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Wastewater aquaculture as a form of environmental pollution control in Nigerian cities

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ABSTRACT: In most cities in Nigeria, Industrial and Domestic effluents are discharged indiscriminately into the environment. In city slums, the usual practice is for people to live side by side with the waste they produce (both liquid and soilid waste) thereby leaving them at the mercy of diseases. In highbrow areas of cities, wastes may be properly drained but channeled into streams, rivers and lakes with the resultant damage to aquatic flora and fauna. Industrial effluents are usually of channeled into water bodies and the cost in terms of fish kills is enormous. The problem is exacerbated by the inaction of government agencies concerned with environmental pollution. This study presents wastewater-fish farming as a possible method of pollution control in Nigerian cities. It reviews previous work done in this area and looks into the possibility of applying them in Nigeria and assesses the profitability of such systems.

Key Words: Environmental pollution; Wastewater; Aquaculture; Industrial effluents; Domestic effluents.

Introduction

There are four broad groups of integrated fish farming systems viz: Plant-fish; Animal-fish; Anima-Plant-fish and Wastewater-fish farming (Nnaji, 2002). Wastewater includes effluents from industrial, agricultural and domestic activities. The global environment monitoring system (GEMS), states that sewage, nutrients, toxic metals, industrial and agricultural chemicals are the main water pollutants with organic matter in domestic sewage being the most widespread pollutant. It estimates that 25,000 deaths a day are caused in developing countries either by direct consumption of polluted water or indirectly by contraction of diseases like Malaria and Bilharzia through disease vectors that live in polluted water (UNEP, 1991).

Effluents from human activity in Nigerian cities can be channeled into areas where they can be treated and used to culture fish and grow crops, which will add to the overall national agricultural production. This study also considered the use of *Lemna paucicostata* (Duckweed) in wastewater (sewage) control.

The Problem of Pollution in Nigerian Cities

There is air, water and land pollution. We are concerned with water pollution. Water quality is determined by parameters like Faecal coliforms; Biochemical Oxygen Demand (BOD); Chemical Oxygen Demand (COD); Nutrients content (nitrates, phosphates etc0); Dissolved oxygen (DO); Suspended Matter; Salinity; Acidity; heavy metal content and Organic micro pollutant content.

The problem of pollution in Nigeria is indeed a serious one. Osae-Addo (in West Central Africa Dept., 1995), reported that about 80% of Nigerian industries discharge their waste (solid and liquid waste) directly into the environment without treatment. Again only about 18% of industries in Nigeria carry out rudimentary treatment of waste before discharge. Four out of Nigeria's 36 states (Lagos, kaduna, kano and Rivers) have 80% of Nigeria's industries located in them and thus water pollution is more severe in them. For instance, about 10,000m^3 of liquid waste is discharged into the Lagos lagoon daily by such varied industries as textile, breweries, detergent, power generation, sawmill, paper/pulp, petroleum companies and domestic sewage. In fact the Lagos state environmental protection agency estimates that pollution and over fishing combined to reduce fish catches from 1 million kg in 1980 to 100,000kg in 1990. The kaduna River also experiences massive pollution from textile, food processing, metal works, petroleum refining and fertilizer companies etc., who deposit all manner of pollutants into it in addition to domestic sewage. It is estimated that 165 million liters of organic waste are discharged daily into the Kaduna River. In a study, theKaduna State SEPA found that Do and COD levels in the river were 6.6 mg/l and 17mg/l before industrial area but became 1.2mg/l and 667 mg/l respectively after the industrial area (West Central Africa Dept., 1995). Also pH increased from 6.6 to 9.6. Table 1 shows the total wastes produced by fourteen different industries in Nigeria. Steel and metal works are the greatest polluters followed by food processing industries (edible oil mills, non-alcoholic beverage, fish companies, bakeries, sugar, cocoa based companies and grain millers).

Table 2 shows some physico-chemical characteristics of effluents from some industries in Nigeria together with FEPA (federal Environmental Protection Agency – now Federal Ministry of Environment) standards. The Table shows among other things the lack of adequate environmental data and standards even on such basic pareameters as effluent temperature.

Problems associated with wastewater-fish Culture

According to Sandbank and Nupen (1984), the largest problem associated with wastewater aquaculture is the accumulation of heavy metals (iron, manganese, zinc, lead and coppe etc.), pathogens and pesticides in the fish and thus the possible transmission of diseases to man. Methods of getting round this problem include:

1. Measurement of physico-chemical parameters of waste water so that they can be in tune with the World Health organization (WHO)standard. The WHO standard for wastewater reuse for aquaculture is 10^3 faecal coliforms/100ml.
2. Removing fish from wastewater pond into clean water ponds months before selling them to remove odour and other unwanted characteristics of such fish (Mukherjee, 1995).
3. Culturing aquatic plants like duckweed in wastewater and then using such plants to feed fish in non-wastewater fish ponds.

Wastewater-fish Farming Experiments

Edwards (1996), reported the use of wastewater for fish farming, rice and vegetable production in Hanoi, Vietnam. The city has a population of over one million people and has about 320,000m^3 of wastewater discharged from it daily. This flows into the Than tri district in the outskirts of Hanoi where it is treated in stabilization ponds and then mixed with water from a nearby river before being used for fish farming and agriculture. 200ha of land is used for wastewater aquaculture giving fish yields of 5-8t/ha/yr while 400ha are usedfor rotation of rice and aquaculture giving yields of 4-5t/ha/yr of fish. The remaining land is used to grow aquatic and land vegetables, which is irrigated and fertilized with wastewater. Fish species cultured here are Silver carp, *Rohu* and Tilapia.

Table 1: Nigeria: Sources of industrial and harzadous waste pollution (tons/year).

S/No.	Industry	Total wastes	Industry	Harzadous wastes	Industry	Solid wastes	Industry	Oil and grease
1	Steel works	469,249	Steel works	50,088	Steel works	423,453	Steel works	8,987
2	Food processing	95,630	Metal fabrication	33,326	Food processing	78,445	Metal fabrication	4,018
3	Tanneries	92,958	Textiles	10,011	Tanneries	21,006	Refineries	3,160
4	Metal fabrication	42,815	Pharmaceuticals	6,260	Cement	8,796	Tanneries	840
5	Textiles	35,901	Tanneries	2,213	Textiles	7,536	Food processing	776
6	Pharmaceuticals	24,537	Refineries	1,322	Breweries	7,433	Textiles	234
7	Pulp and Paper	21,167	Paint	985	Pulp and paper	5,334	Cement	109
8	Refineries	18,149	Industrial chemicals	556	Metal fabrication	5,060	Industrial chemicals	42
9	Slaughter houses	16,764	Food processing	326	Refineries	4,752	Slaughter houses	38
10	Breweries	16,522	Pulp and paper	24	Pharmaceuticals	2,817	Breweries	13
11	Cement	9,023	Slaughter houses	0	Slaughter houses	1,532	Pharmaceuticals	79
12	Industrial chemicals	1,724	Fertilizer	0	Industrial chemicals	961	Paint	57
13	Paint	1,694	Breweries	0	Paint	752	Pulp and paper	0
14	Fertilizer	357	Cement	0	Fertilizer	0	Fertilizer	0

Source: West and Ventral Africa Dept., 1995.

Note: The wastes generated are estimates calculated by the use of the Winvent Waste Estimation methodology. The amounts of waste generated by each sub-sector may not be accurate. The model is, however, an appropriate tool for estimating relative waste generation of different industrial sub-sectors.

Table 2: Physico-chemical characteristics of industrial effluents from Nigeria.

Parameter	Sugar factory	Paper mill	Brewery	Textile factory	Soft drinking factory	Petroleum refinery	Steel making plant	Toward	FEPA's effluent limit for discharge into surface water
Temperature	-	-	32.0	39.0	31-44	7.0-8.2	-	29°C	Less than 40°C
pH	4.8	4.4	9.0	7.1	3.2-11.4	-	6.90	10.2	6.9
Total solids	1415	905	3170	2200	130-680	560-740	-	6960	2000
Suspended solids	468	790	406	10	10-30	5-620	-	2470	30
Dissolved oxygen	-	-	-	-	5.0	Nil-7.3	0.7-4.8	4.50	-
BOD	1688	100	2110	103-	-	-	-	2000	50
COD	1954	730	3000	710	1000-2600	72-800	-	4650	-
Chloride	2.0	-	1.0	285	6.30	268-720	28	2300	2000
Phosphate	1.7	-	1.9	-	0.04-1.60	17-64	-	-	5.0
Iron	0.35	0.65	-	0.5	2.4	0.20-6.30	-	-	20
Chromium	-	-	-	-	-	-	-	39	-
Oil and Chease	-	-	-	10	25	3.7-2.60	-	-	20
Sulphide	-	-	-	3.0	0.91	9.85-1.0	-	127	0.20
Nitrate	-	-	-	-	1.1	1.0-1.5	1.0	-	20
Sulphate	-	-	-	-	32.5	0.03-2.30	6.50	1500	500
Colour	Yes	Yes	Yes	Purple	Yellow	Yellow-	-	-	-
Odour	Yes	Yes	Yes	Yes	Yes	Yes	-	-	-

Source: FMWH (1982); Osibanjo, 1991.

Edwards *et al* (1981), carried out series of experiments in Thailand to determine the performance of *O. niloticus* in fish ponds fed sewage from a high rate stabilization pond. They discovered that fish yield after three months in the 4m^3 concrete ponds with a stocking density of 10/m^3 was 20t/ha/yr (projected figure), despite the fact that the sewage was of weak strength (81mg COD/L). A phytoplankton concentration of 70mg/l wasd adjudged optimal, for good fish growth. The study also showed that maize grows well if irrigated with sewage water.

At NIFFR, Okoye *et al* (1986) did an experiment in the wastewater reservoir of NEPA quarters, New Bussa. The 0.4ha reservoir was fed with wastewater from a section of NEPA quarters, (population of about 2,000 people) and a polyculture of 2,274 fingerlings of *S. galileus* with mean weight of 36.1g and 1,000 fingerlings of *Cyprinus carpio* with mean weight, 7.9g were raised in it. After ten months, 15800kg of *S. galilaeus* (Marketable size) with meat weight of 51.5g and 82kg of *C. carpio*, mean weight 50.3g were harvested. In addition, 173.8kg of *S. galilaeus* (fingerlings) was smoked and used as fishmeanl and an estimated 20,000 fingerlings were produced. They concluded that the wastewater did not favor the growth of *C. carpio* but can be used to produce Tilapia fingerlings for stocking other water bodies or for use as fishmeal.

Otubusin *et al* (1990), also carried out an experiment in the same 0.4ha NEPA quarters waste water reservoir, to determine the effect of stocking densities on *S. galilaeus* production in floating net cages without supplementary feeding. The stocking densities ranged from 20 to 160fingerlings/m^3 and all the stocking densities showed positive fish growth with the 20/m^3 density recording the highest daily growth rate of 0026g/d. At the least stocking density of 20/m^3, productivity of the cage system was six times that of the pond system (i.e. direct stocking of *S. galilaeus* into waste water).

In Malaysia, palm oil mill and rubber mill effluents treated in oxidation ponds are used for fish culture. Fish culture in rubber mill effluents can give fish yields of about 6,900 kg/ha/yr while Tilapia can grow better in palm oil mill effluents digested anaerobically in algae laden ponds than in ponds fertilized with chicken manure at the same loading rate (Mukherjee, 1995).

Duckweed Culture in Wastewater

Duckweed rapidly multiply in sewage and animal wastewater which are rich in nutrients and have the capacity to remove nutrients and other pollutants from such waters which they convert into high protein tissue that can serve as animal feed (Culley *et al*., 1973). A biomass doubling time of 1.2 days has been obtained for duckweed in NIFFR. Mbagwu *et al* (1990), carried out series of experiments of duckweed. The results showed that duckweed is an excellent source of protein for fish and contains higher levels of Fe, K, Ca, Mg and na than other agricultural crops used for fish feed formulation (maize, sorghum, groundnut etc.). Digestibility was on average 84.66% with young *S. galilaeus* utilizing duckweed more than adults while percentage survival was 90% for fish fed at 2% of their body weight.

Economics of Wastewater Aquaculture

Wastewater treatment plants are crucial for safe and efficient wastewater aquaculture. Domestic wastewater can be treated in stabilization ponds and such a pond with a depth of 4-5 ft can achieve 90% reduction in the number of human enteric viruses (rao *et al*., 1981). Wastewater treatment plants are virtually non-existent in Nigeria and therefore companies and government need to invest in this area. Prein (1995), showed that it costs about US$ 0.0042 to treat 1m^3 of wastewater (sewage) in the tropics. This is apart from the investment in buildings and other materials. A 9ha wastewater fish farm with a projected annual fish yield of 63.4t/yr has a projected NPV of US$ 95,200 in tropical areas.

In the experiment conducted by Edwards *et al*., (19981) in Thailand, they estimated that in a city of 100,000 people, about 62.94ha of land is required for sewage treatment, aquaculture and maize cultivation. If the WHO standard of 10^3 coiliforms/100ml is adhered to, total projected gross returns will be US$ 81,473 (i.e. US$ 1293/ha), assuming the fish and maize are sold as food. However, if WHO standard is not adhered to and the fish and maize produced are sold as animal feed, projected gross returns will be US$ 76,673 (i.e. US$ 1218/ha).

References

Culley, D.D. and Epps, E.A. (1973). Use of duckweed for waste treatment and animal feeds. J. Water Pollution Control Federation, 45, pp. 337-347.

Edward, P.; Sinchumpasak, O.; Labhsetwa, V.K. and Tabucannon, M. (1981). The harvest of micro algae from the effluent of a sewage fed high rate stabilization pond by *Tilapia nilotica*. Aquaculture 23(1-4): April, 1981, pp. 83-170.

Edwards, P. (1996). Wastewaters reuse in aquaculture; socially and environmentally appropriate wastewater treatment for Vitenam. NAGA-ICLARM Q, Jan., 1996, pp. 36-37.

Mbagwu, I.G. and F.C. Okoye (1990). Studies on the use of Duckweed (Lemna Paucicostata Hegelm) as fish food. NIFFR Tech. Report Series, 22, pp. 1-23.

Mukherjee, T.K. (1995). Integrated crop-livestock-fish production systems for maximizing productivity and economic efficiency of small holder's farms. IN: J.J. Symoens and J.C. Micha (eds.). The management of integrated freshwater agro-piscicultural ecosystems in tropical areas. Proc. Of FAO/CTA/RAOS Seminar, pp. 124.

Nnaji, J.C. (2002). Integrated fish farming: Combination rates, production figures and economic evaluation. NIFFR Seminar Series, 2002.

Okoye, F.C.; Ita, E.O. and Adeniji, H.A. (1986). Utilization of wastewater for fish production. NIFFR Annual report, pp. 77-79.

Osibanjo, O. (1991). Present water quality status in Nigeria. FEPA, pp. 35-41.

Otubusin, S.O.; Opeloye, G.O.; Asekome, I.G.; Tyobo, P.F. and Ishase, J.I. (1990). Fish culture studies in floating cages in wastewaters without supplementary feeding. NIFFR Annual Report, pp. 51-58.

Osae-Addo in West Africa Dept. (1995). Nigeria strategic options for redressing industrial pollution,vol. 1, Feb., 1995, pp. 1-17.

Prein, M. (1995). Wastewater use in aquaculture: Research in Peru. NAGA-ICLARM Q, Oct., 1995, pp. 11-13.

Rao, C.V.; Lakhe, S.B. and Waghmare, S.V. (1981). Virus removal in waste stabilization ponds in India. Water research,15(7): pp. 773-778.

Sandbank, E. and Nupen, E.M. (1984). Warm water fish production on treated wastewater effluents. Paper presented at Aquaculture, South Africa, cathedral Peak, 3-4 May.

UNEP (1991). Freshwater pollution. UNEP/GEMS Environment Library, No. 6, Nairobi, pp. 4-33.

West Central Africa Dept. (1995). Nigeria strategic options for redressing industrial pollution, vol. 1, Feb., 1995, pp. 1-17.

West Central Africa Dept. (1995). Nigeria strategic options for redressing industrial pollution, vol. 2, Feb. 1995, pp. 3-68.