Research Journal of Applied Sciences, Engineering and Technology 3(10): 1108-1117, 2011
ISSN: 2040-7467
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Submitted: June 15, 2011 Accepted: August 05, 2011 Published: October 20, 2011

Hazard and Risk Analysis in Culture Fisheries

[1]E.N. Ezekiel, [2]J.F.N. Abowei and [3]E.F. Ezekiel
[1]Department of Biological Sciences, Faculty of Science, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria
[2]Department of Science Laboratory Technology, School of Applied Science, Rivers State Polytechnic, Bori, Rivers State, Nigeria
[3]Sammy Close, Owudu Communuity, Bitter Leaf Estate, Aboloma, Rivers State, Nigeria

Abstract: Culture fisheries is multi-faceted and also presents a diverse array of environment ranging from freshwater to marine and from simple stagnant ponds to high tech computerized closed indoor water recirculation systems. The industry is therefore, fraught with potential risks and hazards. Risk analysis is now widely applied in many fields that touch our daily lives. Risk analysis is a process that provides a flexible framework within which the risks of adverse consequences resulting from a course of action can be evaluated in a systematic, science-based manner. Governments and the private sector must often make decisions based on incomplete knowledge and a high degree of uncertainty. Such decisions may have far-reaching social, environmental and economic consequences. An integrated approach to risk analysis will assist the culture fisheries sector in reducing risks to successful operations from both internal and external hazards and can similarly help to protect the environment, society and other resource users from adverse and often unpredicted impacts. The principles for controlling hazards in Culture fisheries will include the identification of hazard, control of the hazard and monitoring of the effectiveness of the controls. This paper reviews the risk concept, general Principles, applications of risk analysis, management of hazards and risks in culture fisheries, application of risk analysis to culture fisheries and proffered management strategy to reduce or minimize hazards and risk in culture fisheries.

Key words: Application, concept, culture fisheries, management, principles, risk and hazard

INTRODUCTION

Culture fisheries is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants up to final commercial production in selected or controlled environments (Erondu and Anyanwu, 2005; Tawari and Abowei, 2011). The rapid growth in the Culture fisheries sector contrasts with the decline or near stagnation in the growth of supplies from capture fisheries. There are inherent hazards and risks associated with culture fisheries production. In developed countries there have been heated debates among stakeholders as to the risks and hazards of the system (FAO, 2006). This does not in any way preclude the importance or significance of aquaculture in the food sector (FAO, 1966). Rather it is a means of resolving issues related to the undesirable effects of the system. Unfortunately, the awareness has not been created in developing countries that produce a major proportion of the products. Culture fisheries products like other foods have hazards that may adversely affect the consumers' health (Ahmed, 1991).

The production system also presents risks to public health. Culture fisheries development can sometimes change landscapes of aquatic systems resulting in habitat destruction and loss of biodiversity (Angulo, 2000). Chemicals used in culture fisheries can become disruptive and when they find their way into natural aquatic systems they can cause irreparable damage to the ecosystem. Effluents from culture fisheries, which consist largely of fish and feed wastes, contain large quantities of nutrients that damage the water quality and also generate unwanted algae (Arthur *et al*., 2004). Introduced non-endemic species may carry diseases and parasites alien to the native with disastrous consequences (WHO, 1989). Farm hands and other workers in aqua farms are susceptible to many injuries in the course of their work.

The fish farmers in the informal sector are more vulnerable. All the stakeholders - farm management, workers and governments do not appreciate the problems that can be solved or mitigated through occupational safety and health (Buras, 1993). Injuries, preventable occupational diseases, and food safety issues abound in

Corresponding Author: J.F.N. Abowei, Department of Science laboratory Technology, School of Applied Science, Rivers State Polytechnic, Bori, Rivers State, Nigeria

such systems resulting in unnecessary loss of man hours, skilled workforce and lives (Charmish, 1996). Hazard and risk analysis is a process that provides a flexible framework within which the risks of adverse consequences resulting from a course of action can be evaluated in a systematic, science-based manner (Clarke, 2002). The risk analysis approach permits a defendable decision to be made on whether the risk posed by a particular action or "hazard" is acceptable or not, and provides the means to evaluate possible ways to reduce the risk from an unacceptable level to one that is acceptable (Edwards, 2001). It is now widely applied in many fields that touch our daily lives. The article reviews the risk concept, general Principles, applications of risk analysis, management of hazards and risks in culture fisheries, application of risk analysis to culture fisheries and proffered management strategy to reduce or minimize hazards and risk in culture fisheries.

Risk concept: The definition of "risk" varies somewhat depending on the sector. Most definitions incorporate the concepts of: uncertainty of outcome; probability or likelihood and consequence or impact (Johnson, 2000). Thus "risk" is the potential for realization of unwanted, adverse consequences to human life, health, property or the environment. Its estimation involves both the likelihood (probability) of a negative event occurring as the result of a proposed action and the consequences that will result if it does happen (Kapuscinski and Hallerman, 1990). As an example, taken from pathogen risk analysis, the *Aquatic Animal Health Code* defines risk as "the likelihood of the occurrence and the likely magnitude of the consequences of an adverse event to public, aquatic animal or terrestrial animal health in the importing country during a specified time period." Some sectors incorporate consideration of potential benefits that may result from a "risk" being realized (financial risk analysis), others specifically exclude benefits from being taken into account (e.g., pathogen risk analysis) (Karanja *et al*., 2003).

The terminology used by some risk analysis sectors is well established (e.g., pathogen risk analysis, food safety, environmental risk analysis), and there is often considerable differences in how individual terms are defined. An attempt at cross-sectored standardization of terms is thus probably futile, and it is thus important that that terms used by the various risk analysis sectors be fully defined at the outset (Karkkainen, 2002).

"Risk analysis" is usually defined either by its components and/or its processes. The Society for Risk Analysis www.sera.org offers the following definitions of "risk analysis":

- A detailed examination including risk assessment, risk evaluation and risk
- Management alternatives, performed to understand the nature of unwanted
- Negative consequences to human life, health, property or the environment
- An analytical process to provide information regarding undesirable events
- The process of quantification of the probabilities and expected consequences for identified risks

It can also be defined as an objective, systematic, standardized and defensible method of assessing the likelihood of negative consequences occurring due to a proposed action or activity and the likely magnitude of those consequences, or, simply put, it is "science-based decision-making" (Mac-Diarmid, 1997). In simple terms, a risk analysis typically seeks to answer four questions:

- what can go wrong?
- how likely is it to go wrong?
- what would be the consequences of its going wrong?
- What can be done to reduce either the likelihood or the consequences of its going wrong? (Mac-Diarmid, 1997; Rodgers, 2004; Arthur *et al*., 2004).

The general framework for risk analysis typically consists of four major components:

- **Hazard identification:** The process of identifying hazards that could potentially produce consequences;
- **Risk assessment:** The process of evaluating the likelihood that a potential hazard will be realized and estimating the biological, social and/or economic consequences of its realization;
- **Risk management:** The seeking of means to reduce either the likelihood or the consequences of it going wrong; and
- **Risk communication:** The process by which stakeholders are consulted, information and opinions gathered and risk analysis results and management measures communicated.

The risk analysis process is quite flexible. Its structure and components will vary considerably depending on the sector (e.g., technical, social or financial), the user (e.g., government, company or individual), the scale (e.g., international, local or entity-level) and the purpose (e.g. to gain understanding of the processes that determine risk or to form the basis for legal measures). It can be qualitative (probabilities of events happening expressed, for example, as high, medium or low) or quantitative (numerical probabilities) (Mott, 1996).

All risk analysis sectors involve the assessment of risk posed by a threat or "hazard". The definition of "hazard" depends on the sector and the perspective from which riskis viewed (e.g., risks to aquaculture or risks from aquaculture) (Ojok, 1995). A hazard thus can be:

- A physical agent having the potential to cause harm, for example:

- A biological pathogen (pathogen risk analysis)
- An aquatic organism that is being introduced or transferred (genetic risk analysis, ecological risk analysis, invasive alien species risk analysis);
- A chemical, heavy metal or biological contaminant (human health and food safety risk analysis, environmental risk analysis)
- The inherent capacity or property of a physical agent or situation to cause adverse effects, as in social risk analysis, financial risk analysis, and environmental risk analysis.

GENERAL PRINCIPLES

Some basic principles that appear to be common to all types of risk analysis are presented below. These involve the broader concepts of common sense, uncertainty, precaution, objectivity, transparency, consistency, scientific validation, stakeholder consultation, stringency, minimal risk management, unacceptable risk and equivalence (Price, 1997).

The principle of common sense: In assessing risks, the use of "common sense" should prevail. In many cases, the outcomes of a risk analysis are obvious and uncontroversial, and a decision can be made without resulting to a full risk analysis, which can be a lengthy and expensive process (Reilly and Kaferstein, 1997).

The principle of uncertainty: All risk analyses contain an element of uncertainty.
A good risk analysis will seek to reduce uncertainty to the extent possible.

The principle of precaution: Those involved in the aquaculture sector have a responsibility to err on the side of caution, particularly if the outcomes of a given action may be irreversible. If the level of uncertainty is high, the Precautionary Principle can be applied to delay a decision until key information is obtained. However, steps must be taken to obtain the information in a timely manner.

The principle of objectivity: Risk analyses should be conducted in the most objective way possible. However, due to uncertainty and human nature, a high degree of subjectivity may be present in some risk analyses. A risk analysis should clearly indicate where subjective decisions have been made.

The principle of transparency: Risk analyses, particularly those conducted by public sector agencies, should be fully transparent, so that all stakeholders can see how decisions were reached. This includes full documentation of all data, sources of information, assumptions, methods, results, constraints, discussions and conclusions.

The principle of consistency: Although risk analysis methodology continues to evolve, it is important that decisions, particularly those made by government, are reached via standardized methods and procedures. In theory, two risk analysts independently conducting the same risk analysis should reach roughly similar conclusions.

The principle of scientific validation: The scientific basis of a risk analysis and the conclusions drawn should be validated by independent expert review.

The principle of stakeholder consultation: If the results of a risk analysis are likely to be of interest to, or impact upon others, then stakeholder consultations should be held. This is accomplished by risk communication, the interactive exchange of information on risk among risk assessors, risk managers and other interested parties. Ideally, stakeholders should be informed/involved throughout the entire risk analysis process, particularly for potentially contentious risk analyses (e.g., ecological, genetic and pathogen risk analyses for the introduction of new aquatic species).

The principle of stringency: The stringency of the risk management measures to be applied should be in direct proportion to the risk involved.

The principle of minimal risk management: Risk management measures that impinge on the legitimate activities of others should be applied only to the extent necessary to reduce risk to an acceptable level.

The principle of unacceptable risk: If the level of risk is unacceptable and no effective or acceptable risk management measures are possible, then the activity should not take place.

The principle of equivalence: Risk management measures proposed by trading partners that meet the acceptable level of risk should be accepted by the importing country.

APPLICATIONS OF RISK ANALYSIS

Risk analysis is now widely applied in many fields that touch our daily lives. These include decisions about risks due to chemical and physical stressors (natural disasters, climate change, contaminants in food and water, pollution etc.), biological stressors (human, plant and animal pathogens; plant and animal pests; invasive species, invasive genetic material), social and economic stressors (unemployment, financial losses, public security, including risk of terrorism), construction and engineering (building safety, fire safety, military applications) and business (project operations, insurance, litigation, credit, cost risk maintenance etc.) (Rodgers, 2004).

Risk analysis is thus a pervasive but often unnoticed component of modern society that is used by governments, private sector and individuals in the political, scientific, business, financial, social sciences and other communities (Uronu and Lekei, 2004). Governments and the private sector must often make decisions based on incomplete knowledge and a high degree of uncertainty. Such decisions may have far-reaching social, environmental and economic consequences. Risk analysis is a process that provides a flexible framework within which the risks of adverse consequences resulting from a course of action can be evaluated in a systematic, science-based manner. The risk analysis approach permits a defendable decision to be made on whether the risk posed by a particular action or "hazard" is acceptable or not, and provides the means to evaluate possible ways to reduce the risk from an unacceptable level to one that is acceptable.

Culture fisheries production may have arisen as an intervention mechanism to enhance food production. It is currently one of the fastest growing food producing sectors in the world. Its global importance is related to its contribution in the reduction of the supply – demand gap of fish products. Production statistics indicate that between 1984 and 1996, there was a three fold increase in aquaculture products (WHO 1999a).

The rapid growth in the Culture fisheries sector contrasts with the decline or near stagnation in the growth of supplies from capture fisheries. The implication is that aquaculture will continue to play an increasing role in fish supplies. Culture fisheries may therefore be a veritable means of alleviating hunger as well as curbing seasonal supply of fish products. Furthermore, it has the capacity of creating jobs since labor would be expected in all the associated industries. Culture fisheries is multi-faceted and also presents a diverse array of environment ranging from freshwater to marine and from simple stagnant ponds to high tech computerized closed indoor water recirculation systems (WHO, 1999b).

The industry is therefore, fraught with potential risks and hazards. Culture fisheries production can be partitioned into the formal and informal sectors of the economy. In the formal aquaculture sector, ownership of farms is corporate and well organized. The farms are large and operate under advanced technology. This is common among the developed countries such as USA, Japan, Norway and France, which contribute about 8.6% of the total global culture fisheries production (WHO, 1999a). The informal aqua culture, however, consists of small holder units, subsistent Culture fisheries practitioners and semi-organized units with low technology and infrastructure especially in the areas classified as low - income - food - deficit countries. This group is represented even in the major Culture fisheries producing countries such as China, India, Philippines, Indonesia and Thailand, which contribute about 80% of the global Culture fisheries production (WHO, 1989).

Culture fisheries producers from Africa also belong to this group. FAO (2006) noted that about 87.1% of the total aquaculture production was from developing countries. Culture fisheries may therefore be a veritable means of alleviating hunger as well as curbing seasonal supply of fish products. Furthermore, it has the capacity of creating jobs since labor would be expected in all the associated industries. Culture fisheries Culture fisheries is multi-faceted and also presents a diverse array of environment ranging from freshwater to marine and from simple stagnant ponds to high tech computerized closed indoor water recirculation systems.

The industry is therefore, fraught with potential risks and hazards. Johnson (2000) defined hazard as 'the presence of a material or condition that has the potential for causing loss or harm'. This implies that there is an inherent existence of threat in that system. Risk on the other hand is defined as 'a combination of the severity of consequences and likelihood of occurrence of undesired outcomes' (Johnson, 2000). In other words, risk is the likelihood that harm or injury from a hazard will occur to specific individuals or groups exposed to a hazard. Thus, for every system or process, there are associated risks and hazards no matter how well managed the system is. There are inherent hazards and risks associated with culture fisheries production.

In developed countries there have been heated debates among stakeholders as to the risks and hazards of the system. This does not in any way preclude the importance or significance of aquaculture in the food sector. Rather it is a means of resolving issues related to the undesirable effects of the system. Unfortunately, the awareness has not been created in developing countries that produce a major proportion of the products. This is predicated on the fact that majority of the producers belong to the informal sector of the economy. Karanja *et al*. (2003) observed that, although this sector contributes significantly to the national economy, its semi-organized and unregulated status create a situation where workers are exposed to innumerable hazards.

Injuries preventable occupational diseases and food safety issues abound in such systems resulting in unnecessary loss of man hours, skilled workforce and lives. The situation is exacerbated by the fact that these farms operate outside the institutional regulatory frameworks and with minimal supervision from regulatory bodies. This paper therefore, highlights the information on hazards and risks in aquaculture and proffers strategies for their management and control (Johnson, 2000). The associated processes in culture fisheries practices are:

Processing: Fish products are processed and package for local consumption and export. The processes are carried out at the local and industrial level. These include

smoking, chilling and freezing, canning, filleting and production of other value - added products.

Laboratories: These are established in research stations, large hi-tech farms and processing plants for environmental/facility water quality monitoring and quality control.

Feed mill plants: These are established to produce on farm or commercial feeds. The scale of operation is varied.

Associated Industries: These are industries that are involved in manufacturing equipment used in Culture fisheries. These include nets, fertilizer plants, biofilter media, drugs, fibre glass tanks, etc. Fin fish, shell fish and other farmed aquatic organisms are produced in freshwater, brackish water and marine environment. The receptacles for cultivation of these organisms include earthen ponds, pens, cages, rice fields, raceways, open water bodies, etc. Based on the level of operation, the system is classified as:

Extensive: In extensive fish culture practice, no exogenous input is used and stocking density is low.

Semi-intensive: Fertilizer is applied in semi intensive fish culture practice to augment or stimulate natural production of food organisms for the cultured organisms; stocking rate is moderate; supplementary feed is provided.

Intensive: The density stocking rate is high and provision of a nutritionally complete feed. About 70-80% of the total global production of farmed fin fish and crustaceans takes place within extensive and semi-intensive farming systems (FAO, 2006). In Asia, integrated farming system, in which livestock wastes are inputs in fish production and waste water fed systems, in which domestic sewage and municipal waste water are used, are common practices. In Africa, culture fisheries are practiced in earthen ponds where livestock wastes (used in fresh or dried state) are used extensively for fertilization (FAO, 1966).

In Asia, cages and pens are usually installed in highly eutrophic aquatic systems. In the earthen pond systems, poly culture of fish species is common in order to fully exploit all the feeding riches. Feeding is supplementary and usually agro by products are utilized for that purpose. However, in the developed countries, aquaculture production is based essentially on the intensive monoculture of high value fish in ponds, tanks or cages at high stocking densities and fed manufactured complete diet. Fish culture in re-circulating system is becoming popular in developing countries. Here water is reused after undergoing a purification process. These farming systems have effluents which are discharged into natural water bodies or adjoining land (FAO, 2006).

Hazards and risks related to aquaculture can be categorized into occupational, environmental and food safety and public health. Each of the different types of hazards has other components such as biological and chemical. The culture fisheries industry has diverse workplaces with individual peculiarities. The hazards in aquaculture can be classified into physical, chemical and biological (Johnson, 2000).

Physical: There are several physical risk factors in the culture fisheries industry. Farm hands and other workers in aqua farms are susceptible to many injuries in the course of their work. The fish farmers in the informal sector are more vulnerable because according to Clarke (2002), governments in developing countries have an apathy to occupational health and safety issues. All the stakeholders-farm management, workers and governments do not appreciate the problems that can be solved or mitigated through occupational safety and health. The list of physical hazards is as follows:

- **Noise:** Feed mill workers (especially those that operate with locally fabricated machines in the developing countries) are exposed to excessive noise. Ojok (1995) attributed the following harmful defects to noise: hearing defects, hearing loss and mental fatigue.
- **Injuries:** Farmers are exposed to diverse injuries such as:
- **Sting from fish spines**: This arises during fish handling without appropriate safety devices. It may cause severe pains and can result to tetanus infection or wit low.
- **Cuts, sprain, fracture, etc:** sharp implements/object such as knives, oyster shells, falls and other predisposing factors can cause these injuries. Hatchery workers are also exposed to the risk of needle stick injury which can open a gateway to many viruses and other diseases.
- **Occupational asthma and rhinitis:** Feed mill workers are at risk of contracting these diseases. Karkkainen (2002) observed that the greatest risks occur in the foodstuffs and agricultural sectors. He attribute dust released from flour and animal feed mill as the second most common cause of asthma.
- Snake bites, crab clawing and bites from fish (such as tiger fish, snapper, etc) are hazards workers in earthen pond fish farms are exposed to, especially when they are not using appropriate protective gear. This is prevalent in rural fish farming.
- **Mechanical injuries:** These are associated with laboratories and processing plants.

Chemical: Culture fisheries practitioners are exposed to chemical hazards through the following routes:

- **Constant use of chemicals:** This includes inorganic fertilizers which are used extensively in enriching fish ponds. Others are lime, pesticides, formaldehyde, etc. Some of these are caustic and can cause severe burns or skin irritation resulting in severe cases of occupational dermatitis. Some laboratory chemicals are hazardous and Inhalation may lead to development of respiratory ailments such as bronchitis, rhinitis and asthma (Uronu and Lekei, 2004). Direct contact with these chemicals could result in burns, skin irritation and allergies. It has been observed that laboratory workers that have prolonged exposure to organic solvents such as chlorinated hydrocarbons, alcohols, ester, ketone, etc. are at risk of brain and nervous system damage. The symptoms include premature ageing, memory impairment, mild depression and anxiety. Karkkainen (2002) has also attributed the following symptoms to formaldehyde poisoning: allergic dermatitis asthma and rhinitis.
- **Acute and chronic pollution of water ways:** Pesticides, oil spills, and other xenobiotics can pollute ponds and water sources which can also pose risks for workers that work in such farms.
- **Flocculants:** These are applied to ponds to precipitate suspended clay particles (WHO, 1999a). Examples are aluminium sulfate (alum), calcium suilhate (gypsum).
- **Disinfectants:** These are used to disinfect equipment and holding units - e.g. formalin hypochlorite, etc.
- **Fumes, smoke and soot:** Fumes from water pumping machines feed mill and other machines; and smoke inhaled by workers smoking fish or drying feed are considered serious health risks. These are associated with asthma, cancer and other serious ailments.

Biological: These include parasitic infestation and pathogenic infections.

- **Parasites:** Examples include leeches in ponds which attack individuals that the wade unprotected. In developing countries where human and animal wastes are used as inputs,nematode,cestode and other parasites are hazards, farm workers are exposed to.
- **Pathogens:** Risk of fungal and other pathogenic infections such as vibrio has a high likelihood in intensively manure ponds. Charmish (1996) observed that individuals pricked by spines of *Tilapia* sp infected by *Vibrio vulnificus* caused amputation of fingers. Fatal cases have also been reported in NSSP operations Manual, 1992 Revision.

There are a variety of risks mediated by environmental effects of Culture fisheries. Uronu and Lekei (2004) divided these into four categories as follows:

Biological pollution: The introduction of non-endemic species into natural water arising from their inadvertent release from aquaculture facilities is considered a serious environmental threat. The introduced species may carry diseases and parasites alien to the native with disastrous Consequences (WHO, 1989). Instances abound where exotic fish species wiped out native stocks.

The Introduced species may have the tendency of out-competing the native stock partly because they do not have natural predators, parasites and pathogens in their new environment. This trend creates biodiversity loss in natural waters. The introduction of genetically modified organisms such as transgenic fish is considered hazardous to the environment. Kapuscinski and Hallerman (1990) and Hallerman and Kapuscinski (1999) noted that such fish would pose ecological or genetic risks when they escape from production facilities.

The authors further stated that the ecological hazards would include the possibility of the transgenic fish being a voracious predator or competitor thereby impacting negatively on key ecological processes. Inter breeding of introduced or transgenic fish with the native stock could cause dilution of the gene pool. Study by Muir and Howard (1999) has highlighted considerable risk of transferring transgenic fish. Transmission of diseases and parasites to native stocks from cage and pen facilities is a major problem. In many countries disease testing and certification programs for animals are not implemented with the result that native stocks are exposed to non endemic parasites and diseases from aquaculture facilities.

Organic pollution: The effluents from aquaculture facilities constitute significant sources of organic pollution. The effluents, which consist largely of fish and feed wastes, contain large quantities of nutrients that damage the water quality and also generate unwanted algae.

Chemical pollution: Use of chemicals in ponds and laboratories constitutes considerable risk to the environment. These chemicals can become disruptive and when they find their way into natural aquatic systems they can cause irreparable damage to the ecosystem. Chemicals such as fertilizers, pesticides, antifoulants (forcages), chemotherapeutants are all considered risk factors in the environment.

Habitat modification: Aquaculture sites negatively impact the environment. Aquaculture development can sometimes change landscapes of aquatic systems resulting in habitat destruction and loss of biodiversity. The newly created habitat may not be able to sustain the natural ecological balance.

Food safety and public health hazards: Culture fisheries products like other foods have hazards that may adversely affect the consumers' health. The production system also presents risks to public health. The major health risks of aquaculture products are biological especially for the organisms produced in waste water or water receiving animal and human wastes. Edwards (2001) noted that the pathogenic, entero-bacteria (from the human digestive tract), have been found in fish guts.

This, therefore, raises the question of the safety of consuming fish products from such environments. Food borne trematodes such as *Clonorchis sinensis* and *Opisthorchis viverrini* are known to cause diseases particularly among Asians that eat their fish raw or poorly cooked. Enteric diseases caused by trematode parasites have been reported in Egypt and Republic of Korea (WHO, 1999b). Fish borne nematodiases have also been reported as incidental infections.

There are hazards associated with human pathogenic bacteria in finfish and crustaceans. These bacteria are partly the indigenous flora and partly a consequence of contamination through human or animal waste (Buras, 1993). Other sources of contamination include postharvest handling and processing. Aquatic microorganisms such as algae and detritus produce toxic compounds, which can present significant human health risks. A good example is the dinoflgellate, *Alexandrium tamarensis*, which causes toxic red tide (Buras, 1993). Humans that consume shellfish (lobster and crabs) that have ingested this organism stand the risk of being afflicted with paralytic shellfish poisoning (Price, 1997). Shellfish have also been implicated as vectors of human pathogens such as vibrio bacterium which is a causative organism of human gastroenteritis.

Filter feeders such as clams, mussels and oysters, which accumulate contaminants in their internal organs, also present potential threat to the health of consumers. Ahmed (1991) reported that the greatest number of seafood - associated illnesses are from consumption of raw molluscs harvested in waters contaminated with raw or poorly treated human sewage. Some chemical products used in aquaculture are considered hazardous in terms of food safety. These include chemical fertilizers, lime, flocculants, algicides, disinfectants and chemotherapeutants.

Some of these compounds may be biomagnified in the animal tissue and so consumers are at risk of intoxication with the chemicals. Other chemicals may be released from other sources e.g. industrial hydrocarbons and thus pollute aquaculture water source. This is more pronounced in urban aquaculture where waste water is reused. WHO (1999a) recommended that fish raised in contaminated water should be considered as risk. Other hazards of public health interest include proliferation of mosquito larvae and cercaria which increase the incidence and prevalence of malaria and filariasis, respectively. This is more common in developing countries where numerous small fish impoundments are constructed thus promoting higher densities of these organisms (Mott, 1996). Food contamination by residues of antibiotics and veterinary drugs is also considered a hazard.

Furthermore, antibiotic resistance has been reported in areas where farmed aquatic animals are receiving treatment. Angulo (2000) reported that the use of antibiotics by the Ecuadorian shrimp farming industry caused the development of multidrug resistant *Vibro cholera*. Humans infected by such antibiotic – resistant organisms would find treatment complicated. The contentious issue of the safety of genetically modified fish is worth looking at. Transgenic fish have been classified as hazardous in terms of food safety because of their potential allergen city and toxicity (Hallerman and Kapuscinski, 1999). These claims, however, need to be validated. In addition introduction of pathogenic organisms during processing of products under unhygienic conditions is also of public health importance.

Management of hazards and risks in culture fisheries: The principles for controlling hazards in Culture fisheries will include the identification of hazard, control of the hazard and monitoring of the effectiveness of the controls. This paper has identified the risk factors and hazards in the section above. In this section, control measures to reduce or minimize culture fisheries risks would be proffered. As stated earlier, ignorance on the part of workers and the apathy of employers and government agencies to their plight have caused preventable fatalities. Production of safe foods from aquaculture is, therefore, the shared responsibility of governments, industry and consumers, each having an important role to play in the protection of human health. Action at all levels is required for the development of regulations and the provision of resources for enforcement of, education and training in, and research on, responsible practices of culture fisheries. We recommend as follows:

- On employment, workers should be well-instructed and trained on the associated risks and hazards of their vocation. There should be a re-orientation of old staff so as to inculcate safety consciousness.
- Personal protective gear should be provided for all categories of staff. The use of such gear should be strictly enforced to reduce risks of accidents or other workplace hazards.
- Laboratory workers and other staff using chemicals should be subjected to regular medical checks for early detection of any adverse impact of chemical intoxication.
- There should be the provision of first aid kits at all culture fisheries facilities and adequate instructions on their usage.

- Proper records of Culture fisheries - related hazards should be kept (and updated) so as to create awareness of the existence of such. This will serve as an advance preventive or precautionary measure.
- Specialist occupational medical clinical service with access to specialized diagnostic and management resource should be established. This service would provide diagnosis and management of occupational diseases and would also serve as quick intervention.
- Governments need to put in place proactive policies and legislation that will envisage problem and institute preventive measures. Enforcement of these measures is imperative.
- Guidelines should be provided by relevant stakeholders on how to achieve a basic level of environmental protection within the vicinity of aqua farms.
- Countries should adopt the Hazard Analysis Critical Control Point (HACCP) framework (Reilly and Kaferstein, 1997) which is an innovation intended to improve food safety.
- To develop appropriate food safety controls, a proper understanding of the association between reduction in hazards associated with food and reduction in risk to consumers is of central importance.
- An integrated approach involving the health education, vector control and selective population chemotherapy should be adopted to address parasite problems.
- Indiscriminate and unregulated use of chemicals and therapeutics should be discouraged so as to protect the ecosystem and public health.

Application of risk analysis to culture fisheries: Risk analysis has wide applicability to Culture fisheries. So far, it has mainly been applied in assessing risks to society and the environment posed by hazards created by or associated with aquaculture development. Examples of risks to society from Culture fisheries include:

- **Environmental risks:** Pollution from feeds, drugs, chemicals, Wastes; alteration of water currents and flow patterns
- **Biological risks:** Introduction of invasive alien species, exotic pests and pathogens; genetic impacts on native stocks, destruction/modification of ecosystems and agricultural lands (mangrove deforestation, salination of rice lands)
- **Financial risks:** Failure of farming operations, collapse of local industry/sector
- **Social risks:** Displacement of artisanal fishers
- Human health risks

These include the risks of environmental degradation; introduction and spread of pathogens, pests and invasive species; genetic impacts; unsafe foods; and negative social and economic impacts. The use of risk analysis can provide insights and assist in making decisions that will help to avoid such negative impacts, thus helping aquaculture development to proceed in a more socially and environmentally responsible manner. Risk analysis is less commonly used to achieve successful and sustainable aquaculture by assessing the risks to aquaculture posed by the physical, social and economic environment in which it takes place. Examples of risks to aquaculture from society and the environment:

- **Environmental risks:** Severe weather patterns; pollution (e.g., agricultural chemicals, oil spills).
- **Biological risks:** pathogen transfer from wild stocks; local predators (seals, sharks etc.); toxic algal blooms, red tide.
- **Operational risks:** poor planning, poor design workplace injuries.
- **Financial risks:** market changes, inadequate financing, currency fluctuations, emergence of new competitors.
- **Social risks:** negative image/press, lack of skilled manpower, competition for key resources from other sectors, theft, vandalism.

These include reduction of environmental risks (e.g. due to poor sitting or severe weather events), biological risks (infection by pathogens via transfer from native stocks, predation by seals and sharks; red tides etc.), operational risks (poor planning, work-related injuries), financial risks (e.g., market changes, currency fluctuations, emergence of new competitors, etc.) and social risks (negative image and resulting product boycott, lack of skilled manpower, competition from other sectors). There exists, therefore, considerable scope to develop and expand the use of risk analysis for the benefit of aquaculture and the social and physical environments in which it takes place.

An integrated approach to risk analysis will assist the culture fisheries sector in reducing risks to successful operations from both internal and external hazards and can similarly help to protect the environment, society and other resource users from adverse and often unpredicted impacts. This could lead to improved profitability and sustainability of the sector, while at the same time improving the public's perception of aquaculture as a responsible sustainable and environmentally friendly activity.

Hazards and risks have the potential of affecting people and all human activities have this inherent capacity. Aquaculture is no exception. However, available information is largely on hazards and risks in developed countries. Unfortunately, in the developing countries where 87% of the global aquaculture production takes place both workers, employers, government and

consumers have tended to ignore policies (where present), which could ensure safe aquaculture practice.

In some countries policies to ensure the enforcement of regulatory standards have not been instituted. This has resulted in unregulated aquaculture with the attendant adverse impact. It is our view that aquaculture stakeholders should work in unison to provide guideline and policies that would promote an environmentally friendly and sustainable industry.

CONCLUSION

The risk concept, general Principles, applications of risk analysis, management of hazards and risks in culture fisheries, application of risk analysis to culture fisheries and proffered management strategy to reduce or minimize hazards and risk is inevitable in culture fisheries management and practices.

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