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Environmental issues of Aquaculture development

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ABSTRACT

This article is addressing the issue of aquaculture generated pollution and the need to monitor and control this problem at the international level. The rapid global expansion of intensive aquaculture production creates conditions in which farmed fish can be constantly exposed to pathogens and the use of chemicals such as antibiotics, antifoulants, and disinfectants are regularly required. The global aquaculture growth and intensification of the production method were accompanied by the increased use of therapeutics and antibiotics which as in other agricultural sectors were embraced as the effective way of treating diseases and controlling pathogens and consequently some of the chemicals used in Aquaculture are extremely valuable and required for the welfare and the economic viability of the sector. Antifoulants and *disinfectants* can be released in the aquatic ecosystem. These chemicals are under scrutiny and some are banned for use in European countries. Depending on the methods of administering antibiotics and therapeutics as well as their elimination from the body, these compounds have played a role in the environmental pollution in different ways. The Aquaculture sector can thrive under conditions of water quality which ensures the optimal ecological parameters for the growing fish. Aquaculture is incompatible with environmental degradation, consequently, aquaculture stakeholders are obliged to protect the surrounding aquatic ecosystem in order to ensure the sustainability of the sector. In fact, although aquaculture has been blamed for generating aquatic pollution, the reverse is frequently observed for example when aquatic pollution from other sectors hinders aquaculture production and fisheries.

INTRODUCTION

Based on the rapidly growing population, the climate change, the limited land and water resources, and the collapse of fish stocks, a food crisis is anticipated in our century.

Aquaculture can provide an alternative source of protein and can be a sustainable alternative solution to overexploited wild fish populations.
Aquaculture refers to the farming and harvesting of aquatic organisms such as molluscs, aquatic plants, fish and crustaceans. Aquatic pollution refers to the direct or indirect introduction of energy or substances by man into the aquatic environment, leading to the deleterious impacts that harm the aquaculture and cause health hazards to human health. The rapid expansion of intensive aquaculture production creates conditions which farmed fish can be constantly exposed to pathogens and the use of chemical such as antibiotics, antifoulants and disinfectants is regularly required.

The Aquaculture sector can thrive under conditions of water quality which ensures the optimal ecological parameters for the growing fish. In other words, aquaculture is incompatible with environmental degradation, consequently aquaculture stakeholders are obliged to protect the surrounding aquatic ecosystem in order to ensure the sustainability of the sector. In fact, although aquaculture has been blamed for generating aquatic pollution, the reverse is frequently observed for example when aquatic pollution hinders aquaculture production and fisheries. For example, aquatic pollution from a range of urban or agricultural sources of pollution are released on the aquatic ecosystem with toxic effects for the aquatic ecosystem and the fish reared in fish farms (**Saad *et al.*, 2020**).

Under environmental conditions of low currents, aquaculture can be a source of pollution due to the nutrient load generation of feed waste, organic and inorganic nitrogen molecules (NHX, NOx) and molecular phosphorus. This organic load generated by aquaculture feed can affect in the water column in the vicinity of the aquaculture site (**Mpeza *et al.*, 2013**). Different assessment methods can be applied to monitoring the effects of aquaculture production on the ecosystem. This paper, therefore, seeks to analyze the environmental issues of aquaculture and to advocate on the need for monitoring and controlling aquatic pollution.

Review of the literature

Therapeutics Chemical and Aquaculture pollution

It is important to note that different chemicals are used in aquaculture for increased production. Some of the chemicals used in the aquaculture production include therapeutics, flesh pigments, disinfectants, anaesthetics and compounds for water treatment. Bioactive compounds have been considered a major part of the strategies used in controlling diseases to enhance aquaculture production. For a long time, the failure or success of the intensive production on aquaculture have relied on the right use of bioactive compounds to control the spread of infectious parasites and diseases in aquaculture production (**Hu *et al.*, 2018**). The indiscriminate application of bioactive compounds into the water has been the major concern of aquatic pollution of the environment. More importantly, bioactive compounds have been found to stay long in the human and animal tissues after they have been consumed.

Some of the chemicals used in Aquaculture are extremely valuable and required for the welfare of farmed fish and the economic viability of the sector. These two parameters are particularly depended on some antifoulants and *disinfectants* which unfortunately can released in the aquatic ecosystem. These chemical are under international scrutiny and some are banned for use in European countries. Traditionally, treatment of fish diseases was done through plant-based compounds that had little impact on the pollution of the environment. However, this has since changed in the sense that therapeutics and antibiotics have been embraced as the common way of treating fish diseases, especially in temperate countries. Depending on the methods of administering antibiotics and therapeutics as well as their elimination from the body, these compounds have played a role in the environmental pollution in different ways. Treatment of fish diseases is administered through different ways such as injection, bath or inclusion of food into the food eaten by the fish. In other instances, pesticides have been used to regulate pests in fish ponds such as shrimps. The most commonly used pesticides are of organophosphate compounds. All these compounds are toxic to the aquatic life especially if used in quite high concentrations. Moreover, intensive aquaculture systems have higher demands for chemicals to treat water and enhance the use of drugs for disease management (**Ni *et al*., 2018**). It is the misuse of these drugs and chemicals that lead to environmental impact particularly aquatic pollution. It is even interesting that some species of bacteria have been able to develop resistance to the used antibiotics and end up transmitting the developed resistance to other bacterial species through plasmids. The antibiotic resistance may be transferred to human pathogens and get to the human population through the human gut.

It should be noted that the introduction of chemicals and antifoulants was a necessary step to support the global growth of aquaculture. Antifoulants were mainly used in the 1970s and 1980s to control the growth of fouling organisms particularly on pen and cage nets. Although these chemicals are used less frequently when compared to the old times, there are still fears that their constant use has led to the extensive accumulation of copper- and organotin-based compounds in the flesh of farmed fish, and ultimately affect the human population negatively. In some instances, construction materials tend to releases different substances such as plastic additives and heavy metals into the environment. Nonetheless, these are toxic substances that affect aquatic life despite the protection provide by their slow rate of dilution and leaching, and low water solubility (**Tavakol *et al.*, 2017**). More specifically, mortalities in coastal aquaculture have been caused by the toxicant leaching from the construction materials and adversely affected the environment and the human population.

Chemical used for controlling sea lice and other parasites and pathogens of farmed fish can result in increased concentration and toxic effects on the in the aquatic ecosystem around fish cages (**Costello *et al.*, 2001; Willis *et al.*, 2005**). As a result, the concentration of some aquaculture chemicals in the benthic ecosystem below cages gradually accumulate with potential environmental toxic effects (**Gillibrand *et al.*, 2002**). In Scotland for example, widely used parasiticides are azamethiphos, teflubenzuron , cypermethrin and emamectin benzoate (**SEPA, 2007**). Some of them can be toxic to crustacean, other exibit a range of ecological changes in the benthic ecosystem surroundind fish cages (**Pahl and Opitz, 1999; Bloodworth *et al.*, 2019**).

Interestingly, pollution has heavily characterized some aquaculture operations. Coastal and land-based developments have led to pollution of the aquaculture. Water has been used as a medium for dispersing and receiving excretory products and other waste materials which have been harmful to the human and aquatic life especially if they are allowed to accumulate (**Tavakol *et al*., 2017**). The aquaculture operations have led to pollution through harmful substances which can be toxic to aquatic life, such as quantifiable concentrations of emamectin benzoate were found in blue mussels deployed up to 100 m from the treatment cages (**Telfer *et al*., 2006**). More importantly, natural water treatment is a preferred way of reducing water requirements and improving stocking densities particularly due to its introduction of phytoplankton to encourage increased food production for the fish. Although phytoplankton plays an important role in the control of water pollution and saving the aquatic life through its production of oxygen during photosynthesis, there are instances when it has accumulated and led to the damage of fish stocks (**De Carvalho *et al.*, 2019**). Therefore, the controlled growth of phytoplankton is a great way of controlling water pollution and protecting aquatic life. Excessive growth of phytoplankton is dangerous to the aquatic life since it causes a deficiency of oxygen during the night process of respiration. It is as well important to note the use of toxic substances such as acids, fertilizers, heavy metals and alkali from the mining and industrial wastes and organophosphate and chlorinated hydrocarbons from the agricultural protection of crops. Although these toxic substances may be dissolved in the water, higher concentrations of these substances in water expose human beings to harmful toxin amounts particularly through drinking or eating aquatic organisms.

Fish farms release organic and nutrient-enriching products that primarily originate from faeces and uneaten food (**Mavraganis et al., 2017**). Furthermore, Fish farms regularly use chemotherapeutics to control bacterial and parasitic infections of farmed fish. These chemicals can easily be released into the aquatic environment where they can affect other aquatic organisms and their habitats. Such chemotherapeutics not only have the potential to negatively impact the environment through their effects on sensitive non-target organisms, but they can also alter the population structure of fauna in the immediate environment including the benthic ecosystem.

Intensive aquaculture can cause pollution in temperate climates in the sense that wastes such as uneaten foods in effluents and fish faeces contain high amounts of BODs and particulate matter that deteriorates water quality and lead to the building of anoxic sediments (**Tavakol *et al.*, 2017**). Nonetheless, it is vital to understand these sediments are richer compared to the natural sediments found in nutrients such as carbon, phosphorus and nitrogen. The bacteria decompose the organic matter and lead to anaerobic conditions within a few millimetres of the sediment surface. The organic load of aquaculture activities is mainly due to food, excretory products (faecal and urinary) which can have an impact on the aquatic ecosystem. Nevertheless, aquaculture does not always alter sediment chemistry or microbenthic ecology, as the degree of nutrient enrichment depends on several different factors, including the species inhabiting the vicinity of the cages, the food being offered, management, currents and depth (**Beveridge, 2004**). Aquatic Pollution can in several cases result in oxygen deficiency, generation of hydrogen sulfide, and blooms of harmful plankton. Aquaculture chemical and the organic waste load generated by fish farms can result in the accumulation of suspended nutrients in the water bodies. Waste solids can form sediments, for example below the cages, which can alter the benthic ecosystem with consequences to the ecology of the aquatic body (**Mavraganis *et al.* 2010; Bloodworth *et al.* 2019**). In turn, this increase in nutrients entering the water results in eutrophication, a condition characterised by massive growth of algae and aquatic plants. When these algae die, they are decomposed by bacteria which use dissolved oxygen. Fish communities cannot thrive in low oxygen concentration, and algal blooms have a significant impact on the recreational value associated with reduced water clarity, foul odours and toxicity. The use of pesticides, antifoulants, antibiotics and disinfectants has consequences to aquatic life in the water body.

Ecological interactions and impacts on the food web

It is quite obvious that intensive farming of fish changes in the environment, especially on the tropics. Higher temperatures in the tropics cause a rapid reaction to aquatic pollution. However, there is limited productivity in tropical environments due to the reduced levels of nitrogen and phosphorus (**Yadav *et al.*, 2018**). Increased intake of nutrients discharge of phosphorus and nitrogen is likely to cause eutrophication since phosphorus or nitrogen limits productivity in a freshwater environment, leading to an improved algal density (**Mavraganis et al., 2017**). Cyanobacteria and other species that have a high tolerance for P: N ratios are quite likely to dominate temperate waters and alter the structure of the phytoplankton community to affect both the autotrophic food webs and quality of the water (**Laws, 2000**). In most cases, eutrophication is recognized through too many algae that turn water in the green soup. However, this is not the case in the tropics where there are floating macrophytes vegetation such as *Salvinia*, *Pistia* and *Eichhornia.* Macrophytes are quite common in shallow ponds where there are chances for light penetration to the bottom during the season for early growth. Excessive growth of macrophytes lead to the restriction of water circulation, restrict the circulation of water, contribution the depletion of oxygen and fish deaths after the death of plants.

Farmed fish can be a source of genetic pollution for wild stocks. The possible accidental escape of farmed animals can have detrimental consequences for the thriving of the local fish populations. Transmission of pathogens, alteration of the local fish fauna species composition, competition of the introduced fish for food and spawning grounds as well as possible genetic pollution of the local stock with genetic material not relevant to the particular local ecosystem are among the well-constituted negative impacts of accidentally or even intentionally released farmed fish **(Hashem et al., 2020**; **Cossu *et al*., 2019**). The farmed fish are often infected with parasites and interact with wild fish populations, because the wild reside nearby and feed on the dispersed uneaten food, as a consequence they are also infected by those parasites (**Tayel *et al.*, 2020**).

Monitoring methods for aquaculture pollution

The natural fisheries around the world have been depleted, making it necessary for different implementation of commercial fishing moratoriums in different parts of the world as the population continues to grow. It is no secret that aquaculture has been growing quite rapidly for food production purposes. Over time, aquaculture has yielded a substantial amount of shellfish and fish to help in feeding the constantly growing population and the increasingly growing appetite for the seafood (**Singh *et al.*, 2019**). Therefore, it is necessary to understand the monitoring methods that will control aquaculture pollution across the world. Different methods can be used for effective monitoring of aquatic pollution and reduce its harmful impacts on the environment.

Monitoring methods on aquatic pollution can be achieved through different tools such as sampling handheld water quality instruments that allows a fast check of the water conditions, as well as the use of continuous multiparameter and monitors that are essential in the helping in the process control for the monitored facility. Therefore, the techniques used to measure and analyze any potential impact must also consider these factors. **Dar and Bhat,** (2020) observed that the best monitoring program would provide an indication of the environmental status of an area using a sufficient number of variables and samples. The monitoring program should consider the natural conditions of the area and assess the environmental impact of the fish farm. This is important, as some aquatic environments receive natural inputs of organic material (e.g. leaf litter) or human inputs that are not related to aquaculture (e.g. agricultural run-off). If these inputs are not acknowledged, then aquaculture could be unfairly blamed for additional organic loading (**Voulvoulis and Georges, 2016**). Sediment ecological Indices are used by environmental regulators throughout the world as standards or for defining certain environmental criteria for sediment quality. Sediment samples are subjected to a variety of different univariate indices as each has different strengths and weaknesses in defining sediment impact (**Cappello, 2018**).

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Pearson & Rosenberg (1978) and **Grizzle & Penniman** (1991) investigated the relationship between nutrient loads and estuarine macrofauna. They observed that near the source of pollution, the numbers of taxa (S) was decreased, but abundance (A) and biomass (B) increased. With pesticides, S, A and B are all decreased near the pollution source (**Kingston, 1992**). Changes in these ecological indices of benthic species can be used to compare sites below and further away from fish farms and the concentration of nutrient or toxic chemical in the benthic ecosystem. These levels ussualy correlate well with the aquaculture intensity (e.g biomass of fish, feed supply) (**Telfer *et al.*, 2006**).

The Azti's Marine Biotic Index (www.azti.es) (AMBI) (**Muxica *et al.*, 2005a&b**). is a biotic index which can be used to asses biotic factors of benthic species. This index is calculated with dedicated softaware and it classifies the benthic ecosystem according to their ecological status to 7 levels: Benthic ecosystem with 1-2 level is slightly disturbed; 3-4 level is moderately disturbed; 5-6 level is heavily disturbed and level 7 is extremely disturbed (**Borja and Muxica, 2005**). The AMBI score can be used to characterise the ecological status and the extent of the ecological degradation (**Muniz *et al.*, 2005; Muxica *et al.*, 2005b**).

Bioenergetic models can provide an indication of the nutrients released in the aquatic ecosystem by fish farms and the effect on the aquaculture impact and to compare with the Environmental Quality Standards or alternatively with Limit of Quantity (EQS, LOQ) of the organic loading, especially on the intensive land based fish farming (**Aubin *et al.*, 2011; Osti *et al*., 2016; Tahar *et al.*, 2018**). In this approach, the monitoring happens with the estimation of the annual farm loading and then comparing it with the limits or the standards, set by regulative organizations, of these loads to assess the impact.

CONCLUSION

Aquaculture is an obvious potential solution for providing precious meat for a rising human population but the sustainability of the sector lies on understanding and serving the interaction between aquaculture and the environment. Aquaculture is one of the diverse productions industries that involve multiple species, different husbandry and production methods. Aquaculture development with no concern for sustainability leads to ecological collapse and increased diseases in the farmed fish, a combination which in turn leads to poor economic returns. It is for this reason that the Aquaculture sector needs to maintain a wealthy relationship with the aquatic ecosystem for the sustainability of the sector. There is a range of methods available to monitor the environmental impact of aquaculture. Constant monitoring is required to safeguard both the sustainability of the ecosystem and the sector. At international level, Marine aquaculture is monitored and regulated through national and international legislations. However, these legislations vary significantly between regions and countries around the world. For example, some antifoulants and *disinfectants* may be banned in the countries of the EE but widely used in nearby non member countries. There is a need for international collaboration in this issue. This effort can benefit from research on the monitoring methods and programs particularly those that are linked to the approach of the ecosystem at larger scales.

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