STANDARD WATER QUALITY REQUIREMENTS AND MANAGEMENT STRATEGIES FOR FISH FARMING (A CASE STUDY OF OTAMIRI RIVER)

N.C. Ezeanya[1], G.O. Chukwuma[2], K.N. Nwaigwe[3], C.C. Egwuonwu[4]

[1]*Department of Agricultural Engineering, Federal University of Technology, Owerri, Nigeria*
[2]*Department of Agricultural Engineering, Nnamdi Azikiwe University, Awka, Nigeria*
[3]*Department of Agricultural Engineering, Federal University of Technology, Owerri, Nigeria*
[4]*Department of Agricultural Engineering, Federal University of Technology, Owerri, Nigeria*

Abstract

A study on standard water quality requirements and management strategies suitable for fish farming is presented. The water quality criteria studied based on physical, chemical and biological properties of water include temperature, turbidity, total suspended solids (TSS), total dissolved solid (TDS), nitrate- nitrogen, pH, biochemical oxygen demand (BOD) and total hardness. Water samples from Otamiri River in Imo state, Nigeria, were analyzed based on the afore-mentioned criteria to assess its suitability as a source of water for fish farming. The results of the analysis compared with international standards revealed that the river temperature of 26.9^{0}C, nitrate-nitrogen value of 0.015 mg/l and total suspended solids of 18.60 mg/l fall within the acceptable range for fish farming. However, the pH of 5.82, total hardness of 5.8 mg/l, total dissolved solids of 13.60 mg/l and biochemical oxygen demand of 0.6 mg/l all differed slightly from the standard recommended values. This study will aid fish farmers on the necessary treatment needed to effectively use water from this source for fish farming.

***Keywords**: Water quality criteria, Otamiri River, biochemical oxygen demand, total suspended and total dissolved solids.*

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1. INTRODUCTION

The major environmental issues of our time are the growing concern about the water quality suitable for use by humans and animals (Calamari and Naeve, 1994). It is a known fact that the water quality condition is constantly being threatened by pollution. The discharge of large quantities of wastes has been largely influenced by industrialization, urbanization, population increase and green revolution (Biney et al., 1994). These have resulted in widely distributed sources of pollution and thereafter, have created significant problem on the rivers and lakes to assimilate contaminants and increase their pollution loads. Aquaculture can be defined as the rearing of aquatic animals. It is the breeding of fish, crabs and other aquatic organisms in specially designed ponds, to enhance better yield and quality of fish and crabs produced. In the case of fish farming, these ponds are known as fish ponds.

In Africa, fish and crabs are widely consumed as a remarkable source of animal protein. In river line communities such the Niger delta communities of Nigeria, fish and crab are more widely consumed than meat. Although fish farming and fish ponds are growing in Nigeria, river fisheries constitute the greater source of fish consumption. River fisheries also constitute the major occupation of many river line communities in Nigeria.

Water as an important natural resource, influences human settlement patterns, agricultural activities and citing of industries (Nwaugo at al., 2006). Incidentally, in wealth generating process, water is a victim of dumping of wastes which degrade the water for other uses (Trouba, 2002). Running waters are exploited to supply irrigation and drinking water, generate electricity, and receive wastes (Tucker and Hargreaves, 2008). Attempts aimed at increasing aquaculture yield through pond fertilization practices especially those involving the dumping of domestic, poultry and organic wastes into the culture systems has been found to affect the microbiology and biochemistry of the culture systems (Ogbulie, 1995).

The flesh of fish is usually infected with a wide range of microbes present in the water body. These bacteria are often found in the scales, gills, gut and alimentary tract of the fish (Pyatkin and Krivoshein, 1986). The amount of bacteria that exist on the body and internal organs of the fish is indicative of the extent of pollution of the water environment.

Furthermore, too many trace elements are mined at a pace that exceeds their natural mobilization rates (Philips, 1991). Also many antropogenically derived metals, pesticides and chemicals, which are regarded as aquatic contaminants have remained in use in both developing and advanced nations of the world (Biney et al., 1994).The overall toxicological impact of this pollution problem is that the fishery productivity suffers after all (Birch et al.,1986). The adverse effect of these organic and in organic pollutants on water quality of seas, rivers, lakes and fish pond, have led to poor yield of fish from these water bodies. This poor yield is very significant coupled with the ever increasing demand for fish, as a better alternative source of animal protein, compared to meat. This paper therefore determined adequate water quality requirements and other management strategies, suitable for optimum yield of fish in fish farming.

The Otamiri River is the major river that flows through the Ihiagwa autonomous community of Owerri west LGA of Imo state, Nigeria, where Federal University of Technology, Owerri is situated. The close proximity of the river to FUT, Owerri makes it a water source that could be harnessed for various domestic and agricultural purposes including aquaculture, irrigation farming and bottled water production.

2. MEASUREMENTS OF WATER QUALITY

In estimating the quality of water, the physical, chemical and biological properties of the water should be considered. Therefore, physical chemical and biological analyses are required to be done. The physical properties of water normally considered include: temperature, colour, turbidity, odour, taste, total suspended solids and total dissolved solids.

Aquatic animals take on the temperature of their environment and are intolerant of rapid temperature fluctuations. Water temperature affects the feeding pattern and growth of fish. Fish generally experience stress and disease breakout when temperature is chronically near the maximum tolerance or fluctuates suddenly. Warm water holds less dissolved oxygen than cool water. This is because every 10^0 C rise in temperature doubles the rate of metabolism, chemical reaction and oxygen consumption in general. Turbidity and colour of water are closely related. High turbidity, one of the major factors that impede light penetration, could be due to presence of planktonic organisms or clay particles.

The chemical properties of water that are of utmost importance in fish farming include: pH, ammonia-nitrogen (NH_{3-} N), nitrite- nitrogen (NO_{2-} N), nitrate- nitrogen (NO_3-N) and total phosphorous (TP) (Pulatsu, et al., 2004). The biological properties that affect aquaculture include: biological oxygen demand (BOD) and presence of bacteria. The biological oxygen demand is a very important factor in determining water quality suitable for fish farming. During respiration, fish like other animals, take in oxygen and give out carbon IV oxide (CO_2), and this fish aerobic metabolism requires dissolved oxygen. The summary of the standard water quality requirements for fish farming is contained in Table 1.

Table 1: Standard Water Quality Requirements for Fish Farming.

S/N	WATER QUALITY CRITERIA	RECOMMENDED VALUE (RANGE)	SOURCE
1	PH	6.6 – 8.5 (saline) 6.0 – 9.0 (fresh)	Davis (1993)
2	BOD	3 – 20 mg/l	Boyd (2003)
3	Temperature	25^0C – 30^0C	FAO (2006)
4	TSS	10 – 20 mg/l	Davis (1993)
5	TDS	0.13 mg/l	Davis (1993)
6	No_3-N	16.9 mg/l	Schewatz and Boyd (1994)
7	Total Hardness	50 – 100 mg/l	WHO (2003)

3. MATERIALS AND METHODS

3.1 Sample Collection and Analysis

In order to obtain raw data needed to carry out this work, three points A, B and C were selected along the length of the river. Sterilized and sealed bottles were used for sample collection. The marked sterilized bottles were dipped into the centre of the river, the seals were removed while bottles were still inside the water and the bottles were filled up to fullness, sealed back and covered with black sack with water to avoid solar radiation effect.

Polyethylene jerry cans were also filled with water and the temperature of the river was measured directly inside the river. These procedures were repeated at each sampling location. All parameters tested were grouped under three heading namely: - Physical, chemical and biological. The physical parameters include: temperature, turbidity, total suspended solids and total dissolved solids. The chemical parameters include pH and Nitrate- Nitrogen (No_{3-}N). The biological parameter includes: Biochemical Oxygen demand.

3.2 Determination of Physical Properties

The turbidity of the water sample was tested using a digital turbidity meter and the turbidity value was read out directly in Nephelometric Turbidity Units (N.T.U). The temperature was measured immediately at the exact point of collection using mercury in glass thermometer calibrated in degree Celsius (^{o}C). The total suspended solids and total dissolved solids were determined using standard method of filtration, evaporating to dryness and weighing. The values obtained were expressed in mg/l.

3.3 Determination of Chemical Properties

The pH values of the samples were determined using pH meter and displayed on the digital dial of the pH meter. The

Nitrate –Nitrogen (NO_3-N) test was done using the Spectrophotometer test, and the result was obtained in mg of Nitrate per liter sample of water.

3.4 Determination of Biological Properties

The Biochemical Oxygen Demand (BOD) was determined using dissolved oxygen meter, incubator and BOD bottles. The BOD bottles were filled with the sample and the dissolved oxygen measured and recorded (D_1) with the calibrated (dissolved oxygen meter) before incubating at 20^oC for 5 days. The dissolved oxygen was measured after incubation and recorded as (D_2). The BOD was calculated using the equation below.

$$\textbf{BOD (mg/l)} = (D_1 - D_2) / 0.5 \quad (1)$$

Where, 0.5 is the dilution factor.

The Total Hardness was done using the Eriodrome indicator/ Digital titrator method. The digital titrate required was recorded once the color changed from red to pure blue and the value was multiplied by 2.0 to obtain the mg/l total hardness in $CaCo_3$.

4. RESULTS

The results of water quality tests conducted at Otamiri River are summarized in Table 2.

Table 2: Results of water quality tests carried out at Otamiri River.

Quality Parameter	Unit	Point A	Point B	Point C	Mean Value
Temperature	^0C	27.1	26.9	26.7	26.9
Total suspended solids (TSS)	Mg/l	17.2	19.5	19.0	18.60
Total dissolved solids (TDS)	Mg/l	13.0	13.9	13.9	13.6
pH	-	5.98	5.98	5.50	5.82
Total hardness	Mg/l	5.98	5.20	6.22	5.80
Biochemical Oxygen Demand (BOD)	Mg/l	0.7	0.5	0.6	0.6
NO_3-N	Mg/l	0.008	0.014	0.023	0.015

Point A = Otamiri at Douglas road; Point B = Otamiri at Ihiagwa bridge; Point C = Otamiri at FUTO bridge

The mean values of water quality parameters compared with standard values are summarized in Table 3.

Table 3: Mean Values of water quality parameters compared with international standards.

Quality Parameter	Unit	Mean value (Otamiri River)	International Standards
Temperature	^0C	26.9	15 – 30
Total suspended solids (TSS)	Mg/l	18.60	10 – 20
Total dissolved solids (TDS)	Mg/l	13.60	0.13
pH	-	5.82	6.0 – 9.0
Total hardness	Mg/l	5.8	50 – 100
BOD	Mg/l	0.6	3 – 20
NO_3-N	Mg/l	0.015	16.9

4.1 Discussion / Management Strategies

4.1.1 Temperature

The temperature of Otamiri River was found to be 26.9^0C. This value falls within the range of 25^0C to 30^0C for optimum yield in aquaculture recommend by FAO (2006). In fish farming heating of the water may be necessary if the temperature of the water falls below the recommended range.

4.1.2 Total Suspended Solids

The value of total suspended solids for Otamiri River is 18.60 mg/l. This value falls within the standard range of 10 - 20 mg/l recommended by Davis (1993). Based on criteria of total suspended solids, the Otamiri River is suitable as a source of water for fish farming. However if the total suspended solids exceeds the standard range, the water can be treated by filtering before being used for fish farming. This can be achieved by incorporating filter materials of recommended size in the water inlet system of the fish farm.

4.1.3 Total Dissolved Solid

The value of total dissolved solids for Otamiri River is 13.60 mg/l. This value is far greater than the standard value of 0.13 mg/l recommended by Davis (1993).This implies that Otamiri River should first be treated with chemicals to reduce the quantity of dissolved solids to the acceptable range before it could be used as a source of water for fish farming.

4.1.4 pH

The average value of the pH of Otamiri River is 5.82. This value is slightly lower than the standard range of values of 6.0 - 9.0, recommended by Davis (1993).The pH value of 5.82 is indicative that the water is too acidic for optimum yield of fish. It is therefore necessary to treat the water. The water of Otamiri River should be treated by adding lime to it. This practice will increase the pH of the water. Sometimes the pH of the pond water can change quickly as a result of heavy rain which may carry acidic substances, dissolved from the soil into runoff water, into the pond. In this way, the pond water gets more acidic thus leading to decreased pH value .Therefore, there is need for periodic check of water pH in fish pond. However, if the pH of the water is too high, above the recommended standard, the water will be too alkaline. This means that more acid substances should be added to the water to reduce its pH value.

4.1.5 Total Hardness

The total hardness of Otamiri River is measured as 5.8 mg/l. This value is far below the standard range of 50 – 100 mg/l as recommended by WHO (2003). This implies that the water is too soft, and the amount of water soluble salts it contained is low. To increase the hardness of the water to reach the acceptable value, lime should be added. It therefore implies that water pH (degree of acidity or alkalinity) and water hardness can all be changed by adding lime to the pond as described above.

4.1.6 Biochemical Oxygen Demand

The Biochemical Oxygen Demand (BOD) for Otamiri River is 0.6 mg/l. This value is less than the standard range of 3-20 mg/l recommended by Boyd (2003).The oxygen content of a river may be affected by such activities as washing and bathing. The BOD of water in fish ponds can be increased using mechanical aeration and by keeping the water at optimum temperature. This is because too high a temperature reduces the amount of dissolved oxygen. Over stocking of fish in the pond could be another cause of oxygen shortage.

4.1.7 Nitrate- Nitrogen (No_3-N)

The value of 0.015 mg/l of NO_3-N for Otamiri River is within the standard safe limit of 16.9 mg/l recommended by Schwartz and Boyd (1994). Thus based on Nitrate – Nitrogen content, Otamiri River is suitable for fish farming. Values of Nitrate –Nitrogen >16.9 mg/l is considered not suitable for fish farming.

4.1.8 Turbidity

High turbidity of water can decrease fish productivity, as it will reduce light penetration into the water and thus oxygen production by the water plants. Dissolved suspended solids will also clog filters and injure fish gills (Carballo et al., 2008). Carballo et al., (2008), gave a suitable method for reducing turbidity using a silt catchment basin. This is in the form of a small reservoir at the inlet of the pond. The water flows into this reservoir and is kept there until the mud settles on the bottom. Then the clear water is let into the fish pond. Another method to decrease turbidity is to apply lime, gypsum or preferably alum at 1 gram per 100 liters of water. However, the only real long term solution to turbidity is to divert muddy water away from the pond and ultimately protect dykes from erosion, which cause the high water turbidity.

5. CONCLUSION

The specific objective of this work was to establish water quality requirements and management strategies for fish farming, using Otamiri River as a case study. Water quality is a measure of the physical chemical and biological properties of the water. It was discovered in the course of the research that optimum yield of fish in fish farming operation is dependent on these properties of water which include: temperature, total suspended solids, total dissolved solids pH, total hardness, biochemical oxygen demand (BOD) nitrate-nitrogen (NO_3-N) and turbidity. The analysis carried out at Otamiri River showed that only temperature, TSS, No_3-N and turbidity, fell within the accepted range of values for fish farming. This development necessitated the introduction of management strategies and practices which will improve on the water quality and bring it to the acceptable standard, based on other water criteria. Some of the management strategies include: the addition of lime, mechanical aeration, introduction of additives like acidic salts, and incorporation of filters etc.

REFERENCES

[1] Biney, C.; Amuzu, D.; Calamari, N.; Kaba, I.C.; Mbone, H.; Naeve, P.B.; Ochumba, O.; Radegonde, V.; and Saad, M.A. 1994. Review of heavy metals. Committee on Inland fishery Advisory. Caribbean Inland Fishery_Association (C I F A). Tech papers 25: 33- 39.

[2] Birch, P.B.; Forbes, G.; and Schoffield, N. J. 1986. Monitoring the effects of catchment management practices. Water scientific Technology 18: 53-61.

[3] Boyd, C.E. 2003. Guide lines for aquaculture effluent management at farm-level. Aquaculture, 226: 101-112.

[4] Calamari, D.; and Naeve, H. 1994. Towards Management of the aquatic environment. Caribbean Inland fishery Association (CIFA) Technical papers. 25: 7- 22

[5] Carballo, E.; Eer, A.V.; Schie, T.V.; and Hilbrands, A. 2008. Small- Scale fresh water fish farming. Agrodok 15.

[6] Davis, J. 1993. Survey of Aquaculture effluents permitting and 1993 standards in the South. Southern Regional Aquaculture Centre, SRAC publication no 465 USA, 4PP.

[7] FAO (Food and Agriculture Organization of the United Nations). 2006b. State of World Aquaculture. 2006. FAO Fisheries Technical paper 500. Rome: FAO Fisheries Department.

[8] Nwaugo, V.O.; Obiekezie, S.O.; Onyeagba, R.A.; Okereke, J.N.; and Udebuani, A. 2006. The physico-chemical investigation of Amicol Lake in Ivo area of Ebonyi State, Nigeria. World Journal of Biotechnology, 7: 1055-1061.

[9] Ogbulie, J.N. 1995. Microbial Ecology of Nigerian fish culture systems. PhD Thesis. University of Port Harcourt, Nigeria. 314 pp.

[10] Philips, D.J.H. 1991. Selected trace elements and the use of Biomonitors in sub tropical marine ecosystem. Revise Environmental Contaminated Toxicology. 120:105-129
[11] Pulatsu, S.; Rad, F.; Koksal, G.; Aydin, F.; Benli, A.C.K.; and Topcu, A. 2004. The Impact of Rainbow Trout farm Effluents on water Quality of Karasu stream, Turkey. Turkish Journal of fisheries and Aquatic Sciences. 4: 09 -15
[12] Pyatkin, K.D and Krivoshein, Y.S.1986. Microbiology. MIR publishers, Moscow.167 pp.
[13] Schwartz, M.F and Boyd, C.E. 1994. Channel Catfish Pond Effluents. Prog. Fish Cult, 56: 273 -281.
[14] Trouba, D. 2002: Why balance water use? Journal of Stockholm water front 2:2 Stockholm, Sweden.
[15] Tucker, C.S and Hargreaves, J.A. 2008. Environmental Best Management practices for Aquaculture. Blackwell Publishing. U.S.A.
[16] WHO (World Health Organization). 2003. Global journal of pure and Applied Science Vol. 4 No. 2.