sustainable in view of government-initiated efforts to organize the industry into a network composed of complete hatcheries (breeding centers), meaning hatcheries that maintain broodstock for seedstock production and basic hatcheries that simply obtain eggs from the breeding centers (Sugama *et al*., 2016). This system has been adopted in milkfish seedstock production, which enables Indonesia to export seedstock to other milkfish producing countries like the Philippines and Taiwan. The same approach is being used for grouper seed production. If the Southeast Asian countries can adopt a similar scheme in the production of other economically valuable aquaculture species then the problem of inadequate seedstock can be partly addressed. Aside from inadequate seedstock, another issue that has plagued the aquaculture industry is the production of healthy or disease resistant stocks and prevention of the spread of infected seedstock through importation and/or local stock transfers. This has been a major concern particularly in species that are susceptible to viruses that can be spread by way of seedstock movement. Examples of disease-prone stocks include penaied shrimps and some high-value marine fishes that suffer mortalities brought about by deadly viruses. Solutions to such problems sometimes start in the production of specific pathogen-free seedstock and/or the prevention of stock infection and vertical transmission of the disease by injecting potential broodstock with species-specific vaccines. Early detection using molecular tools likewise help screen infected seedstock. Guidelines and/or criteria for evaluating good quality seedstock prior to being sold locally and exported or post-procurement and importation, as the case may be, often include the need for pathogen screening as part of quarantine procedures.

Other issues that have to be continually looked into with regard to seedstock production would be on how to maintain the genetic quality of the stocks being produced apart from other technical concerns which can be addressed through research and development. ***Appendix 5*** contains a summary of the constraints in the seed production industry in the Southeast Asian region.

6.3.4 Challenges and Future Direction

Challenges in the production and dissemination of quality aquaculture seedstock remain to be both technical and non-technical in nature. As previously emphasized, most of the issues that may be complicated to address is on how to technically produce healthy seedstock as the Southeast Asian aquaculture is constantly being challenged by having to intensively produce commodities in the grow-out phase. The approaches being pursued are being addressed by advanced techniques in PCR-assisted disease diagnosis apart from the development of schemes to produce disease and/or stress resistant stocks using genomic information. With molecular tools that can be employed to survey and collect highly genetically variable broodstock from the wild, continuously monitor the genetic integrity of hatchery broodstock (including changes in successive generations of the same), address aquatic health management problems, and enhance genetic enhancement schemes in the production of quality aquaculture seedstock, the industry as a whole can look forward to benefitting from quicker R&D solutions to problems on aquatic seed production. As for the non-technical challenges, perhaps additional enabling laws and or current policies particularly on the adoption and implementation of good aquaculture practices should be promoted and strictly observed especially in many developing countries where the seedstock industry is composed mostly of small-scale hatcheries. Collective efforts, not only from the hatchery industry sector but from all the stakeholders, should be pooled to help the aquaculture industry achieve its production targets.

6.4. Producing Safe and Quality Aquaculture Products

The use of antibiotics and other chemicals in aquaculture is widely practiced to help meet the increasing demand for fish food from aquaculture. These antibiotics and chemicals appear to be part of material inputs during rearing, mostly from feed ingredients and as therapeutants for prevention or treatment of diseases. Thus, cultured shrimps and fish in various stages from hatcheries to grow-out ponds are exposed to chemicals. Consequently, with the ever-growing demand for food safety, fish farmers are faced with the challenge of producing safe food from farm to fork. Government regulations are becoming stricter on the uncontrolled use of chemicals due to their adverse effects on human health and the environment, and the development of pathogen resistant bacteria. Many chemicals have already been banned and the use of some is being regulated. The spectrum of allowable chemicals for aquaculture is becoming narrower, with the trend towards the use of environment-friendly mitigating agents geared to a more responsible approach to aquaculture.

6.4.1 Current Status

Concerns for safe, effective, and minimal use of chemicals in aquaculture in order to protect human health and the environment are reflected in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). In 2000, a comprehensive report on use of chemicals in Asia with emphasis on various aquaculture systems, species, and country regulations regarding distribution and use was made available after the Experts Meeting on the Use of Chemicals in Aquaculture in Asia at SEAFDEC/AQD in 1996 (Arthur *et al*., 2000). Since then sustained efforts were made to update the general information based on chemical usage in aquaculture in Asia and understand the realities and uncertainties in the regulatory frameworks governing the use of chemicals to ensure food safety and minimal impacts on public health and the environment. Many countries are now imposing strict food safety requirements, among which, monitoring of the maximum residue levels and banned chemicals on imported aquaculture products, would likely pose significant difficulties to countries exporting aquaculture commodities in the future.

A series of regional workshops on Harmonization of Guidelines for the Use of Chemicals in Aquaculture and Measures to Eliminate the Use of Harmful Chemicals was organized by Malaysia in 2009, 2010, and 2012, and participated by representatives from the AMSs. The ASEAN Guidelines for the Use of Chemicals in Aquaculture and Measures to Eliminate the Use of Harmful Chemicals was published in 2013. Developed to help national regulators and stakeholders in managing the diverse use of chemicals in aquaculture, this set of Guidelines was so designed that it can be implemented within the specific policy and legal framework of each AMS. It outlines the rules and responsibilities of the competent authority or national regulators, the manufacturers and traders of chemicals, and the aquaculturists in each AMS regarding the safe methods of manufacturing, procurement, use, and disposal of chemicals to ensure food safety, and protection of public health and the environment. It also outlines the channels of communication of the competent authorities with the national stakeholders, other ASEAN competent authorities and relevant organizations about the use of chemicals and current laws and regulations regarding chemicals in aquaculture as well as the manner of monitoring the progress of the competent authorities in the implementation of the Guidelines. The set of Guidelines also presents a list of commonly used chemicals and drugs in aquaculture among the AMSs which have been deliberated on and agreed upon during the regional workshops. SEAFDEC supports and promotes the adoption of the Guidelines among its Member Countries and compliments this with the guidelines on the use of antibiotics and other chemical inputs based on scientific information gathered from projects funded by the Government of Japan Trust Fund and other relevant SEAFDEC studies.

Due to the growing awareness on issues on food safety of aquaculture products, SEAFDEC considered it an urgent matter to help establish, support, and promote regional guidelines on the right usage of antibiotics and other chemical inputs that will allow farmers to increase production of safe aquaculture products. The findings from SEAFDEC/AQD research and the outcome of the harmonization of guidelines on the use of chemicals in aquaculture were consolidated in a SEAFDEC/AQD publication "Important Findings and Recommendations on Chemical Use in Aquaculture in Southeast" (Coloso *et al*., 2015). Also included in this monograph is technical information on three important chemicals, namely: ethoxyquin, organotin compounds and melamine, the residues in aquaculture products which threaten the food safety of aquaculture commodities.

SEAFDEC/AQD conducted studies to determine the withdrawal or depletion periods of antibiotics on different fish species cultured in the tropics. Although the mechanisms of accumulation and withdrawal of antibiotics and chemicals have already been well studied in developed countries, these data were generated using their species and under conditions that are different from the conditions prevalent in the Southeast Asian region. Thus, studies were conducted to estimate the depletion of two types of antibiotics, oxytetracycline (OTC) and oxolinic acid (OXA) on four fish species, namely: milkfish (*Chanos chanos*), hybrid red tilapia (*Oreochromis mossambicus-hornorum* x *O. niloticus*), mangrove red snapper (*Lutjanus argentimaculatus*), and orange spotted grouper (*Epinephelus coioides*).

In line with the promotion of food safety awareness in the Southeast Asian region, another SEAFDEC/AQD study surveyed the levels of antibiotics and pesticide residues in aquaculture products from culture systems such as ponds and cages or pens from the three major islands of the Philippines (Luzon, Visayas, and Mindanao). Samples were obtained from the markets or from fish farms and transported to SEAFDEC/AQD Tigbauan Main Station in Iloilo, Philippines where the samples were analyzed for the presence of organochlorine pesticide (OCP), OTC, and OXA antibiotic residues. Some samples still contain residues of these antibiotics and the banned OCP. For instance, in a specific *Macrobrachium* sample from Luzon, higher level than the Permissible Exposure Limits (PEL) and Maximum Residue Levels (MRL) of Endrin and its metabolite, and Endosulfan I were detected, indicative that the banned OCPs are still being used presumably in agriculture operations and that they enter the culture system through water run-offs.

Ethoxyquin is a chemical added to aquafeed to prevent oxidation or rancidity of fats, and is known to be one of the best feed antioxidants but is also responsible for a wide range of health related problems in dogs, as well as in humans. Tolerance level in uncooked muscle meat of animals is 0.5 ppm. However, Japan lowered the residual limit in shrimp to 0.01 ppm in 2012, and this caused alarm and financial losses to farmers from countries that export shrimp to Japan. In 2014, Japan formally increased the allowable limit from 0.01 ppm to 0.2 ppm in crustaceans. Although it is a twenty-fold increase in the allowable level, it is still lower than acceptable tolerance level of 0.5 ppm. Nevertheless, this brought some relief to shrimp exporting countries like Viet Nam, India, and Philippines.

Organotin compounds, like tributyl or triphenyl derivatives of tetravalent tin, have been extensively used as algicides and molluscicides in anti-fouling products. In the Philippines and other Southeast Asian countries, triphenyltin (brand names Aquatin, Brestan, or Telostan) has long been used as molluscicide in brackishwater earthen ponds to control the population of pond snails in milkfish culture. The use of organotins has been restricted in many countries, including the Philippines because of their effects on aquatic organisms and persistence in the environment. They render the soil sterile, considerably non-biodegradable, bioaccumulate in fish and snails, and are hazardous to humans. The concept of integrated pest management, the use of metaldehyde and tobacco dust, and lime treatment are just some ways to control the population of snails. Although organotins are banned in the Philippines, illegal importation has continued because its usage is allowed and continues to be practiced in neighboring countries. A uniform implementation of the ban in Southeast Asian countries will be helpful in limiting the use of this chemical in aquaculture.

Melamine is an adulterant that can be added to feed ingredients for aquafeeds to artificially inflate the apparent protein content. Together with cyanuric acid, it has been found that crystals formed from melamine and cyanuric acid can cause kidney damage in mammals, fish, and shrimp. If in doubt of the source and quality of feed ingredients and aquafeeds, samples should be submitted for melamine and cyanuric acid analysis. Their presence in feed ingredients and aquafeeds are biomarkers for contamination, adulteration, or intentional addition to increase crude protein levels. The United Nations' Codex Alimentarius Commission has set the maximum amount of 1.0 mg/kg melamine in powdered infant formula and 2.5 mg/kg in other foods and animal feed. While not legally binding, the recommended levels can serve as basis for banning the importation of products with excessive levels of melamine.

Along with the research activities to promote awareness of food safety of aquaculture products, SEAFDEC/AQD organized the International Training Course on Food Safety and the International Workshop on Food Safety of Aquaculture Products in Southeast Asia in May 2013 and November 2013, respectively. In the workshop, the status of food safety and traceability of aquaculture products were presented by the SEAFDEC Member Countries. In general, the countries are heading towards farm certification and implementation of protocols that would prevent the occurrence of food safety hazards in farm level, specifically, the considerations addressed in Good Aquaculture Practices (GAP). Each country identified their responsible authority in monitoring and regulating the food safety of aquaculture products. The training and workshop aimed to disseminate and exchange information in order to promote and encourage regional initiatives in ensuring the food safety of aquaculture products in the ASEAN region. Both the international training course and workshop were financially supported by JTF of the Government of Japan.

6.4.2 Issues, Challenges, and Constraints

The concept of food safety of aquaculture products should always start at the farm level. However, there seems to be a low awareness on this aspect on the part of marginal fish farmers who have lesser access to information, especially on the proper handling of chemicals, appropriate administration of antibiotics, and the hazards that these chemicals and drugs can bring to humans, animals, and the environment.

Due to the increasing demand of consumers for safe aquaculture products, stricter government laws implementing food safety requirements will be a challenge to fish farmers. Farm certification may become mandatory from being recommendatory. Preventing the occurrence of food safety hazards at the farm level is by far, a better tool to produce safe aquaculture commodities than removing the hazards in post-harvest operations. The implementation of GAP can be a tool to address the concerns on food safety, however, this can put heavy strain on the part of fish farmers and may be dealt with non-compliance and even rejection by farmers if they are not appropriately prepared and informed.

The adoption and implementation of harmonized guidelines on the use of chemicals for aquaculture in AMSs would require a massive effort on the part of each government and the competent authorities. Monitoring agencies of each country should be more vigilant and play a greater role in the implementation of the guidelines. More specifically, banned and regulated chemicals should be properly monitored.

6.4.3 Future Direction

Problems on antibiotic residues and evaluation of their withdrawal or depletion period on other tropical aquaculture species and monitoring of chemical contaminants either introduced during culture or inherently present in the culture environment are just some of the science-based future studies for consideration. Adhering to the principles of GAP should be promoted and recommended to all aquaculture operations, especially to small-scale and medium-scale aquaculture facilities. Governments should render assistance, especially to marginal fish farmers relevant to food safety and the ASEAN GAP. Information dissemination on food safety on farm level should be intensified.

Worthy of consideration also is the record of updated inventory of the amount of chemicals being used by each AMS, their application and assessment of the effect on the target objective of usage and the side effect to humans and the environment. Each AMS should have already adopted the ASEAN Guidelines for the Use of Chemicals in Aquaculture and Measures to Eliminate the Use of Harmful Chemicals (ASEAN, 2013). Nonetheless, competent authorities should be well-equipped with laboratory facilities and police powers for proper implementation.

6.5 Addressing Concerns Due to Intensification of Aquaculture and Climate Change

As the biggest producer of fisheries products both from capture and aquaculture, Asia has been considered the birthplace of aquaculture (FAO, 2016b; FAO, 2016c; Tacon *et al*., 1995). From 1950 to 2014 (**Figure 77**), Asia provided an average of 83% to the total world aquaculture production, with Southeast Asia contributing 9-31% to Asia's total aquaculture production (**Figure 78**). Indonesia and the Philippines contributed the most at 23-63% and 10-45% of the total, respectively (**Figure 79**). With the increasing demand for fish and fishery products and the dwindling supply of wild aquatic resources, aquaculture, considered a reliable solution to food security problems, is being intensified to compensate for the declining fisheries production. Aquaculture intensification has already caused aquaculture production to overtake the contribution of capture fisheries to the total world production at 51% in 2013 (FAO, 2016b).

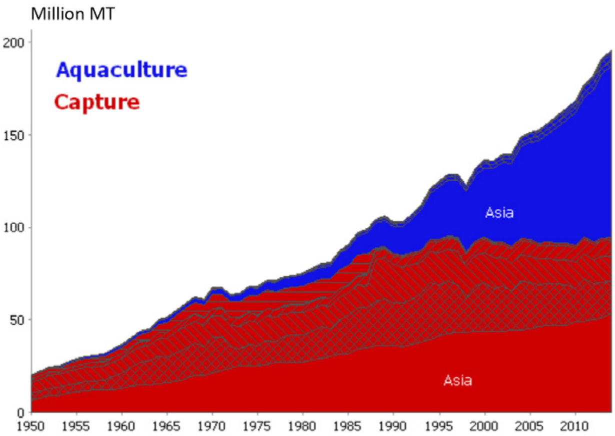

Figure 77. Total world capture (red) and aquaculture (blue) production from 1950 to 2014 by quantity; shaded areas with different patterns represent different continents and plain area represents Asia

Source: *FAO Database 2016*

However, as aquaculture production intensifies, a number of problems have been linked with it. The phenomenal growth of aquaculture in the recent years has caused modification, destruction or complete loss of habitat; unregulated collection of wild broodstock and seeds; translocation or introduction of exotic species; loss of biodiversity; introduction of antibiotics and chemicals to the environment; discharge of aquaculture wastewater, thus coastal pollution; salinization of soil and water; and dependence on fishmeal and fish oil as aquaculture feed ingredients, to name a few (Beveridge *et al*., 1994; Chua *et al*., 1989; Iwama, 1991; Naylor *et al*., 2000; Primavera, 2006). Thus, efforts have been done to balance the need to increase production and minimize the impacts of aquaculture on the environment.

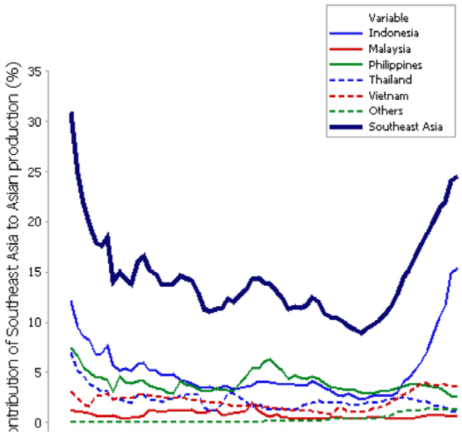

Figure 78. Contribution of Southeast Asian countries to aquaculture production in Asia, and top aquaculture producing Southeast Asian countries (1950-2014)

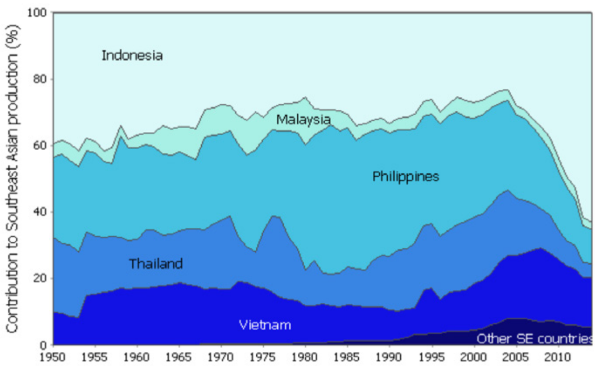

Figure 79. Contribution of Indonesia, Malaysia, Philippines, Thailand, Viet Nam and other Southeast Asian countries (Brunei Darussalam, Cambodia, Lao PDR, Myanmar, Singapore, and Timor-Leste) to aquaculture production in Southeast Asia from 1950 to 2014

Source: *FAO Database 2016*

Aside from aquaculture, the natural environment has also been greatly affected by extreme weather conditions brought about by climate change. Scientific evidence of the warming climate system is unequivocal and compelling. Extreme events, like numbers of recorded high temperature, numbers of intense rainfall, strengths of typhoons and storms, and the like, have been increasing since the 1950s (IPCC, 2007). Southeast Asia is not spared