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Aquaculture as Source of Environmental Contaminants: A Study of Earthen Pond versus Plastic Pond

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Abstract:

In Sub-Sahara Africa, small-scale aquaculture systems (earthen ponds and plastic basin ponds) have become popular as means of fish cultivation, both for subsistence and as a source of income. Their successful practice, however, involves the use of organic and inorganic chemical substances which may accumulate in pond water and sediments, ultimately finding their ways into the larger environment when the ponds are eventually emptied. This may have significant impact on the environment, since individual communities have thousands of such small-scale systems which are largely unregulated. In this study, we investigated the physico-chemical characteristics and heavy metal composition of typical earthen and plastic ponds. Result of physicochemical analyses revealed the possibility of release of carbonaceous organic materials which may deplete the oxygen levels in natural waters for their decomposition. Such organic materials would come mainly from plastic ponds, as a result of leaching of the plastic monomers and additives into the pond water. The study indicated that both earthen and plastic ponds could contribute to the contamination of the environment by heavy metals, especially Copper (Cu), manganese (Mn) and Zinc (Zn). Possible contributions to Cu, Mn and Zn levels are 3.92 mg, 2.68 mg and 2.63 mg respectively, per litre of earthen pond water; and 2.57 mg, 1.94 mg and 2.08 mg respectively, per litre of plastic pond water discharged into the environment. Sediment/sludge of both earthen and plastic ponds have the potential to spike Cu levels in the environment by 5.27 mg and 3.61 mg per kg of sediment discharged, respectively. This study constitutes an initial investigation into the environmental impacts of earthen and plastic pond aquaculture (with respect to chemical contaminants) and could assist authorities in tropical Africa to formulate policies to ensure that the sustainability and quality of the natural environments are not compromised by the proliferation of small-scale aquaculture systems.

Keywords: Environment, aquaculture; contaminants, water quality characteristics, heavy metals, sediment

1. Introduction

There is a need to meet up food demand by replenishing the continuously depleted population of fish stock available in natural water bodies as human population increases around the world. Man's conscious attempt to increase fish production through aquaculture has played an important role in enhancing food security and human nutrition, especially in many developing countries. As a result, aquaculture provides controlled cultivation and harvest of aquatic organisms to ensure its year-round availability. Unlike land under cultivation, the world's oceans, lakes, rivers and streams are usually public, common resources and managing common resources could be problematic. In aquaculture, man-made water bodies are dammed for use, providing favorable conditions necessary for the survival of cultivated aquatic organisms. With key control on parameters such as water quality, stocking density, feed quality, aeration and mineral availability (Makori *et al.*, 2017), the optimum condition for fish production has been achieved and the process has been explored for human benefits.

The seemingly controlled environment for fish farming (the pond) presents a dynamic zone of activities. Its chemistry is expressed by the physical, chemical and biological characteristics (Mwekaven *et al.*, 2017; Makori *et al.*, 2017) and assessed by pH, conductivity, alkalinity, acidity, hardness, chloride, sulphates, nitrates, phosphates, total solids, solid matters, dissolved oxygen, chemical oxygen demand, biochemical oxygen demand, and mineral composition (Imsland *et al.*, 2007; Bhatnagar and Devi, 2013). Also important is the pond's bottom zone, which may be composed of soil, organic solids, inorganic compounds and trapped gaseous components. It is a complex heterogeneous medium, which shows spatial variability in physical and chemical properties at micro and macro scales (Younis and Tesfamariam, 2017). Due to its adsorptive tendency, this bottom zone can be a carrier and potential source of contamination for the larger environment. The adsorption is strongly influenced by the prevailing pH, redox condition and relative concentration of ions present in the aqueous solution in contact with the zone.

In aquaculture, aquatic organisms cultivated maybe plants, fish or shellfish (oysters), mussels, clams, shrimp, crabs, crayfish, etc. These organisms usually take-up minerals and trace metals from soil sediments and associated water. When fish are exposed to water laden with trace metals quantities above specified environmental standards, it becomes inimical to their growth and survival. This condition is also known to disturb the delicate balance of the aquatic

ecosystem, which has been noticed to manifest in the presence of some irregularities in fish physiology (Finerty *et al.*, 1990; Guerrin *et al.*, 1990). These minerals are not removed from water bodies through any natural elimination process, but move from one section of the aquatic environment and may be transformed through food chain in a phenomenon called bioaccumulation (Power and chapman, 1992). Exposure of human to aquatic foods contaminated with excess minerals and metals may have wide range of adverse effects, including nervous system and kidney damage, liver damage, cancer, genetic mutation and tumors (Monisha *et al.*, 2014; Dinesh *et al.*, 2019; Jarup, 2003).

Successful practice of aquaculture, even on a small scale, requires the use of a wide variety of chemical materials. These often include inorganic and organic fertilizers, copper sulphate, potassium permanganate, lime, phostoxin, rotenone, various forms of pesticides, antibiotics and antimicrobials, salt and formalin (Jilani *et al.*, 2012; Belal *et al.*, 2013; Bui *et al.*, 2016). Many of these are used in high concentrations, especially in aquaculture systems where egg hatching and juvenile production are the focus. Whilst the chemicals may have proved to be effective for their intended use, a major environmental concern is inherent in their use. This is because they often contain inorganic and metallic impurities which, after the active ingredients have been consumed, remain in the ponds, and are eventually emptied into the larger environment. This applies, not only to the pond water, but also to the bottom zone or sediment, which is equally excavated and transferred into the open environment in a major operation referred to as demudding. Thus, the practice of fish farming constitutes a potential source of contaminants to the total environment. Whilst a systematic study has been conducted to compare earthen pond system with cage (plastic) pond alternative, with respect to the quality of fish product, yield, and derivable profit (Olaoye *et al.*, 2014); there is no evidence of a study comparing the extent of environmental contamination resulting from earthen pond and cage aquaculture systems in tropical Africa. Such an investigation is needed as pollution from these systems may be significant, more so that millions of people now engage in small-scale fish farming using either or both of these practices (Wuyep and Rampedi, 2018).

This study therefore determines the physiochemical characteristics of spent water from earthen and cage (plastic) fish ponds. It also investigates the concentration of heavy metals in water and associated sediments from earthen and plastic fish ponds. Apart from determining which of earthen and plastic aquaculture systems impacts the environment more negatively and contributes the most to environmental contamination, the study also seeks to provide insight into the role played by the available soil-water interphase in earthen pond system with regards to heavy metal release, and in comparison, with plastic cage aquaculture.

2. Materials and Methods

2.1. Study Site and the Ponds

The study was conducted within the research farm at the Federal University of Technology, Akure, Nigeria. A circular earthen pond (2 m diameter and 2 m deep) was dug manually and the surrounding area was weeded. As normally done by commercial fish farmers using earthen ponds, the dug pond was treated with Phostoxin to kill potential predators of fingerlings that would be grown in the pond. Such predators may include big snakes, tortoises and monitor lizards. The pond was then left for 2 weeks before stocking with 200 catfish (*Clarias gariepinus*) juvenile, each weighing between 6 and 8 g.

A large plastic Geepee™ water tank, made of high-density polyethylene, 2m (diameter) x 15 cm (thickness) was purchased and used for the plastic pond experiment. The tank was cut open at the top, so that the remaining length is approximately 2 m. It was placed beside the earthen pond and stocked with the same number of catfish fingerlings. Both ponds were operated with distilled water filled to about 1.8 m depth.

Fishes in both ponds were fed with Durante™ floating feed, sizes 1.5mm, 1.8 mm, 2mm and 4mm in succession for 2 months, and then switched to sinking feed 2mm to 8 mm until they were 6 months old, when they were all removed from the ponds.

2.2. Sampling of Water and Sediments

The left-over waters of the ponds were sampled for physicochemical and heavy metals analysis. In each case, 2 litre of water was sampled over five spots on the surface of the pond. It was divided into two portions (1 litre each) and transferred into clean dry glass bottles. 5 % nitric acid was added to the portion for heavy metal analysis in each case. The samples were then refrigerated prior further analyses.

Water present in each pond was pumped out completely to expose the sediment in the earthen pond and the bottom sludge in the plastic pond. Small soil/sludge samples were scooped from five equally spaced-out pots in each case. They were combined to give representative composite sediment sample for each pond. The sediment samples were air-dried in the laboratory for 2 weeks at room temperature and sieved using 2 mm - size mesh.

To take into account the possible contribution of the background level of heavy metals in the sediment of the earthen pond prior to fish growing, soil samples were sampled from the freshly dug pond as done for the sediment of the pond after the growing period. The samples were dried and treated as for the sediment/sludge samples.

2.3. Physicochemical Analyses of the Water Samples

2.3.1. pH and Electrical Conductivity

pH of the water samples was measured *in situ* with pH meter (APHA 460 Testre-1 model) after standardizing with pH 4 and at pH 10 buffer solutions. Conductivity of the water samples was measured with a conductivity meter (WINLAB model), following calibration with 0.01M KCl solution.

2.3.2. Acidity and Alkalinity

To determine acidity, sodium hydroxide (0.02 M) was titrated against 100 mL of water containing phenolphthalein (2 drops). Acidity was determined by simple acid-base molarity calculation. For alkalinity, 0.02 M HCl was titrated against 100 mL of water using the mixed indicator (phenolphthalein and methyl orange) method (Ademoroti, 1996).

2.3.3. Determination of Chloride, Nitrate, Sulphate and Phosphate

Chloride (Cl⁻) in the water samples was determined by Mohr titrimetric method. 1 mL of 5 % potassium chromate (K₂CrO₄) solution was added to 100 mL of sample and titrated with AgNO₃ solution (0.028 M) to a reddish-brown end point. Nitrate (NO₃⁻) was determined in the water samples by sodium salicylate spectrophotometric method and Phosphate (PO₄³⁻) was determined by vanado-molybdate colorimetric method, both described by Ademoroti (1996). To determine sulphate, standard solutions of Na₂SO₄ (2 to 20 mg/L) were shaken with 10 mL of NaCl-HCl solution, 10 mL of alcohol-glycerol mixture and 5 g of BaCl₂. Absorbance of the resulting solutions were read at 425 nm and a calibration curve was prepared. The water samples were treated similarly and their SO₄²⁻ concentration determined from the calibration curve.

2.3.4. Total, Calcium and Magnesium Hardness

Total hardness was determined by titrating 0.01 M ethylenediamine tetraacetic acid (EDTA) solution against 50 mL of water containing 2 mL KCN solution and 2 drops of eriochrome black T indicator. For calcium hardness, the EDTA solution was titrated against water sample containing 2 drops of murexide indicator. Magnesium hardness was calculated as the difference between total and calcium hardness.

2.3.5. Total Solids, Total Dissolved Solids and Total Suspended Solids

Total solid (TS) was determined by drying 25 mL of well-mixed water to constant weight in an oven at 105 °C. For total dissolved solid (TDS), 250 mL of homogenized water sample was filtered through a glass microfiber. The filtrate was dried in a preheated (105 °C) porcelain dish and further heated to constant weight in a muffle furnace at 550 °C. TS and TDS were calculated as stated by APHA (2005) and total suspended solid (TSS) was known from the difference between TS and TDS.

2.3.5. Dissolved Oxygen, Biological Oxygen Demand and Chemical Oxygen Demand

Dissolved oxygen (DO) was determined *in situ* with a Hanna DO kit. 2 mL each of MnSO₄·5H₂O and alkaline iodide solution were added to 250 mL of water sample. 100 mL of the solution was acidified and titrated with 0.024M. Na₂S₂O₃·5H₂O, using starch as indicator. DO was calculated from equation 1.

$$\text{DO (mg/L)} = \frac{V \times N \times 1000 \times \text{Equivalent weight of Oxygen}}{\text{Volume of Sample}} \quad \dots\dots\dots (1)$$

where V and N are volume and concentration of Na₂S₂O₃·5H₂O, respectively.

DO was also determined for a 100 mL of sample incubated at 20 °C in a dark bottle for 5 days. Biological oxygen demand (BOD) was obtained from equation 2.

$$\text{BOD} = \text{DO} - \text{DO (after 5 days)} \quad \dots\dots\dots (2)$$

Chemical oxygen demand (COD) was determined by titrimetric method using ferrous ammonium sulphate, as detailed by Ademoroti (1996)

2.4. Digestion of Samples and Heavy Metals Analyses

Nitric acid (5 mL) was added to 100 mL of water sample and the mixture was slowly evaporated to near dryness. The remaining liquid was filtered into a 100 mL standard flask and made up to the mark with distilled water. For sediment samples, 10 mL of nitric acid and 5 mL of 30 % hydrogen peroxide were added to 1 g of sieved soil sample in a Kjeldahl flask and the mixture was heated to full digestion (Vodopivec *et al.*, 2019). The resulting liquid was filtered into a 100 mL standard flask and made up to the mark.

All sample digests were analyzed for copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb), manganese (Mn), iron (Fe), zinc (Zn) and nickel (Ni) by atomic absorption spectrophotometry, AAS (Buck Scientific Model 210VGP). As part of quality control, all glass apparatus used were leached with dilute acid and washed many times with distilled-deionized water to ensure no metal contaminants were introduced. Accuracy of the analytical method was validated by digesting and analyzing spiked distilled-deionized water samples, with recovery ranging from 97.2% to 99.1%.

3. Results and Discussion

3.1. Physico-Chemical Characteristics of Water from Earthen and Plastic Cage Ponds

Table 1 shows the physicochemical properties of water samples from the earthen and plastic ponds. Water chemistry is of great importance to freshwater systems, as it provides indication of the ability to support aquatic life (Rathore *et al.*, 2016). In this study, the physicochemical characteristics serve to give insight into the likelihood of earthen pond water and plastic pond water to alter the quality of open surface water when they are eventually released into the environment, as it is the usual practice in aquaculture.

The pH gives an indication of the ponds' overall chemical processes and whether they tend towards acidic or alkaline nature. Results presented in Table 1 reveals that the pH of water from both ponds are in the alkaline range, although that of the earthen pond is more alkaline (8.6) than that of the plastic pond (7.5). While this pH range is consistent with the quality of water tolerable to many fish species (Makori *et al.*, 2017; Deekae *et al.*, 2010), the value obtained for the earthen pond is slightly above the upper limit of 6.5 - 8.5 specified by the world health organization (WHO, 2011). The pH values are in agreement with the alkalinity of the pond waters, a measure of the ability to neutralize strong acids, usually expressed as mg/L CaCO_3 . Earthen pond with higher pH value had higher alkalinity (240 mg/L), compared with the alkalinity value of 180 mg/L determined for the plastic pond. Consequently, acidity was higher in the plastic pond (400 mg/L) and lower in the earthen pond (140 mg/L). These results indicate that plastic pond water had higher level of dissolved CO_2 than earthen pond water.

Parameter	Earthen Pond	Plastic Pond	Parameter	Earthen Pond	Plastic Pond
pH	8.6 $\pm$ 0.05	7.5 $\pm$ 0.00	Dissolved Solid (mg/L)	600.0 $\pm$ 0.32	400.0 $\pm$ 0.88
Conductivity ($\mu\text{S}/\text{cm}$)	1055.0 $\pm$ 0.50	321.5 $\pm$ 1.50	Chlorides, Cl^- (mg/L)	425.4 $\pm$ 3.09	499.8 $\pm$ 3.54
Acidity (mg/L)	140.0 $\pm$ 2.00	400.0 $\pm$ 3.60	Dissolved Oxygen (mg/L)	5.7 $\pm$ 0.25	2.7 $\pm$ 0.10
Alkalinity (mg/L)	240.0 $\pm$ 3.00	180.0 $\pm$ 3.10	B.O.D (mg/L)	29.4 $\pm$ 0.60	16.2 $\pm$ 0.60
Total hardness (mg/L CaCO_3)	240.0 $\pm$ 2.20	189.0 $\pm$ 1.42	C.O.D (mg/L)	95.9 $\pm$ 0.10	160.0 $\pm$ 0.05
Calcium hardness (mg/L CaCO_3)	67.5 $\pm$ 2.00	111.0 $\pm$ 0.50	Sulphate, SO_4^{2-} (mg/L)	29.6 $\pm$ 1.57	34.6 $\pm$ 0.05
Magnesium (mg/L CaCO_3)	172.5 $\pm$ 1.00	78.0 $\pm$ 2.50	Nitrate, NO_3^- (mg/L)	3.7 $\pm$ 0.02	5.8 $\pm$ 0.06
Total solid (mg/L)	1000.0 $\pm$ 3.18	1200 $\pm$ 4.11	Phosphate, PO_4^{3-} (mg/L)	19.2 $\pm$ 0.06	39.8 $\pm$ 1.34
Suspended solid	400.0 $\pm$ 0.08	800.0 $\pm$ 0.46			

Table 1: Physicochemical Characteristics of Water from Earthen and Plastic Ponds
Values are means of three replicates $\pm$ standard deviation

Electrical conductivity measured for the earthen pond was higher (1055.5 $\mu\text{S}/\text{cm}$) than that of the plastic pond (321.5 $\mu\text{S}/\text{cm}$). This could be as a result of continuous dissolution of ions from the soil in contact with the water in the earthen pond (Kataria *et al.* 2011). The plastic pond had no bottom soil in contact with the water, so the possibility of such dissolution is excluded. The conductivity value for both the earthen and plastic pond waters are however above the guideline value (250 $\mu\text{S}/\text{cm}$). Conductivity of water is influenced by the concentration of ions in solution – the higher the amount of salt dissolved in water, the higher its conductivity (Rusydi, 2018). Thus, conductivity values obtained for the two samples are consistent with the dissolved solid/salt (DS) content, which is 600 mg/L for earthen pond water and 400 mg/L in plastic pond water. Total solid (TS), a combination of both dissolved and suspended solids (SS), is higher in the plastic pond water than in the earthen pond water, due to the higher amount of SS in the former.

Hardness is due mainly to the presence of metallic ions Ca^{2+} and Mg^{2+} in water. Total hardness was 189 mg/L for plastic pond water and 240 mg/L for the earthen pond water. The higher hardness of the earthen pond water may also be attributed to the influence of the soil below the pond, unlike the plastic pond water which is not in contact with the earth. Dissolved oxygen (DO) was lower in the plastic pond water (2.7 mg/L) but higher in the earthen pond water (5.75 mg/L). Two possible reasons may be responsible for these results. First, the earthen pond is exposed to a larger surface of the atmosphere and a greater access to oxygen in air. Secondly, the bottom zone in the earthen pond may contain aquatic plants, algae, and phytoplankton which utilize dissolved CO_2 for photosynthesis and release oxygen into the water.

Chemical oxygen demand (COD), a measure of pollution of water by all oxidizable organic contaminants (both biologically active and biologically inert), was found to be higher in the plastic pond (160 mg/L) compared to the earthen pond (95.9 mg/L). On the other hand, the biological oxygen demand (BOD), a measure of pollution of water by organic

matter that can be oxidized/broken down by aerobic bacteria in water, was higher in the earthen pond water (29.4 mg/L) than in the plastic pond water (16.2 mg/L). Since COD takes into account the oxidation of carbonaceous chemical substances like petrochemicals and organic monomers, these results strongly indicate that materials and additives used in making plastic cages are leached into the plastic pond water over time, leading to the higher amount of oxygen required for their oxidation. Such leaching of materials may be promoted by other chemicals like pesticides and fertilizers that are normally added to ponds for proper fish growth.

Concentration of chloride ion (Cl^-) measured in both the earthen pond and the plastic pond exceeded the WHO recommended value of 250 mg/L, above which undesirable taste become apparent. The value was 499.8 mg/L for plastic pond water and 425.4 mg/L for earthen pond water. Nitrate (NO_3^-), sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) concentrations are all lower in the earthen pond water than in the plastic pond water. This may be attributed to the fact that the ions are plant nutrients and are being utilized by lower plants and algae growing in the earthen pond, resulting in their depletion from the water. Presence of such nutrient-consuming species is unlikely in the plastic cage pond, so that the ions are fully contained in such a system. This notwithstanding, the results indicate that the discharge of water from earthen pond or plastic pond aquaculture is not likely to constitute a source of contamination of the open environment with respect to NO_3^- , SO_4^{2-} and PO_4^{3-} . Levels of NO_3^- and SO_4^{2-} of both pond waters are well within the WHO guideline limit of 50 mg/L and 500 mg/L, respectively.

3.2. Heavy Metal Concentrations of Water from Earthen and Plastic Cage Ponds

To assess the potential of heavy metal contamination of the environment with water from earthen pond and plastic pond, concentrations of various heavy metals were determined in the water samples and the results are presented in Table 2. Maximum limits for some of the metals specified by WHO are stated in the table. While the available WHO standard provides guideline values for drinking water, it serves as a benchmark in this study to assess the extent of pollution of water by heavy metals resulting from the different modes of aquaculture investigated.

Cr, Pb, Cd, Ni, Cu, Mn, Fe, Zn were all detected in earthen pond water, whereas only the latter four were detected in plastic pond water. Cu was the metal detected at the highest level, giving 3.92 mg/L in earthen pond water and 2.57 mg/L in plastic pond water. Both values exceeded the WHO guideline limit for Cu in water. The relatively high concentration of Cu in the pond waters may be traced to the application of Copper sulphate (CuSO_4), intended to prevent the growth of algae in both systems. These results reveal that a substantial amount of elemental Cu is retained in pond waters after the growing period, and may contribute significantly to its level in the natural environment, when the pond waters are eventually discarded. Whilst catfish (*Clarias gariepinus*), used in this study and most commonly grown in Africa, may well tolerate the concentration of Cu present in the pond waters, residue of the metal in the discarded pond water is a source of concern in the interest of the natural ecosystem. This is because Cu has been shown to be very toxic to other fish species and aquatic life forms, even at concentrations well below that measured in the final pond waters. It impairs metabolism and nutrient absorption in *Mystus vittatus* and significantly reduces body length and weight in Caspian sea kutum (*Rutilus frisii kutum*) (Gharedaashiet al., 2013; Subathra and Karuppasamy, 2007). Cu has also been shown to worsen the effect of acidification and warming on early life stages of microscopic algae species *Macrocystis pyrifera* and *Undaria pinnatifida*, ultimately disrupting the completion of their life cycles (Pablo et al., 2018). The ability of Cu to bioaccumulate in many bird species is also worth mentioning (Einoder et al., 2018).

Metal	Earthen Pond	Plastic Pond	WHO Limit
Copper	3.92 ± 0.12	2.57 ± 0.09	2.00
Chromium	0.05 ± 0.00	ND	0.05
Lead	0.03 ± 0.01	ND	0.01
Manganese	2.68 ± 0.03	1.94 ± 0.13	N.S
Iron	0.13 ± 0.02	0.04 ± 0.00	N.S
Cadmium	0.01 ± 0.00	ND	0.003
Zinc	2.63 ± 0.08	2.08 ± 0.02	N.S
Nickel	0.02 ± 0.00	ND	0.07

Table 2: Heavy Metal Concentrations (mg/L) of Water from Earthen and Plastic Ponds

ND - Not Detected; N.S – Not Specified by WHO

Concentrations of Mn and Zn measured in both earthen pond and plastic pond waters indicate that the two systems contribute to the contamination of the environment by these metals. Whilst no WHO guideline limits are specified for Mn and Zn (as they are not expected to be found in water at levels that could constitute a threat to human health); amounts emanating from these fishing practices, 2.68 mg/L and 1.98 mg/L respectively for earthen and plastic ponds, calls for some concern in view of the sustainability of the ecosystem. Mn bioaccumulates in many aquatic species, and particularly in invertebrates where bioaccumulation factor up to 40,000 have been reported, compared to the maximum of 600 recorded for fish species. Mn acts as a competitive inhibitor of calcium-regulated ion channels in nerves and membranes of invertebrates, inhibiting synaptic and neuromuscular transmission (Pinsino et al., 2012; Holmes et al., 1999). Concentration of Zn measured in each pond water was comparable to that of Mn. Although Zn is an essential trace element required by nearly all organisms for metal-activated enzyme functions, amount emerging from these earthen and plastic fish-growing operations may not be disregarded, given the fact that hundreds of thousands of fish farms are

typically located within and around each community, and may be discharging pond waters into the same natural waters. Invertebrates and marine macro and microalgae are known to be sensitive to Zn at concentrations below that which affect fish species (UK Marines, 2019). Concentrations of Fe measured in the two pond waters are considerably lower than those recorded for Cu, Mn or Zn.

Overall, the concentration of each heavy metal was higher in the earthen pond water than in the plastic pond water – Cr, Pb, Cd and Ni were not detected in the plastic pond water. The presence of Cr, Pb, Cd and Ni in the earthen pond water sample may not be attributed to the operation of this type of fish farming, but may be a result of the interphase of the pond water with the ground beneath it (as detailed in section 3.3).

3.3. Heavy Metal Concentrations in the Sediment of Earthen and Plastic Cage Ponds

Table 3.3 shows concentration of the heavy metals determined in the sediment below the pond waters for both earthen and plastic aquaculture systems. In addition, it shows background concentration of heavy metals in the dug earthen pond, prior to stocking it with fish and the subsequent operations.

Detection of metals in the sediment follow the same pattern as for the corresponding pond water samples (i.e. Cr, Pb, Cd and Ni were not detected in the sludge sample from the plastic pond). However, concentrations of the detected metals are generally higher in the sediment/sludge than in the corresponding water samples in both cases. This observation is consistent with the accumulation and distribution characteristics of heavy metals and other pollutants in aquatic environment, as the benthic habitat often serve as reservoir or sink for most chemical contaminants.

In order to assess the extent of contamination of the pond sediments and their potential to contaminate the natural environment, we compared results obtained in this study with the maximum permissible concentrations (MPC), based on the work of Crommentuijn *et al.* (2000). The MPC take into account the ecotoxicity effect of heavy metals on plant species, on fauna such as arthropods and earthworms, on the development of microbiological processes, the tendency of the metals to go into solution, and the possibility to enter ground and surface waters. Thus, values above the MPC suggest that the particular metals in the sediment or soil may constitute a hazard to the environment. For metals that the MPC are specified for, the results show that the concentration of metals measured in the earthen and plastic pond sediments are mostly below the MPC, implying that the levels of metals in sediment/sludge resulting from single operation of earthen or plastic pond do not constitute a source of environmental concern. The only exception is Cu, in which the MPC is exceeded in both sediment types, even after taking out the background Cu concentration in the soil for the earthen pond. As for the pond waters in both cases, this study reveals that Cu concentration in the sediments/sludge of both pond types constitute a source of contamination of the environment with this metal.

Metal	Background Concentration	Earthen Pond	Plastic Pond	MPC*
Copper	0.02 ± 0.00	5.27 ± 0.05	3.61 ± 0.10	3.5
Chromium	0.08 ± 0.02	0.11 ± 0.02	N.D	3.8
Lead	0.16 ± 0.01	0.08 ± 0.03	N.D	55
Manganese	0.21 ± 0.00	3.42 ± 0.15	2.15 ± 0.04	N.S
Iron	0.06 ± 0.01	0.21 ± 0.00	0.09 ± 0.01	N.S
Cadmium	0.02 ± 0.01	0.03 ± 0.01	N.D	0.76
Zinc	0.11 ± 0.05	3.14 ± 0.07	2.72 ± 0.11	16
Nickel	0.08 ± 0.03	0.07 ± 0.00	N.D	2.6

Table 3: Heavy Metals Concentration (mg/Kg) In Sediment from Earthen and Plastic Ponds

ND - Not Detected; *Maximum Permissible Concentration Based on Potential

Ecological Toxicity (Crommentuijn

et al., 2000); N.S - Not Specified

The background concentrations of the metals in dug pond provide further insight into the results obtained for the two systems. Firstly, all the metals analyzed were detected in the background soil at values ranging generally from 0.02 to 0.21 mg/kg. Secondly, the same type of metals (Cu, Mn and Zn) were found occurring at relatively higher concentration in both earthen and plastic pond sediments. Considering the fact that the two ponds were run in parallel, utilizing same source of water, same type of feed, fish stock, antibiotics, and other inputs; and considering also the fact that the plastic pond is a fully contained system, with no contact whatsoever with the soil underneath; it implies that the metals detected in the plastic pond system represent the actual metals that emerge, as a result of the entire fish-growing operations. This explains why these metals were detected in high concentrations, and were the same set of metals detected in higher concentrations in the earthen pond sediment. Other metals measured at low concentrations in the earthen pond sediment appear to result from the contact of this type of pond with the background, which has trace amounts of the metals. This also explains why concentrations of these metals are low in the water sample of the earthen pond and have resulted from continuous dissolution of minerals from the ground into the water. Such contribution to the heavy metals level of the sediment and water in earthen pond aquaculture would vary both in magnitude and types, depending on the geology of the pond location.

Whilst the specified MPC value for most of the metals were not exceeded in the sediments, a common observation, after the discharge of earthen and plastic pond sediments, is the attraction of reptiles, birds and flying insects to the discarded sediment, apparently to feed on dead fish tissues and other possible organic materials in the sediments. Such

direct contact of the species with the contaminated pond sediments may inadvertently lead to ingestion of the metals, alongside any nutrient derived from the discarded sediment, and may therefore represent an exposure route of these animals to the metals. However, the extent to which this affects the species involved remains to be fully studied and characterized.

4. Conclusions

We have investigated the physico-chemical characteristics of waters from earthen and plastic ponds, as well as the levels of heavy metals from both water and sediment of the ponds, with a view to assessing their potential to contaminate the environment. Alkalinity, biological oxygen demand, total hardness and conductivity were all higher in the earthen pond water than in the plastic pond water. Conductivity measured in both waters exceeded the guideline limit, as a result of high level of dissolved salts in the pond waters. Concentrations of phosphate, nitrate, sulphate and chloride ions were higher in the plastic pond waters than in the earthen pond waters; both aquaculture practices have the potential to add to the environmental levels of these ions, especially chloride, whose concentration in both waters exceeded the suggested limit. More importantly, the study revealed that organic materials used in making plastic may leach into the pond waters, resulting in high chemical oxygen demand of waste water from plastic pond systems, and subsequently high chemical oxygen demand of any natural water which may receive it.

Both aquaculture types have the potential to add to the amount of Cu in the environment, as revealed by the amount of this metal detected in the waters and sediments. Furthermore, the discharge of waste water from both earthen and plastic ponds could add to the levels of Mn and Zn in the environment. Indeed, many studies in the region have reported high concentrations of heavy metals in rivers and sediments, suggesting mining activities, discharge of effluents from industries and hospitals, fumes from exhaust of automobiles and crop farming as contributors. This study has revealed that the discharge of water and sediments from aquaculture practices is yet an unrecognized source of Cu, Mn, and Zn contamination in the region. Being an initial study within Tropical Africa to examine this effect, the outcome is highly significant for regulatory agencies to set up policies to regulate aquaculture, in Nigeria, as well as in other developing African nations, many of which have similarly large number of individuals engaged in earthen and plastic pond fishery practices.

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