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ENVIRONMENTAL FRIENDLY AQUACULTURE KEY TO SUSTAINABLE FISH FARMING DEVELOPMENT IN NIGERIA

[1] Akinrotimi, O.A.; [2] Abu, O.M.G; [3]Aranyo, A.A.
[1, 3,]African Regional Aquaculture Centre/Nigeria Institute for Oceanography and Marine Research, P.M.B. 5122, Port Harcourt, Rivers State. [2]Department of Animal Science and Fisheries, Faculty of Agriculture, University of Port Harcourt, Port Harcourt, Rivers State, Nigeria.

ABSTRACT
Aquaculture production in Nigeria has increased tremendously in recent times; along with this increase is the rise in the level of waste outputs from aquaculture practices. The discharge of waste from aquaculture operations on continuous basis leads to eutrophication and destruction of natural ecosystem in receiving water body. Controlled wastes production strategies is necessary to maintain sustainable aquaculture growth into the future, as long-term sustainability of fish culture systems depends on their ability to reduce their waste outputs. The release of solid wastes is mainly a function of the digestibility of various dietary components while the release of dissolved wastes is mainly a function of the metabolism of nutrients by the fish. This paper critically reviews the impacts of aquaculture wastes on the environment and the strategies to mitigate the effect of these impacts. Future trends and research needs on aquaculture induced effluents are outlined. As the amount of nutrient discharge is typically site and operation specific, effective farm management has been identified as the most important factor to avoid effluent pollution.

Keywords: Aquaculture, environment, fish, farm effluents, sustainable development

INTRODUCTION

Fish is very important in the diet of many Nigerians, high in nutritional value with complete array of amino acids, vitamins and minerals (Akinrotimi, et al., 2007a). In addition, fish products are relatively cheaper (Table 1) compare to beef, pork and other animal protein sources in the country (Amao *et al.*, 2006). FAO (2007) reported that fish contribute more than 60% of the world supply of protein, especially in the developing countries. In Nigeria, fish supply is from four major sources *viz.*, artisanal fisheries, industrial trawlers, aquaculture and imported frozen fish (Table 2). Production from aquaculture is increasing compared to artisanal sources and supplied between 5 – 22% of total domestic fish production between 2000 – 2007(FDF, 2007). This increasing production is not able to meet the increasing rate of consumption because of the wide gap between fish demand and supply (Table 3), which is on the rise as a result of population explosion in the country in recent years (Falaye and Jenyo-Oni, 2009).

Aquaculture in Nigeria, which started in Panyam fish farm in Jos in 1951, has now spread to all parts of the federation, encompassing all aquatic environments and using a range of aquatic species. From an activity that was principally small scale, non-commercial and family based, aquaculture now includes large scale commercial and industrial production of high value species that are being traded at local, regional and international levels (Akinrotimi *et al.*, 2010a). Although production in the country is largely based on small-scale operations in most parts, there is a wide consensus that aquaculture has the potentials to meet the growing demand for nutrition food fish, contribute to the growth of economy and support the sustainable livelihoods of many communities, especially in the rural parts of the country (FAO, 2006).

As the aquaculture becomes more intensive with corresponding increase in wastes output, the effect of these wastes on the receiving environment has been a crucial issue, generating a lot of concern among the aqua culturists, environmentalists, fishery biologists and the general public. This paper critically reviews the incidence of aquaculture mediated pollution and its effects on the environments.

Table 1: Average Prices of some commonly consumed meat products in Southern Nigeria

Meat product	Year		
	2000 N. K	2003 N. K	2010 N. K
Beef	300.00	500.00	800.00
Pork	280.00	380.00	700.00
Chicken	380.00	500.00	750.00
Goat meat	400.00	500.00	800.00
Cat fish	350.00	400.00	500.00
Tilapia	200.00	280.00	350.00

Source (FDF, 2008)

Table 2: Nigeria fish supply by sector

Sector	2000	2001	2002	2003	2004	2005	2006	2007
Artisanal	418,069.00	433,537	450,965	446.203	434,830	513,537	53,332	504,227
Aquaculture	25,720	26,398	30,664	33,667	43,950	56.355	84,523	85.087
Industrial trawler	23,308.3	28,378	30,091	33,882	30,421	33,778	33,778	28,193
Imported Fish	557,884	681,152	663,180	663,152	611,152	646,484	646,484	737,666

Source (FDF, 2007)

Table 3: Projected Human Population, Fish Demand and Supply in Nigeria (2000 – 2015)

Year	Projected Population (Million)	Projected Fish Demand (Tonnes)	Projected Domestic Fish Supply (Tonnes)	Deficit (Tonnes)
2000	114.4	1,430,000.00	467,098.00	962,902.00
2001	117.6	1,470,000.00	480,163.60	984,836.40
2002	121.0	1,412,500.00	507,928.20	1,004,572.00
2003	124.4	1,555,000.00	522,627.10	1,063,082.60
2004	128.0	1,600,000.00	536,917.60	1,063,072.40
2005	131.5	1,643,750.00	552,433.10	1,091,317.00
2006	135.3	1,691,250.00	567,948.60	1,23,301.40
2007	139.1	1,732,750.00	583,872.40	1,154,873.00
2008	143.0	1,782,300.00	600,612.80	1,186,887.20
2009	147.1	1,838,750.00	617,353.20	1,221,397.00
2010	151.2	1,810,000.00	634,500.20	1,255,440.00
2011	155.5	1,943,750.00	652,606.60	1,291,143.00
2012	160.0	2,000,000.00	689,958.00	1,328,508.00
2013	164.0	2,113,750.00	709,683.10	1,365,042.00
2014	169.1	2,175,000.00	730,248.00	1,404,067.10
2015	174.0	2,055,000.00	671,492.30	1,444,752.10

Source: (FDF, 2008).

INTENSITY OF AQUACULTURE PRODUCTION

In many parts of the globe the aquaculture activities has increased giving rise to global efforts to eliminate hunger and malnutrition by supplying fish and other aquatic products rich in protein, essential fatty acids and minerals (FAO, 2007). Aquaculture production in the world has grown tremendously over the past 10 years from production of less than one million tones in the early 1950 to 48.11 million tones in 2005 (Table 4). Asian and the Western Europe contributed the highest volume of production in the world, while sub Saharan contributed the least. Despite the low aquaculture production in sub-Saharan Africa, some improvements are taking place, when compared to the past production trends (Gabriel *et al.*, 2007).

Through out Nigeria, the last few years witnessed a rapid expansion in aquaculture. Available data showed that fish production from aquaculture ranges from 15,840 metric tonnes in 1991 to 25,720 mt in the year 2000 and 86,350mt in 2009 (FDF, 2010). However, there exists evidence that substantial part of fish production from home stead farms, rural aquaculture and small scale fish farms scattered all over the country are not documented (Akinrotimi *et al.*, 2007a) However, Anetekhai, (2004) observed that production varies from 0.5mt/ha in small scale to as much as 10mt/ha in large scale for earthen ponds and this largely depends on level of management intensity.

The culture of clariid catfish has grown rapidly in the country since 1985 and this species is grown by both small-scale and large – scale fish farmers in all the states of the federation with a total production of 61,916mt valued at US86 million in 2007 (Table 5) making Nigeria the largest producer of catfish in Africa, and third in the world (FAO, 2009).

With the introduction of tank culture cum flow through, enhanced by water recirculation systems, there has been a considerable increase in production of fish per unit area throughout the federation. The level of growth and intensification witnessed in aquaculture recently has raised several environmental issues that need to be addressed in the context of the sustainability of the aquaculture industry.

Table 4: Aquaculture Production (volume and value) in 2005 in different region of the world

Country/Region	Production volume (million tones)	Production volume (%)	Production value US$	Production Value (%)
China	32.4	67.3	35.99	51.22
Rest of the Asia Pacific	10.7	22.3	20.6	29.3
Western Europe	2	4.2	5.42	7.72
Latin America and the Caribbean	1.4	2.9	5.24	7.47
North America	0.6	1.3	1.3	1.86
North Africa	0.6	1.2	0.83	1.19
Central and Eastern Europe	0.3	0.6	0.67	0.91
Sub-Saharan Africa	0.1	0.2	0.25	0.36
World total	48.1	100	70.3	100

Source: (FAO, 2006)

AQUACULTURE, ENVIRONMENT AND SUSTAINABILITY

Aquaculture practices as a business venture is capable of bringing significant development in the rural and urban areas by improving family income, providing employment opportunities and reducing problems of food supply and security (Akinrotimi et al., 2009). However its dependence on national resources from the environment and its potential for placing greater demands on these may place it in direct competition and possible conflict with other demand such as environmental issues (NACA/FAO, 2001).

Out of the intricate web of factors influencing third world countries sdevelopment, environmental matters are assuming a position of top priority. The constraints that resources degradation places on prospects for economic development are so apparent that environmental consideration once viewed as luxuries that developing countries could hardly afford are now necessities no country can ignore (Raji, 2007). This is very critical because, the objectives of development which are normally geared towards establishing appropriate patterns of growth and raising standard of living standard often set in motion, process that tend to be destructive to the environment (Raji, 2007; Obasohan, 2009). The world conservation strategy (IUCN, 1980) noted that development that is inflexible and little influenced by ecological considerations is unlikely to make the best use of available resources.

Table 5: Production of Cultured Clarrid cat fish in best 20 countries in 2001

S/N	Country	Quantity (t)
1	Thailand	146,000
2	Indonesia	77,332
3	Nigeria	61,916
4	Uganda	20.941
5	Malaysia	18,486
6	Netherlands	4,800
7	Philippines	2,376
8	Hungary	1,724
9	Syria	1,030
10	Cambodia	800
11	Poland	380
12	Brazil	362
13	Kenya	302
14	Mali	300
15	Belgium	250
16	Togo	200
17	Romania	118
18	Italy	115
19	Cameroon	110
20	South Africa	100

Source: FAO (2009)

There is therefore, a rising demand worldwide for economic growth and productive development, which have been accompanied by increasing public sensitivities to environmental impact (UNDP, 1994). The 1992 United Nations Commission for Environment and Development Conference brought these issues to wider public attention and political focus, resulting in a serious commitment for environmental protection and sustainable development.

Sustainable development has become an overriding strategic issue in developing countries where much consideration was not given to environment management in the past (FAO, 2004). Sustainable development as a concept has been described as development that meets the needs of the present generation, without compromising the ability of future generations to meet their own needs (WCED, 1987; Annick, 2000). Hence, the need for sustainable developments of aquaculture in Nigeria is crucial and urgent to avert further environmental degradation consequent of aquaculture pollution. Therefore, adoptions of developmental policies and practices that will ensure environmentally sustainable technologies and resources efficient farming systems are necessary for optimum performance of fish in culture medium (Oribhabor and Ansa, 2005).

AQUACULTURE WASTE OUTPUTS

Aquaculture wastes by definition, includes all materials that are not removed through harvesting. The principal wastes being uneaten feed, excreta, chemicals and therapeutics (Bergheinm and Asgard 1996; Sindilario, 2007). Aquaculture wastes outputs and loads vary widely, depending upon the species cultured, farming system and the aquatic environment employed (NAA, 1998; Boyd and Queroz, 2001). Amirkolaie (2011), noted that the waste produced in aquaculture farm operations can be divided into solid and dissolved waste The solid wastes can further be divided into settle able and suspended solids. Solid wastes as reported by Brinker *et al.,* (2005), originated mainly from uneaten or spilled feed and from the excreted faeces. While the dissolved wastes consist of ammonia, phosphorus and metabolites excreted by the fish and also the suspension of nutrients from the solid waste fraction dissolved in the culture water (Amirkolaie, 2005). The quality of effluents released from some fish farms is comparable to polluted fresh water and domestic waste water (Table 6).

In many aquaculture systems, about 20 to 40 % of the dietary dry matter is incorporated into the fish body during feed assimilation and the rest excreted (Brinker, 2008). The proportion excreted of uneaten or spilled feed, ranges between 5 and 15% (Cho and Bureau, 1997; Ogunkoya *et al.,* 2006). The amount of feacal wastes released in aquaculture ranges between 0.2 and 0.5kg dry matter per feed and this depends on fish species, culture systems, feed composition, feeding regime, water temperature and culture medium (Chen, *et al.*, 1997; Bureau and Hua, 2010).

Waste water outputs in all aquaculture systems are discharged with the effluent water (Tacon and Forster, 2003). Akinrotimi *et al.* (2007b) reported that the amount, frequency and composition of the waste discharged with the effluent water differ between the various types of culture systems, and husbandry practices employed. (Table 7).

The culture system commonly practiced in Nigeria includes stagnant tank, flow through, earthen pond and water recirculation systems. In stagnant and flow-through tank culture systems all dissolves wastes and suspended solid are released into the environment on continuous basis throughout the production cycle. On the other hand, wastes from earthen pond are released periodically in most cases at the end of production cycle and consist of a mixture of inorganic and organic particulate materials (Akinrotimi *et al.,* 2007c). While in the recirculation system Gabriel *et al.* (2009) observed that the wastes released is low, compared to tanks and earthen pond culture.

Apart from wastes from feed nutrients, metabolites and plaktonic biota, depending on management practices; and culture systems being practiced, waste waters from aquaculture may also contain residues of some chemicals, such as, medicants, feed additives, antibiotics, fertilizers, disfectants, hormones, therapeutants and anaesthetics (Table 8), commonly applied during farm operations (Subasinghe *et al.,* 2001; Schneiders, 2006; Raque d' Orbacastel *et al.* 2009).

Table 6: The quality of fish farm effluent, river water and domestic waste water

Parameters	River water	Fish farm effluent	Domestic waste water
BOD (mg/l)	1.0 – 5.0	3.0 – 2.0	300
Total N (mg/l)	1 – 2	0.5 – 4.0	75
Ammonia N (mg/l)	0.11 – 0.5	0.2 – 0.5	60
Total P (mg/l)	0.02 – 0.10	0.05 – 0.15	20
Suspended solid (mg/l)	25 – 60	5 – 50	Sw

Source: (Warrer – Hansen 1982)

Table 7: Composition of Waste Water discharges from different culture system

Effluent nutrient concentration (mgl^{-1})	Culture system			
	Stagnant	Flow through	Water Re-circulation system	Earthen pond
Total nitrogen	2.46	1.81	0.91	1.90
NH_4 – N	0.32	0.20	0.08	0.21
$N0_2$ – N	0.018	0.07	0.001	0.009
$N0_3$ – N	1.42	0.88	0.02	0.98
Total phosphate	0.053	0.040	0.006	0.047
Phosphate	0.038	0.021	0.010	0.030
Total solids	9.0	6.8	2.0	7.2

Source: (Akinrotimi et al., 2007d)

Table 8: Major Chemicals used in Aquaculture Practice

Category	Examples
Fertilizers	Inorganic – NPK, nitrates, phosphates, ammonium compounds Organic – urea, poultry waste, animal dump
Disefectants	Hypochlorite, iodophonres, ozonation, formalin
Antibacterial agent	Amoxylin, tetracyclines, oxytetracycline, doxycline, flomequine
Therapeutats	Acriflavine, glutaraldehydes, levamisole, niclosamide
Antioxidants	Butylated hydoxyanisole, butylated,ydroxytoluene, propylgallat
Feed bindders	Lingnin, beftonite, magnesite
Feed Enzyme /Growth promoter	Dietary phytase
Probiotics	Prolife, Prostant
Anaesthetics	Metomidate, M222, benzocine, quinaldine
Hormones	Ovaprim, ovatide, methyldesterone, oestradiol

Source: Gesamp, 1997; Boyd and Massent 1999; Barrows, 2000; Hua and Bureau, 2006)

IMPACTS OF AQUACULTURE WASTES ON THE ENVIRONMENT

As a result of the growth and expansion witnessed in aquaculture industries over the past decades, much attention has been given to the environmental effects of such activities (Fernandes *et al.,* 2001). This is because rearing fish in an intensive manner involve the transformation of dietary inputs into fish biomass, this process generates wastes, which are in many cases difficult to contain and recover (Pandey and Satoh, 2008). The release of wastes in the form of effluents into aquatic ecosystem results in alterations of the receiving environment. The magnitude of these changes as Akinrotimi *et al.* (2010b) noted, mostly depends on the types of feed, feeding rate and frequency, culture systems, and physico-chemical and biological characteristics of the receiving environment. Reid, *et al,* (2008) also reported that different water bodies will react differently to influx of the same amount of certain wastes. The response in fresh water will be different from that of marine environment. The environmental impact of aquaculture is seen in a variety of ways, some of which are highlighted as follows:

1. Eutrophication

Ecosystems of water body can show a typical reaction or shift in the river continuum when disturbed by nutrient rich fish farm effluents (Loch et al., 1996). Effluents with high organic loads show a dominance of heterotrophic bacteria and sewage fungi suppressing the primary production (Villanueva *et al.,* 2000). The heterotrophic dominance is followed by an increased primary production measures as chlorophyll. The increase is related to the inorganic total nitrogen and total phosphorous enrichment (Fries and Bowles, 2002). The heterotrophic and eutorophic change is often accompanied by a shift in the macro invertebrates community from intolerant, species upstream the discharge point, to nutrient tolerant species, indicating an ecosystem degradation (Selong and Helfrich, 1998).

2. Reduction in Dissolved Oxygen (D0) Level

Release of aquaculture wastes into the aquatic ecosystems results in overproduction of organic matter and its subsequent decomposition usually leads to reduced dissolved oxygen concentrations in the bottom water strata and sediments of aquatic ecosystems. Viadero *et al.* (2005) observed that typical values of dissolved oxygen content in trout farm effluent is between 1.26 and 3.2mg^{-1} and when released into the receiving water body it further reduces the DO values below 5mg^{-1} especially in a environment with poor waters mixing situation, which may impose a stressful condition on fish (Schaperclaus *et al.,* 1990; Mailland *et al.,* 2005).

3. Production of toxic micro-organisms

Constant flushing of fish farm effluents into the receiving waters have been reported to stimulate the production of some toxic algae such as cyanobacteria, dinoflagellates and diatoms (Bureau and Hua, 2010). The toxins produced by algae can remain inside algal cells or they may be released into the surrounding water. Aquatic animals may be affected through drinking the water or ingesting algal cells through feeding activity. These algal toxins can be also bioaccumulated and biomagnified through food chains and food webs and reach toxic levels in some organisms meant for human consumption (Camargo and Alonso, 2006).

4. Direct toxicity on Aquatic animals

Nitrogenous wastes is a major component of aquaculture wastes, which can directly result in deleterious effect most especially unionized ammonia which is very toxic to aquatic animals, particularly fish. (Green *et al.,* 2002). Also nitrite can have a toxic effect on aquatic animals, it interfere with the oxygen carrying capacity of haemoglobin, leading to the oxidation of haemoglobin to methaemoglobin (Carnago and Alunso, 2006). Ammonia has been reported to induce high level of toxicity in fish even at low concentrations. Toxicity of ammonia to culture fish in aquaculture is a determinant factor of waste water treatment methods and exchange requirement of land based aquaculture operations (Brinker, 2009). Stephen and Farris (2004), noted that elevated ammonia concentrations can lead to blood ammonia intoxication or autointoxication in fish, and destruction of downstream communities in aquatic environment. High ammonium concentration leads to an ionic imbalance in the blood and acid-base distribution in the systems of the fish (Twitchen and Eddy, 1994).

5. Interstitial Clogging and Substrate embeddedness

Suspended solids from aquaculture wastes deposited in the receiving water bodies have been reported to cause interstitial clogging and substrate embeddedness (Selong and Helfrich, 1998; Magnt et al., 2008). In the deposited sediments, heterotrophic bacteria show profuse growth leading to additional interstitial clogging and deoxygenation, as well as increase in colony-forming units (Carr and Goulde, 1990). This phenomenon if continues unabated will have deleterious effects on the benthic organisms that are found in the receiving water bodies.

6. Disrupts fish assemblage in the wild

Disruption of fish assemblage in the natural environment is one of the effects of aquaculture wastes discharges into the environment Oberdorff and Purches (1994) and Prevost (1999) described changes in the natural population of various species of fish as a result of continuous discharge of trout farm effluent into Brittanu rivers. These authors discovered alterations in the index of biotic integrity based on 10 fish assemblages proportional to elevated dissolved nutrient concentrations, due to discharge from trout farms. The fish assemblage changes to pollution tolerant and exotic species (*Rutilus rutilus*) in the trout farm influenced areas, while pollution sensitive species such as *Cottus gobio* and *Salmo salar* were reduced in abundance.

7. Reduces aesthetic value of the environment

Continuous discharge of aquaculture wastes into the environment especially land based aquaculture have been reported to reduce the aesthetic value of the environment. Akinrotimi *et al.,* (2009) reported that effluent from some catfish farms in Port Harcourt metropolis in Rivers State, Nigeria that is constantly released into the environment, leads to destruction of the aesthetic value of the surrounding, with putrefying odour emanating from these areas. The release of these wastes on continual basis can lead to the buildup of some pathogenic organisms and results in the outbreak of epidemic disease.

STRATEGIES TO REDUCE THE IMPACT OF AQUACUTLURE WASTES ON THE ENVIRONMENT

The negative impacts of wastes from aquaculture on the environment do exist. Therefore strategies that will reduce and mitigate these effects is crucial to the sustainability of aquaculture venture in Nigeria and some of which are highlighted as follows.

Proper Planning of Fish Farms

While establishing fish farms, there should be proper planning concerning the issue of waste management procedures. According to Milden and Redding (1998) effluent treatment possibilities should be included in the facility in the planning stage itself in order to reduce the effluent loads and make the treatment more efficient for example the use of dual drain tanks to concentrate settable solids into a smaller, more effectively treated flow, which lead to an overall improved effluent (Summerfelt *et al.,* 2004). At the planning level, some factors such as, land topography, scale of production, culture species and production function of the farm must be taken into consideration for effective waste management. The level of urbanization of the farm location is also a cogent issue, This means, that there must be effective planning, which must be based on good knowledge of the environment, such as water bodies, benthic conditions and the wider aquatic ecosystem as well as surrounding land areas(Akinrotimi, *et al.,* 2009).

Good diet Formulation

Digestibility of the ingredients and nutrient composition of the diet are the main factors affecting waste output in an aquaculture production system. Hence, minimizing waste output from fish in culture medium should therefore start at the source which is diet formulation and processing (Cho and Bureau, 2001). This is because, solid wastes in fish farm consists mainly of fiber from grain and plant ingredients that are not easily digestible by the fish. Reduction of solid wastes output from aquaculture operation can be achieved by using highly digestible ingredients with high protein and lipid contents (Bureau and Cho 1999) and excluding poorly digested grain by-products. This would increase palatability, digestibility and energy density of the feed and will go a long way in reducing the feed conversion ratio of the fish, thereby enhancing good carcass weight gain and consequently lowers solid wastes output in the culture medium (Bureau and Cho, 2010).

Improve Feeding Strategy

Feeding strategy or regimes involves the method, rate, and frequency of feeding fish. The feeding strategy deals with alternatives to reduce the uneaten feed and increase feed efficiency. This is because feed wastage and feed ratio are highly correlated; leading to high levels in waste production at higher feeding rates (Van der Meer *et al*., 1997). Hence for efficient management of waste production, *ad libitum* feeding is not advisable. Feeding should be done based on standard feed chart for each species (Cho and Bureau 1997) and should stop near satiation under close-look.

Different strategies have been used by many fish farmer s to deliver feed rations to fish and also to monitor feed intake, so as to reduce feed losses in the culture medium (Cripps and Bergheim, 2000). Hand feeding is the oldest and most commonly used method in fish feeding, especially in the developing countries of the world. This may be an efficient technique in terms of conversion of feed into waste as feed delivery stops when fish approach satiation. There are other feeding methods such as fixed feed ration systems and demands feeders. The choice to be adopted according to Summerfelt *et al.* (1995) is based on fish size, feeding behaviour, scale of operation and cost. However, demand feeders are suitable for a large-scale fish farm to deliver high rates of feed with the least amount of waste.

Feeding regimes in fishes are subjected to variations in feed intake within a day or between days, months or years (Jobling and Boardwith, 1991). Therefore, to reduce waste output, optimal time for feeding should be adjusted according to the daily feeding activity of the species (Bolliet *et al.*, 2001). For example, in salmonids, feeding activity is concentrated during the day (Helfman, 1993), while catfish feed more at night (Gabriel *et al.*, 2007). Feeding frequency also determines the rate of waste output in aquaculture. Akinrotimi *et al.* (2010b) reported that for optimum performance in the culture medium and to reduce waste output, farmers should not feed their fish more than three times in a day.

Practice of Integrated fish farming

Integrated fish farming is a diversified and coordinated way of farming with fish as main target (Ayinla, 2003). This involves combination of animal husbandary or crop with fish production in a farm simultaneously. Akinrotimi *et al.* (2005) reported that in some parts of the country, especially in the rural areas, there is combination of fish production with planting of arable crops such as vegetables, whereby the effluents from the fish pond are released into the farm to serve as manures. This system promotes optimal utilization of resources and environmental sustainability. Moreover, Akinrotimi *et al.*, (2010c) equally observed that many species of vegetable can grow well in waste water discharged from intensive fish farms. Thereby reducing the nutrients and particulates loads to the environment.

Recycling aquaculture waste

The wastes excreted by fish in forms of dissolved nitrogen and phosphorous material can be re-used inside the system and converted into valuable products for the fish (Graber and Junge, 2009). When fish are fed, they can retain 20-50% Nitrogen feed and 15 – 56% phosphorous in feed (Shneider *et al.*, 2004). The remaining of these minerals are released in the surrounding water and can be converted into useful items by phototrophic and heterotrophic organisms (Schneider, 2006). The bio-treatment of waste water with algae to remove nutrients such as nitrogen and phosphorous has long been recognized as a solution to convert dissolved wastes into harvestable products (Borowideka and Borowilzka, 1980; Komer and Vernaat; 1998; Verdegem *et al.*, 2003). The conversion of nutrients into good products which can be utilized again in fish production caused a significant decrease in the output of dissolved wastes into the environment.

Good farm Management

Effective management practices have been recognized as key to environmental sustainability of a fish farm (Akinrotimi *et al.,* 2010d). This is based on the hydrographic character of the farm site and the degree of impact, which is as a result of assimilative and dispersive capacity of the farm location and production capacity of culture systems. Farm sites with good water exchange should be selected; if possible in order to reduce fish farm related environmental impacts (Crozier, 2000). Good management practices should be practiced so as minimize feed wastage in order to reduce environmental impact of aquaculture. Also farms should be encouraged to have soak-away pits to reduce the discharge of farm effluents into the environment. The overall management of aquaculture operations should aim towards the development of best environmental practice, which can be defined as the implementation of procedures that would ensure the sustainable management of aquaculture.

Regular Monitoring of Fish Farms

Monitoring practices must be adopted, which must be based on the species of fish, culture systems, culture techniques, nature and uses of the environment. Monitoring activities can be applied at different stages of the farming activities that are, pre-operational, operational or post operational stages and must consider the various interests of the public, regulators, farmers and scientists.

There should be regular monitoring of farms operations in aquaculture from time to time. The monitoring programme should target three main interest groups: the scientists, the regulators and the farmers, each of them is responsible for contributing and extracting different types of information (Fernandes *et al.,* 2001). The regulator agencies are to develop easily enforceable best environmental practices that complied with the international standard, and set environmental quality objectives so that the environment can be monitored and regulated in such a way that these objectives would be achieved (Ackefors, 2000, Schneider *et al.* 2004).

The scientists in monitoring fish farms are to collect data from various farms, based on standard principles and methodology. They are responsible for keeping the monitoring programmes updated in terms of relevant research findings. From the farmers' point of view, the purpose of monitoring programme is to achieve affordable, applicable, useful and easily understandable best environmental practices, where farmers will be exposed to short and long term training to ensure that the farmer has up to date information and understands the implication of the farming operations (Maroni, 2000).

CONCLUSION

For aquaculture to be sustainable, production systems must focus on the interactions between the culture techniques and the environment. It is pertinent to note that the growth and the expansion of aquaculture as an industry occurred during a period of growing concern of its environmental implications. As a result, the sustainability of aquaculture practices has come into increasing scrutiny for social equity, ecological integrity and long term economic viability. The social implications generally becomes evident from the very early stages of farm development, but the ecological impacts may take a much longer time to unravel and the reducing effects may be monumental.

Against this background, it is widely accepted that aquaculture requires a framework of regulations to ensure sustainability and minimize potential environmental impacts. Good management is therefore essential so that any aquaculture activities fit in a sustained manner within the environmental policies that will enhance harmonious operations of aquaculture practices in a particular locality.

Regulatory activities must focus on the overall impact of aquaculture on the environment. In this regard regulations must conform to national policy and international standards. For instance in Nigeria the Federal Environmental Protection Agency (FEPA) has powers on matters relating to environmental protection. It is on record that effluent limitations for non-point and point sources have been established, for the practices of environmental friendly aquaculture which will ultimately leads to sustainable fish farming with no negative impact on the environment.

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Corresponding author
Akinrotimi, O.A.
African Regional Aquaculture Centre/Nigeria Institute for Oceanography and Marine Research, P.M.B. 5122, Port Harcourt, Rivers State, Nigeria.
E-mail: ojoakinrotimi@yahoo.com