandoned after 2~10 years due to environmental and disease problems caused by the accumulation of nutrients, declined access to clean water, etc. or simply because of lowered yields or profits *(Flaherty and Karnjanakesorn, 1995; Barraclough and Finger-Stich, 1996; Dierberg and Kiat- tisimkul, 1996; Sansanayuth et al., 1996.)*.

However, in general, these conventional measures cannot help to reach a sustainable production and development for the shrimp farming industry in Malaysia. Because, to some extent, these issues didn't find the key solutions, especially from the waterbody where the shrimps are living.

3. Technical solutions

In an effort to mitigate crop losses of shrimps from those disease problems, some approaches have been developed, such as selective breeding of specific pathogen-free (SPF) and specific pathogen-resistant (SPR) shrimp, and then culturing these virus-free shrimp seed in a biosecure system *(Lotz, 1997)*. Using probiotic in shrimp aquaculture to improve the growth performance *(Liu et al., 2009)*, immunity, and disease resistance is also well studied *(Chiu* *et al., 2007; Tseng et al., 2009)* and has been applied in the aquaculture farming system.

The most common products used in pond aquaculture are fertilizers and liming material. Disinfectants, antibiotics, algaecides, herbicides, and probiotics are also used to improve the production. Concern is being expressed regarding the potential impact of aquaculture chemicals on the aquatic environment, adjacent terrestrial ecosystems and human health. There is a lack of information about the quantities of chemicals used in shrimp farming in the different south-east Asian countries. The absence of such quantitative information makes it very difficult to assess the impact of shrimp farming chemicals on the environment.

However, with the available information on the types of chemicals used, the main aspects regarding their environmental fate may be discussed. There are three main groups of substances used in shrimp farming that can affect the environment in different ways, i.e. toxic chemicals, antibiotics and nutrients.

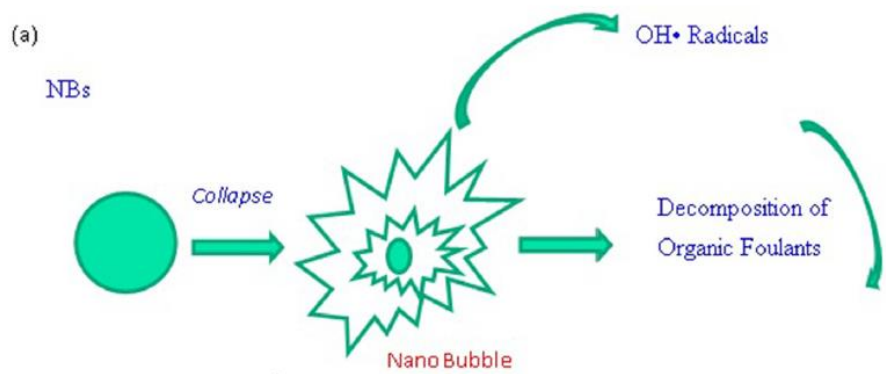
Chemicals spread in the environment as a result of their use in aquaculture can be acutely toxic, mutagenic or have other negative sub-lethal effects on the wild flora and fauna. The dispersion of antibiotics after treatment in shrimp ponds or hatcheries can cause resistance among the pathogens, and a changed micro-organism composition in the aquatic environment. Effluents with high nutrient content can cause local or regional eutrophication.

In recent decade, however, one of significant discoveries in interfacial physics is nano-bubbles, which are micro/nano-scope gaseous domains that form at the interface between solid and liquid. Nano-bubbles (NB) present characteristics that make them special in relation to the ordinary bubbles (macro-bubbles) because of their reduced diameter size. Some of the advantages of the NB are their high specific area (surface area per volume) and the high stagnation in the liquid phase, which increase the gas dissolution. Moreover, it was reported that when nano-bubbles collapse, free-radical generation occurs, due to the high density of ions in gas – liquid interface just before the collapse.

There are applications of NB in different fields, which include the water treatment by flotation, taking advantage of the high specific area of NB; the sterilization using ozone gas, which has its dissolution increased with NB generation; contrast agent for ultrasonography and the possible use in food industry for foam products, carbonated drinks and as a nutritional supplement carrier, in which bubble stability is desired.

Furthermore, the use of Nano-bubbles in water was reported to be effective for the acceleration of metabolism in shellfishes and vegetables, as well as in aerobic cultivation of yeast, accelerating the growth and increasing the yield of the products. This effectiveness, however, cannot be explained only by the increase of the Dissolved Oxygen (DO) concentration, using Nano-bubbles in the solution for the hydroponic cultivation of lettuce, observed acceleration in growth in comparison with lettuce grown in solution containing similar DO concentration but without NB. Therefore, the NB should play an important role in the physiological activity in cells.

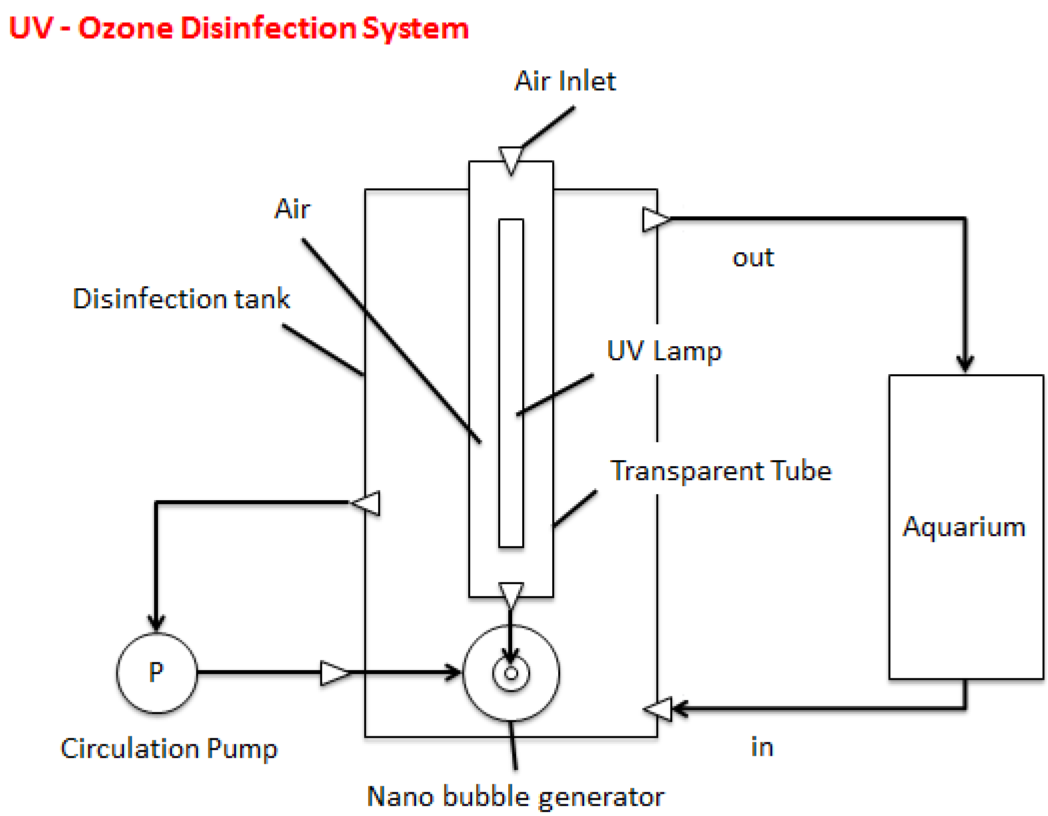
Nano-Bubbles that were electrochemically generated were shown to effectively remove adsorbed proteins (e.g., bovine serum albumin) on both hydrophobic and hydrophilic surfaces *(Chen et al., 2006; Liu et al., 2008)*. The rough mechanism of the Nano-bubble removing the virus proteins or organic foulant on the surface of shrimp body could be implied by the Figure below.



Nano-bubble working principal

Regarding the advantages of this Nano-bubbles approach, to enhance the disinfection of the shrimp aquaculture water, an UV-Ozone Disinfection system combined with nano-bubbles generator was invented by Professor Zhang Zhenjia from SJTU in China.

The schematic diagram of this patented system is plotted as follows:



Schematic diagram of a Nano-bubble system

The UV, secondary ozone and nano-bubble combined water treatment device, consists of the enclosure, the influent inlet, effluent outlet and air inlet on the enclosure, the central outer casing, central inner casing, UV lamp and the perforated aeration tubes inside the enclosure; the influent inlet is set beneath the enclosure, the effluent outlet is set on the top of the enclosure. The UV lamp, the central inner casing, the central outer casing are set from the inside-out and installed in the center position of the enclosure. The air inlet is connected to the central outer casing; the perforated aeration tube is connected to the bottom of the central inner tube and the outer tube. Comparing to the current techniques, this invention presents good performance of bacteria and viruses extermination (greater than 90% of the common bacteria; around 99.9% of *E.coli* and Virus) and it can reduce the chromaticity of water greater than 30 times. With its simple structure and easy operation and application, it can be used into the water disinfection and decolorization, which leads it to the wide range of applications in water treatment.

To our concern, we focus on the water treatment because we believe that water is the source of all things.

4. Market perspectives

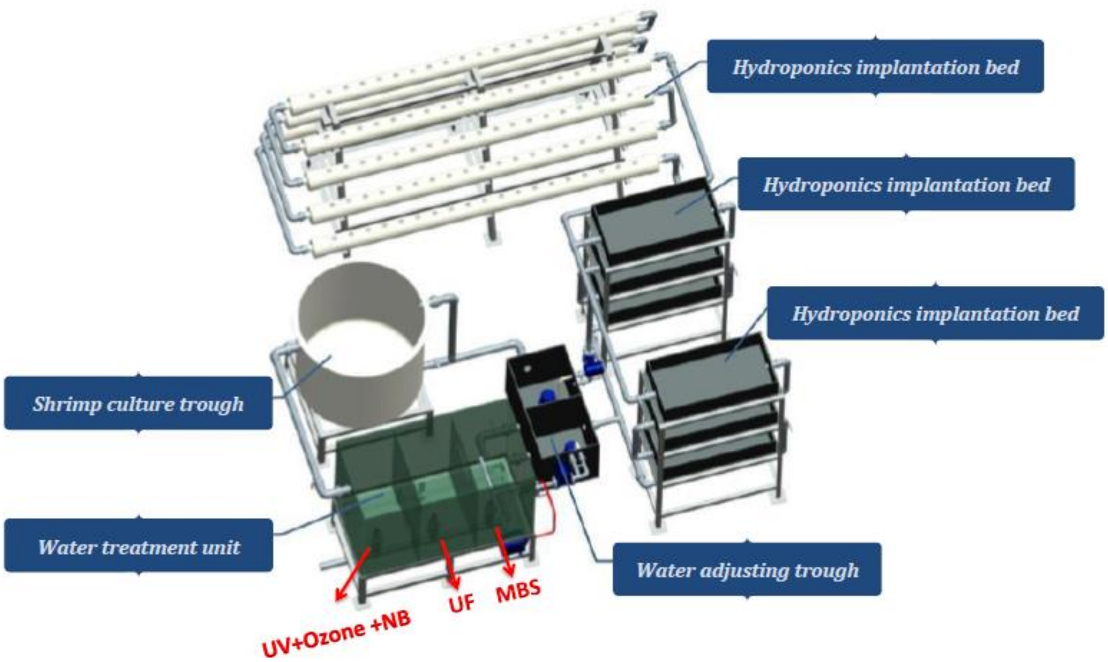
In the National Shrimp Industry Seminars of 2013, the Minister of Agriculture and Agro-based Industry Ministry of Malaysia, DatukSeriNohOmar said that despite the reduction in shrimp production in Malaysia since 2011, the government plans an annual yield of 214,000 tons of shrimp products by 2020, which worth 6.5 billion ringgit. However, according to the Malaysian Department of Fisheries (DOF) statistics, the shrimp production in 2011 was about 65,000 tons, but decreased to around 48,000 tons in 2012, not optimistically, it will still decrease to 40~50% of that amount by 2015.

The breeding cost of the Cost-intensive type of farming is rising, mainly due to the high feedstuff prices, which accounted for 54-63% of total costs. By 2014, Malaysia shrimp farming costs increased 5-8%, mainly because of feed and shrimp prices of 5-6%, electricity and labor costs increased from 5% up to 10%. The cost in Malaysia was $ 3.6 / kg (size 70 / kg, density 100 / square). Besides the cost of feedstuff, the land rents in Malaysia are rising, starting from 2009 at least 10% by year, and the labor costs are also rising, which accounted for 5-9% of the total cost.

To satisfy the increasing interest in an environmentally friendly shrimp culture within the shrimp farming industry and efforts to reach a sustainable production, the natural open mode of shrimp farming should make changes.

Since an Aqua-ponics System could help to reach a sustainable yield of shrimp and certain types of vegetables as byproducts.

The system is shown as follows:



After the treatment in the system, ammonia concentration in the water could be reduced less than 0.5 ppm by MBS, moreover, greater than 90% of the common bacteria; around 99.9% of E.coli and Virus will be exterminated by UV+Ozone, and the Nano-bubbles will supply high oxygen content water for shrimps; meanwhile, debris in the water could be more easy to remove.

With this Aqua-ponics System, the risk in current mode of shrimp farming should be reduced; and it will lead to a sustainable production. However, the market potential is to be well evaluated and capital and operation cost, etc. should be better estimated for marketing application.