

THE EFFECTS OF FISH POND TYPES ON THE PHYSICAL AND CHEMICAL WATER QUALITY AND ITS IMPLICATIONS ON FISH HEALTH IN MAIDUGURI METROPOLIS, NIGERIA

THILZA I.B.¹, MUHAMMAD T.², KIGIR E.S.³, MOSES D.G.⁴, KWAGHE A.V.¹, OKWOR G.O.⁵,
UNDIANDEYE J.U.⁵

1. DEPARTMENT OF VETERINARY MEDICINE, UNIVERSITY OF MAIDUGURI, P.M.B 1069, BORNO STATE, NIGERIA.
2. WHO NATIONAL POLIO LABORATORY, UNIVERSITY OF MAIDUGURI TEACHING HOSPITAL, BORNO STATE, NIGERIA.
3. DEPARTMENT OF VETERINARY ANATOMY, UNIVERSITY OF MAIDUGURI, P.M.B 1069, BORNO STATE, NIGERIA.
4. NATIONAL VETERINARY RESEARCH INSTITUTE, VOM, PLATEAU STATE, NIGERIA.
5. DEPARTMENT OF VETERINARY MICROBIOLOGY AND PARASITIOLOGY, UNIVERSITY OF MAIDUGURI, P.M.B 1069, BORNO STATE, NIGERIA.

thilzathilzathilza@yahoo.com

ABSTRACT: Fish performs all their body functions in water. The quality of the water in which fish are contained is therefore very important to their livelihood. In the present study, some physico-chemical parameters such as temperature, alkalinity, PH, turbidity, suspended solids, dissolved oxygen, dissolved carbon dioxide, nitrites, ammonia, chlorine, hydrogen sulphide, chromium, iron, copper, zinc and total water hardness content of five farms aquaculture ponds each for plastic, concrete and earthen ponds types on the first days of water change and on the last days of water change was analysed for assessment. The studies were undertaken from the month of January to March, 2009 during which the physico-chemical parameters were analysed and compared with the aquaculture water quality standard of Kumar (2004). The temperature values remained within the standard values in the all the aquaculture pond types. PH values of the aquaculture ponds ranges from 4.7-6.8 as against the standard water quality i.e 6.5-8.0. Turbidity, suspended solids, dissolved carbon dioxide, nitrites, ammonia, hydrogen sulphide, alkalinity contents increased on the last days of water change in the aquaculture ponds while dissolved oxygen, heavy metals and total water hardness contents shows a decreased in their values for all the aquaculture pond types on the last days of water change. The stocking density, rate of feeding, frequency of water changes had effect on the water quality parameter and consequently growth rate of the fishes. The variation in the physico-chemical parameters of the aquaculture ponds above or below standard values has potential effects on the health and productivity of aquaculture. The study indicates that the pond water quality of the plastic and to a lesser extent concrete pond pose lesser threat to the livelihood of the fish as compared to the earthen pond types due to the management practices on the farms although the constant change of water in the plastic and concrete pond types increases the chances of heavy metals being absorbed in the tissues of fishes causing health threat to both the fish and consumers of fish. [Report and Opinion. 2010;2(3):71-78]. (ISSN: 1553-9873).

KEY WORDS: physico-chemical water qualities, fish, health

INTRODUCTION

Most fishes live their entire lives in water and in some ways they benefit from this arrangement. For example they do not need to expend energy in supporting their own weight; however, there are drawbacks. Water, as the universal solvent, makes prevention and control of physical and chemical contamination of water bodies more difficult than in equivalent areas of land. Fish can be affected by such contaminants arriving from outside their own activities. Food they consume is carried within the water, and their waste products, such as faeces are passed into it; their activities such as breeding and storing up pond

mud during feeding, all produce materials which move into the water. These materials all come into intimate contact with the body surfaces of the fish, and they have to be 'breathed' and 'drunk' (LaDon, 2000). The quality of the water in which fish are contained is therefore very important to their livelihood. However, different species can tolerate different levels of contamination (Edward 1993).

Adverse environmental parameters can have direct or indirect effects on fish. Direct effects are where tissues are damaged directly by a water quality problem, such as ammonia causing gill damage. In some cases such effects can be mitigated by other

parameters. For example, the toxicity of ammonia is much reduced by low pH and low temperature. The indirect effects of a less than ideal environment are high stress levels and these leads to a reduced resistance to disease from other sources and reduced tolerance to other stress (Fry, 1947). The main objective in any fish holding system should be to create and maintain water quality within the tolerance limits of the species being held. In order to achieve these aims, the water entering the aquaculture system should be within the required limits. Also, any material introduced, either from external source or by excretion must be removed so that they do not become a problem. Such removal can be by processes within the system such as filters, or by water replacement. The latter method is commonly used to keep the water quality of the system within acceptable limits (Brett, 1979).

MATERIALS AND METHOD

Study area

Maiduguri is the capital of Borno state, the most north-eastern state in Nigeria with an area of 69,435 square kilometer. It lies between latitude 10°N and 13°N and longitude 12°E and 15°E. Relatively humidity is generally low throughout the state, ranging from as low as 13 percent in driest months of February and March to the highest values of severity to 80 percent in the rainy season months of July and August. The rainy season last for less than eighty days in the extreme north, the mean annual rainfall is about 600mm or less than 500mm in the extreme north around Lake Chad. Drought are endemic and rainfall tends to have been in decline since 1960s (Troncy, 1989).

Questionnaire survey

A questionnaire survey was administered using the constructive method to determine fish pond types, fish species, size/age of stock, stocking density, pond size, type of feed, frequency of feeding, frequency of water change was administered in five farms each for different pond types.

Determination of weight of fish

The weight of a total of 60 juvenile fish from different pond types (plastic, concrete, earthen) with the similar management practices was taken. For each pond types, two farms with the similar management practices were considered and ten juvenile fish from each pond was weighed on biweekly bases for a period of twelve weeks using a weighing balance.

Sample collection

The study was carried out for a period of three months from the month of January to march. Different aquaculture pond types were considered in five farms

for each pond types. They include plastic, concrete, and earthen ponds. Water samples were collected between 8.00am to 9.00am using a wide mouth sterile transparent plastic jar of 1.5 liters capacity and from 10 to 15cm depth from the water surface.

Water analysis

The water temperature, dissolved oxygen and pH was measured at the place of sampling sites using standard mercury thermometer, dissolved oxygen meter and microprocessor based pocket pH meter respectively. For the study of alkalinity, suspended solids, carbon dioxide, nitrites, ammonia, water hardness, hydrogen sulfide, chloride, chromium, iron and copper, the samples was analysed in the laboratory with HI 83200 multiparameter ion specific meter and HI 93703 Microprocessor turbidity meter for the measurement of turbidity following standard methods of American Public Health Association (APHA, 1992). The results of analysis were expressed as milligrams per liter except temperature measured as degree celsius (°C) and turbidity in formazin turbidity unit (Ftu).

Statistical Analysis

Statistical analyses were performed with GraphPad InStat statistical soft ware (2004). Variation in the three pond types of each parameter were compared by using ANOVA.

RESULTS

The results of analyses in the three aquaculture pond types (plastic, concrete and earthen) in Maiduguri Metropolis are as mean and standard deviation presented in table 1 and 2. A minor variation of temperature was recorded in all the pond types irrespective of the day of water change (table 1 and 2) and values falls within permissible value by Kumar (2004). The alkalinity values ranges from a high of 233.60 ± 87.67 in the plastic pond type (table 2) and a low of 177.40 ± 41.49 in the concrete pond type (table 1). The alkalinity values fall within standard values of 10-400 in the two days of water change for the three pond types and significant variation was observed in the earthen pond types. The PH values of the aquaculture ponds were range between 4.70 ± 0.84 in the earthen pond types and 6.80 ± 0.45 in the concrete pond types (table 1 and 2). PH values are quite stable on the first and last days of water change for plastic and concrete pond types but there was a decrease in the PH values on the last day of water change in the earthen ponds. The PH values were within standard values for the plastic and concrete pond types but below standard for the earthen pond types (table 1 and 2).

The turbidity values was observed to be highest in the earthen ponds with a high of 93.16 ± 70.93 (table 2)

and lowest in the plastic pond type with a low of 2.50 ± 2.44 on the first days of water change (table 1). The Suspended solids values is observed to be above standard and highest in the earthen pond type just after and before toping the pond with water and lowest in the plastic pond types . Values are within standard for plastic and concrete pond types on the first days of water change (table 1) but their values increased on the last days of water change with the concrete pond having values above the standard value of <80 .

The maximum value of dissolved oxygen concentrations was observed in the concrete pond on the first days of water change and lowest value in the earthen pond on the last day of water change. Values were observed to be within standard values in the aquaculture pond type on the first days of water change but values were observed to decrease on the last days of water change with values below standard in the earthen pond types (table 1 and 2).

Within the investigation period, dissolved carbon dioxide concentration was observed in all the pond types increased on the last days of water change with earthen pond having the highest concentration of 21.00 ± 6.68 just before toping and plastic pond with the lowest concentration of 5.66 ± 2.78 on the first days of water change, but its values supersedes that of concrete pond types on the last days of water change

(table 1 and 2). Ammonia and nitrite values showed highest values in the earthen pond types on the first and last day of water change, though values in the plastic and concrete pond types are observed to increase on the last days of water change and values are above the permissible value in all the aquaculture pond types. Ammonia values showed significant difference within the aquaculture pond types (table 1 and 2).

Chlorine values are above the standard value in all the aquaculture pond types (table 1 and 2) except plastic and concrete aquaculture ponds on the last days of water change which falls within the standard value (table 2). Hydrogen sulphide values are above standard value in the three aquaculture pond types but values are observed to be higher on the last days of water change in concrete and earthen ponds (table 2) but remain same for plastic ponds on the first and last days of water change (table 1 and 2).

Heavy metals (chromium, iron, copper, zinc) concentrations were observed to be high and above standard values in all the aquaculture pond types with the plastic pond types having the highest values and earthen pond types having the lowest concentration on the first days of water change. On the last days of water change, heavy metals concentrations were observed to have decreased in all the aquaculture pond types (table 1. and 2).

Table 1. Physico-chemical water characteristic of fish ponds on the first day of water change/just after toping for earthen pond

PARAMETERS	PARAMETERS IN THE POND TYPES				STANDARD
	PLASTIC	CONCRETE	EARTHEN		
Temperature ($^{\circ}$ C)	25.60 ± 3.58	24.10 ± 3.29	28.42 ± 3.08		20-30
Alkalinity	204.40 ± 67.78	177.40 ± 41.49	124.80 ± 18.32		10-400
PH	6.50 ± 0.76	6.80 ± 0.45	5.80 ± 0.71		6.5-8
Turbidity (Ftu)	2.50 ± 2.44^a	4.36 ± 4.65	83.78 ± 83.28^b		<80
Suspended solid (mg/l)	12.27 ± 7.49^a	16.98 ± 12.28^a	165.61 ± 73.57^b		<80
Dissolved oxygen (mg/l)	8.00 ± 4.69	9.24 ± 1.34^a	3.20 ± 2.95^b		3 to saturation
Dissolved carbon dioxide (mg/l)	5.66 ± 2.78^a	5.98 ± 2.29^a	17.84 ± 5.92^b		0-10
Nitrites (mg/l)	2.45 ± 1.98	1.50 ± 1.35	4.87 ± 2.56		<1.0
Ammonia (mg/l)	4.32 ± 1.23^a	5.08 ± 4.78^a	20.80 ± 4.82^b		<1.0
Chlorine (mg/l)	0.12 ± 0.19	0.10 ± 0.20	0.03 ± 0.04		<0.003
Hydrogen sulphide (mg/l)	1.30 ± 1.32^a	0.86 ± 1.81^a	4.90 ± 2.56^b		<0.003
Chromium (mg/l)	0.50 ± 0.20	0.74 ± 10.43	7.34 ± 11.08		up to 0.01
Iron (mg/l)	1.82 ± 1.71^a	0.06 ± 0.09^b	0.03 ± 0.08^b		up to 0.01
Copper (mg/l)	0.75 ± 0.78	0.55 ± 0.04	0.40 ± 0.36		up to 0.01
Zinc (mg/l)	0.05 ± 0.05	0.08 ± 0.05	0.04 ± 0.04		up to 0.01
Total water hardness	127.80 ± 44.78	138.60 ± 52.67	307.60 ± 223.23		10-400

One way ANOVA with Turkey multiple Comparisons post test.

Different superscripts within rows indicate significant variation at $P \leq 0.05$

Table 2. Physico-chemical characteristic of fish ponds on the last days of water change/just before toping for earthen pond

PARAMETERS	PARAMETER IN THE POND TYPES			
	PLASTIC	CONCRETE	EARTHEN	STANDARD
Temperature (°C)	24.40 ± 2.58	23.60 ± 2.41	25.8 ± 2.77	20-30
Alkalinity	233.60±87.67 ^a	190.40±21.20	128.20 ±21.26 ^b	10-400
PH	6.60 ± 0.89 ^a	6.70 ± 0.76 ^a	4.70 ± 0.84 ^b	6.5-8
Turbidity (Ftu)	6.84 ± 5.66 ^a	8.77 ± 12.91 ^a	93.16 ± 70.97 ^b	<80
Suspended solid (mg/l)	16.66 ± 7.46 ^a	96.47 ± 104.40 ^a	298.81 ± 16.22 ^b	<80
Dissolved oxygen (mg/l)	4.80±1.30 ^a	4.60 ±1.67 ^a	2.09 ± 1.00 ^b	3 to saturation
Dissolved carbondioxide (mg/l)	12.20±8.74 ^a	7.92 ±3.48 ^a	21.00 ± 6.68 ^b	0-10
Nitrites (mg/l)	5.13 ± 2.95	3.40 ± 3.51	6.71 ± 2.45	<1.0
Ammonia (mg/l)	5.02 ± 1.79 ^a	8.52 ± 6.10 ^a	24.90 ± 2.45 ^b	<1.0
Chlorine (mg/l)	0.00 ± 0.00	0.00 ± 0.01	0.02 ± 0.04	<0.03
Hydrogen sulphide (mg/l)	1.30 ± 1.32	1.82 ± 2.34	6.90 ± 8.19	<0.03
Chromium (mg/l)	0.04±0.56	0.02 ± 0.56	0.01 ± 0.05	up to 0.01
Iron (mg/l)	0.60 ± 0.56	0.03 ± 0.05	0.01 ± 0.01	up to 0.01
Copper (mg/l)	0.33 ± 0.40	0.21 ± 0.05	0.15 ± 0.09	up to 0.01
Zinc (mg/l)	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	up to 0.01
Total water hardness	113.40 ± 33.47	135.8 ± 51.50	252.00 ± 219.05	10-400

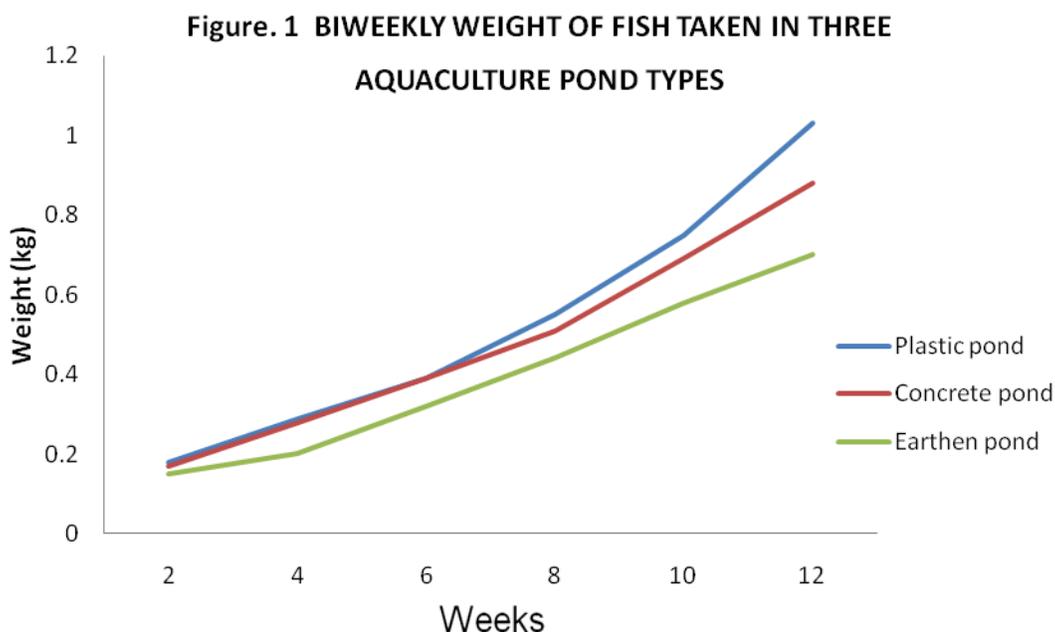


Table 3. Average rate of feeding and number of fish in each pond types

POND TYPES	NO. OF FISH PER POND	RATE OF FEEDING (Kg/day)
Plastic	396	3.16
Concrete	578	3.38
Earthen	2280	1.70

Table 4 Average stocking densities and size of fish stocked in the aquaculture pond types

POND TYPES	STOCKING DENSITY (No. of fish/m ³)	SIZE (inches)
Plastic	212	3.5-5.5
Concrete	81	2-9
Earthen	117	4-6

DISCUSSION

The water utilize for aquaculture in Maiduguri are mostly from borehole. The results of the physico-chemical parameters of aquaculture ponds were compared with the prescribed water quality standard by Kumar (2004).

In Maiduguri, Borno state, the temperature is quite high during the dry season. The temperature could reach a high of 40°C. The present study was conducted within the month of February to April. In the present study, the observed values of temperature indicate that the water quality would not be affected by this parameter.

The PH of the aquaculture pond water samples varied from 5.80 in earthen pond to 6.80 in concrete pond types. It can thus be concluded that the higher acidic value in earthen pond types is due to the chemical additives applied to the aquaculture pond with an objective of better production. In the present investigation, it has been found that the PH of plastic and earthen pond water showed permissible values of PH that has been prescribed by Kumar (2004).

In the present investigation the mean alkalinity value of the three aquaculture pond type fall within permissible standard values by Kumar (2004), with the plastic pond having the highest value and the earthen pond types were having the lowest value. The high alkalinity observed in the plastic and concrete pond type may be the reason of the stable PH values observed in these ponds. As deduced by Joseph et al (1993) in a pond with higher alkalinity, the PH shift is reduced. The low alkalinity observed in the earthen ponds may be due to the weak buffering system, as documented by Svobodova (1987) without a carbonate buffering system, free carbon dioxide will form large amounts of weak acid (carbonic acid) that may decrease the PH level. The low alkalinity in the earthen pond types may be due to insufficient or absence of liming activities in these ponds and this can be achieved by adding calcium in form of calcium hydroxide, calcium carbonate and calcium dioxide (Ben-Yami, 1986).

Dissolved oxygen (DO) is one of the most important abiotic parameters influencing the life in aquatic environment. Normally high DO is encountered in unpolluted ponds and low levels of DO in polluted ponds. Further depletion of DO to the level of anaerobia is most critical manifestation of pollution (lester, 1975).

DO concentrations were above 4mg/l in plastic and concrete ponds which is adequate enough to support aquatic life. In the present investigation it has been found that the DO value is more in some pond types. The high value of DO in the plastic and concrete pond as compared to standard (3 to saturation) might be due the frequency of water change in the two ponds and the use of mechanical aerators which is used to enhance production. The earthen pond has the lowest value of DO. This may be due to the presence of microbes and plants as fish are not the only consumer of oxygen in aquaculture system; bacteria, phytoplankton and zooplankton consumes quantities of oxygen as well (Boyed, 1999). This low DO observed in earthen aquaculture ponds may possibly lead to asphyxiation and death of fishes as deduced by Saunder (1962).

According to Tucker (1993), Carbon dioxide (CO₂) concentrations in aquaculture systems are generally low because the CO₂ in the water will normally near equilibrium with atmospheric CO₂ which is low. This may be the reason why CO₂ values of plastic and concrete ponds are low on the first day of water change but remain within the permissible values. There values increased on the last days of water change with the value of CO₂ in plastic and earthen ponds above standard values. This may be due to the high stocking density observed with the plastic pond and lack of buffering activities taking place in the farms. The high values observed in the earthen ponds are due to cultured fish and decomposers producing CO₂ faster than it can move it to the atmosphere (Tucker, 1993).

Fish exposed to excess CO₂, there blood equilibrate with excess pressure in the water. Bubbles formed in the blood will block the capillaries. In

severe cases of CO₂ exposure, death occurs rapidly due to blockage of major arteries. (Boyed and Tucker, 1998 and Bouck, 1980).

In the present study, the earthen aquaculture ponds are observed to have the highest turbidity values. This is due to the high value of suspended solids observed in these ponds and presence of algae. The high turbidity values in this pond could have led to the production of hydrogen sulphide observed in this pond as deduced by Bristow et al (1996), when organic solids settle to the pond bottom, they contribute to the biological oxygen demand of the sediment that may lead to anoxic area and hydrogen sulphide production. The turbidity values in the plastic and concrete ponds are within permissible values but there is an increase in their values on the last days of water change. The increase in value may be as a result of accumulation of faecal materials and uneaten fish feed (Piper et al, 1982 and Wedemeyer, 1996) as the frequency of water change in some of these farms are as long as every six days. The low stocking densities and high rate of feeding in the concrete ponds could have amounted to the presence of uneaten fish feed in the ponds (table 3 and 4)

In the present study, it has been found that the aquaculture ponds have increased values of suspended solids on the last days of water change. The earthen ponds have the highest values of suspended solids. This is due to sedimentation of unused agrochemicals, manure and excreta. The high suspended solids associated with this pond type contributed to the slow growth rate of fish grown in this pond type; as deduced by Piper et al (1982) and Wedemeyer (1996), solids in water may interfere with fish finding food or may damage the gills of fish. The slightly high values of suspended solids observed in the concrete pond types on the last days of water change is as a result of the low stocking densities and high rate of feeding in the pond as accumulation of the uneaten fish feed could contribute to the high values seen on the last days of water change.

In the present investigation of chlorine in aquaculture ponds in Maiduguri, it has been observed that although the fish farms uses water from borehole and well, chlorine is observed to be present in the aquaculture ponds. This indicate possible water pollution by disinfectants used to disinfect the plastic and concrete ponds before stocking while that seen in the earthen pond types may be due to contamination of inflow of waste from terrestrial runoff. The tolerable recommended value of chlorine by Kumar (2004) is as low as <0.03mg/l. Fishes exposed to higher values are restless and body heamorrhagic. Fish leaps out of the water. Skins and gills of fishes are covered with thick layer of mucus. There is

spasmic movement of the mouth fins and tail. The buccal spasm hinders respiration, so that the fish suffocate and ultimately dies (Bohl, 1989).

According to Seegert and Brooks (1978), chlorine is relatively unstable and can be removed by aeration, sunlight or activated carbon. This may have been the reason why chlorine was not seen in plastic and concrete pond types on the last days of water change. The continual presence of chlorine in the earthen pond types could be due to the high concentration of organic substances, which makes aeration ineffective as aeration will encourage decomposition of organic matter as deduced by kumar (2004) as well as the continues inflow of waste from terrestrial runoff.

In the present study, it has been found that the three aquaculture pond types have hydrogen sulphide values higher than the recommended values by kumar (2004) on two days of water change with the earthen aquaculture ponds having the highest values. This is due to the high bacteria content associated with this pond type, as hydrogen sulphide is a poisonous gas produced by anaerobic activity of bacteria (Piper et al, 1982; Tucker, 1993; Wedemeyer, 1996). According to Wedemeyer (1996), the un-ionized form is freely across the gills and toxicity of hydrogen sulphide increases with decreasing PH. It could be deduced from the present investigation of hydrogen sulphide that fish grown in the earthen pond type are likely to suffer from hydrogen sulphide toxicity as the earthen ponds has been observed to have a decreased PH.

The concentrations of ammonia and nitrite give a useful indication of pollution in the aquaculture pond types and this has the ability to support plant growth. The observed high and increasing ammonia and nitrite values above the permissible value by Kumar (2004) in the plastic ponds types could be due to the high stocking densities observed in the pond as against the recommended stocking densities of 200fishes/m³ or m³ by Brune and Tomasso (1991) thus there is accumulation of excreta in the pond, and the high ammonia and nitrite concentrations observed in the concrete pond types could be due to the high rate of feeding and low stocking density densities, hence the excess feed decomposes and pollutes the pond water. According to Vamos and Szollozy (1974), high values of ammonia and nitrite in the earthen pond types is due to addition of manure to fertilize the pond or through the process of nitrogen fixation by algae and water plants.

According to Alabaster and Lloyd (1980), ammonia poisoned fish congregates close to the water surface, gasp for air and are restless. The skin is light coloured and covered with thick layer of

mucus. In some cases haemorrhages occurs mainly at the base of the pectoral fins. Vamos and Szollosy (1974) documented that in nitrite poisoned fish, a brownish colour of blood on the gills is seen indicative of increase in methaemoglobin, as nitrite bound to haemoglobin giving rise to methaemoglobin which reduces the oxygen transporting capacity of the blood.

Many ground waters contains elevated levels of heavy metals (Boyd and Tucker, 1998) hence boreholes and well waters used for aquaculture could have amounted for the high values seen on the first days of water change which are above permissible values of up to 0.001 for all heavy metals. On the last days of water change for plastic and concrete pond types and just before toping of pond water for earthen pond types; levels of all the heavy metals reduced. This reduction in value is due to the heavy metals entering the aquatic food chain through the direct consumption of water or biota and via non-dietary routes such as uptake through absorbing gill epithelia (Brezonik et al; 1991). On the last day of water change, though values of metals reduced, it seems to be highest in the plastic pond. This could be due to the frequency of water change observed in such ponds which constantly add metals to the pond. Fish has the tendency to accumulate these metals in significant quantity and to serve as a source of health risk to man and other predators (Brezonik et al; 1991).

In the present study it has been found out that the earthen pond has the highest value of total water hardness, this is due to the addition of lime in an objective for high better production (Rashmi et al, 2008). Values seen in plastic and concrete pond types are due to exogenous and endogenous product formation in the aquaculture ponds (Rashmi et al, 2008).

Calcium and magnesium ions comprise hardness. If hardness is deficient, fish do not grow well. Low hardness can be adjusted by addition of lime or calcium chloride (Joseph et al, 1993).

CONCLUSION AND RECOMMENDATION

Most fish farmers in Maiduguri Metropolis grow their fish in plastic, concrete and earthen pond types. The management practices in these farms have been found to have effects on the physico-chemical water characteristics in these ponds and are aquatic potential health risk factors. From the present study it can be enumerated as below:

From the production view, the plastic pond type was observed to be most suitable for fish production in comparison to the concrete and earthen pond types because of the high stocking density and low level of contaminants. Most of physico-chemical parameters

values in the plastic and concrete pond types were observed to be within permissible limit and could support aquatic life and could pose less health risk to the fish with rapid growth rate.

From the public health point of view, the earthen pond type has been observed to be more suitable for fish production, as heavy metals concentration just before toping the pond with water is more than levels found in the plastic and concrete pond types indicative of the fish absorbing and accumulating these heavy metals from its environment into its body tissues and depleting it from its environment. The fish is eaten wholly thereby posing a health risk of heavy metal poisoning to humans and other fish predators.

Based on the findings of this study, the following recommendations are made:

(1) The use of water recirculation system /closed system/ filtration system. This is where the filtration of the tank water takes place through screen filters to remove big solids matter, sediment filter to remove suspended solid matter, clarifiers to clarify the water and reduce the mineral and elements level in the water accumulating due to various biological and biochemical activity, biofilters to remove the dissolved gases and ammonia, UV irradiation to kill bacteria, fungi and viral pathogens in water, ozonation to kill the germs and oxidize the dissolved organic matter, PH stabilizer to keep the optimum level as illustrated in appendices 1.0. Filtration system gives a continuous movement of pure water which is considered good living environment for fishes and the natural systems condition is preserved as the water is used continuously. The minerals and vitamins leached into the water during feeding and decomposition of fecal matter will be available to fishes always. This management practice will pose less or no health risk to the cultured fish and to man and will equally enhance fish health, growth and productivity.

(2) Work should be carried out on other water quality factors that are important in fresh water aquaculture systems and method to monitor them.

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