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Research Article

Soil and Water Environments of *Clarias gariepinus* Fish and their Correlated Major Mineral Composition from a Man-Made Pond in Nigeria

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ABSTRACT

This report concerned the study of the soil sediments, ambient water and their major mineral elements in conjunction with the body parts of *Clarias gariepinus* fish on wet weight basis. Water had pH of 6.9 at 26.8OC, conductivity was 211.10 µS/cm3, low phosphate of 0.0218 ppm and BOD of 1.898ppm. Most concentrated mineral value was shared between K (166.87 – 258.68mg/100g) and P (112.42 – 1302.32mg/100g); also highest mineral concentration in the fish samples (on parameter basis) was shared between head (2.974 – 1302.32 mg/100g) and liver (37.71-379.70mg/100g). Minerals in soil sediments were significantly higher than the corresponding parameter values in the ambient water: soil sediment (7.955-179.2ppm) and water (0.014-101.42ppm); whereas P (179.12ppm) was the most concentrated in soil sediments, Na (101.42ppm) was the most concentrated in the water. Non-alienation values were high in the pairs: M/H [0.9325(93.25%)], H/L [0.5698 (56.98%)], M/L [0.5922 (59.22%)] and SED/WAT [0.9405 (94.05%)]. In the mineral safety index (MSI), only P in the head was higher than the standard by a value of 8.10% whereas all other MSI values were lower than the standard; hence, only P could be deleterious when the head of *C. gariepinus* is consumed. Bio-concentration factor values were moderate to high except in P.

KEYWORDS: *Clarias gariepinus* parts, pond environments, minerals, Bio-concentration factors.

INTRODUCTION

Animal protein intake by Nigerians has been very low due to a decrease in animal production per capita and the rising growth in the human population.[1] Fish have however become the major source of animal protein. Over the last 40 years, there had been a gradual increase in world production of fish from aquaculture sources at estimated value of an average annual rate of 8.8%.[2] Many experts agree that the most significant increase in the consumption of fish is due to higher population, income and urbanization.[3]

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Fish has existed in Africa since 200BC[4] and are known as tropical fishes. In the tropical forest margins of the West African coast, fish is a crucial source of protein and the dried form, a common condiment[5] Over 500,000,000 people in developing countries depend directly or indirectly on fisheries and aquaculture for their livelihood.[6] The freshwater fish species of Nigeria is the richest in West Africa, with more than 268 known presently. They comprise Nilo-Sudanian, Guinean and Zairean fishes.[7]

The state of world fisheries and aquaculture[8] gave the following data. Projected fish trade, 2030 (live weight equipment):

	Exports		**Growth**	**Imports**		**Growth**
Region/country	**(1000 tonnes)**		**2016 to 2030**	**(1000 tonnes)**		**2016 to 2023**
	2016	2030	(%)	2016	2023	(%)
Africa	2782	2304	-17.2	4239	6111	44.2
Nigeria	14	15	6.6	661	1034	56.4

Aquaculture food fish production by region and selected major producers (thousand tonnes: percent of world total)

Region/selected countries	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**
Africa	110	400	646	1286	1772	1982
	0.5%	1.2%	1.5%	2.2%	2.3%	2.5%
Nigeria	17	26	56	201	317	307
	0.1%	0.1%	0.1%	0.3%	0.4%	0.4%

Total and per capita apparent fish consumption by region and economic grouping, 2015

Region/economic grouping	**Total food fish**	**Per capita food fish**
	consumption (million tonnes live wt. equivalent)	consumption (kg/year)
Africa	11.7	9.9

Projected fish production, 2030 (live weight equivalent)

Region/country	**Fisheries and aquaculture**			**Agriculture**		
	Production		Growth	Production		Growth
	(1000 tonnes)		2016 to 2030 (%)	(1000 tonnes)		2016 to 2030
	2016	2030	%	2016	2030	%
Africa	11260	13556	20.4	1982	3195	61.2
Nigeria (after Egypt and Morocco)	1041	1231	18.2	307	418	36.2

Fish farming is a vibrant and dynamic commercial sector in Nigeria ripped with investment and employment opportunities. The Aquaculture industry is not new to Nigeria, the fish documented fish farm dates back to about 50 years +. Oladejo[9] states that production is projected to exceed 150mln tonnes by the year 2010. Eze and Ogbara[10] reported that pond fisheries is being practiced in Nigeria in large scale for better augmentation of fish products. The African catfish *Clarias gariepinus* is widely cultivated in Africa and it is an important commercial mud fish for the Nigerian fishing industry and it is mostly cultivated in Kajola fish farm in Ibadan, Nigeria.[11]

Clarias gariepinus or African sharptooth catfish is a specie of catfish Claridae, the air breathing catfishes.[12] They are distributed throughout Africa and the Middle East, and live in freshwater lakes, rivers and swamps, as well as human made habitats, such as oxidation ponds or even urban sewage systems. The African sharptooth catfish was introduced all over the world in the early 1980s for aquaculture purposes, hence is found in countries far outside its original habitat, such as Brazil, Vietnam, Indonesia and India.[12]

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Clarias gariepinus is a large eel-like fish, usually of dark grey or black colouration on the back, fading to white belly. In Africa, this catfish has been reported as being second in size to the *vundu* of the Zambesian waters,[13] although *Fishbase* suggests the African sharptooth catfish surpasses that species in both maximum length and weight.[14,15] *C. gariepinus* has an average adult length of 1-1.5m (3ft 3in – 4ft 11in). It reaches a maximum length of 1.7m (5ft 7in) TL and can weigh up to 60kg (130 Ib).[14] These fish have slender bodies, flat bony heads, notably flatter than the genus *Silurus*, and broad terminal mouths with four pairs of barbels. They also have large accessory breathing organ composed of modified gill arches. Also, only the pectoral fines have spines.[13] It is a nocturnal fish like many catfish. It feeds on living, as well as dead animal matter and plant matter.[16] Due to its wide mouth, it is also able to swallow relatively large prey whole, e.g. waterbirds such as common moorhen.[17] It can crawl on dry ground to escape drying pools, it can also survive in shallow mud for long periods of time, between rainy seasons. The rearing of the African catfish in Africa started in the early 1970s in Central and Western Africa, as it was realized to be a very suitable species for aquaculture.[12]

Clarias gariepinus: scientific goes thus: Domain (Eukaryota); Kingdom (Animalia); Phylum (Chordata); Class (Actinopterygii); Order (Siluformes); Family (Clariidae); Genus (*Clarias*); Species (*C. gariepinus*); Binomial name (*Clarias gariepinus* Burchell 1822).

Pond water parameters are often overlooked. However, having the correct water parameters is one of the most important factors for a successful, healthy pond. Correct parameters mean fish will be healthy. Aerobic bacteria can do their job properly and finally, any plants added will contribute positively to the condition of the pond.[18] The maximum amount of oxygen that can physically be held in water is 18.0 mg/L whereas minimum is 6.0mg/L. Cold water van hold almost twice as much oxygen as warm water.[18] The pH levels in ponds are very important and pond pH levels of somewhere between 7.5pH and 8.5pH are recommended. This is the perfect balance for not only bacteria in our products but also the inhabitants of the pond. Ammonia is a product of fish excrete waste. Nitrifying bacteria fed by calcium carbonate can break the ammonia, turn it into nitrite. Nitrite is then further oxidized to its final state (nitrite). All these three may be dangerous to the fish and need careful monitoring. Pond ammonia should be 0.00ppm-0.5ppm at neutral pH; nitrite is best between 0.00ppm-0.25ppm; nitrate levels should be around 20-60ppm.[18] Phosphate can be in pond water in many forms: soil planting containers, fertilizers in soil prior, tap water (to stop water pipes corrosion). Essential part of fish food is phosphate and can be released as fish waste into the pond. Phosphate in fish pond should be about 0.05ppm.[18]

Fish production results in the generation and accumulation of fish pond sediment in aquaculture systems over time. Fish pond sediment constitute a mixture of fish waste, decaying plant remains, dead algae, uneaten feed and faeces [19,20,21,22], and as such they are rich in organic matter and nutrients. It is estimated that 10-30% of fish feed becomes faeces.[22] Pond sediment nutrient rich in nitrogen (1.08-7.03g/kg), carbon (18.3-92.3g/kg), phosphorus (0.22-2.07g/kg), magnesium (0.62-2.93g/kg), potassium (0.62-2.25g/kg). The characteristics of fish pond sediment differ depending on many factors including the type of aquaculture system, the type and age of the fish, water quality, feeding type and regime, weather conditions, etc. Fish pond sediment needs to be managed and handled rapidly in an environmentally sound and sustainable manner.[23]

Metals are introduced into the aquatic system as a result of the weathering of rocks and soils from volcanic eruptions and from several activities involving the mining, processing and uses of metals and industrial materials that contain

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metal contaminants.[24,25] Osborne and Mendel[26] as well as others[27,28,29,30] had concluded that mineral elements are of vital concern in nutrition. Mineral element that are required in relatively large amounts in the body are grouped as major or macro elements.[31,32] These are calcium, phosphorus, potassium, sulphur, sodium, chlorine and magnesium. Sodium, chlorine and potassium are identified as the major electrolytes of body water.[31]

The solvent power of water ensures that it usually contains dissolved gaseous elements and compounds and metals such as sodium, magnesium, calcium and probably iron. The presence of metal pollutants in freshwater is known to disturb the delicate balance of the aquatic ecosystem. Fishes are notorious for their ability to concentrate metals in their muscles[33] and since they play an important role in human nutrition, they need to be carefully screened.

Little attention has been paid to the comparative study of major mineral composition in these matrices (soil sediment, ambient water and fish anatomical parts).[34,35,36] This work provided information on the concentration and bio-concentration factors of calcium, magnesium, sodium, potassium and phosphorus in the anatomical parts (head, muscle and liver) of *Clarias gariepinus* fish and the associated sediment and ambient water in freshwater man-made ponds. The physicochemical properties of the ambient water was also determined.

MATERIALS AND METHODS

Sampling

Samples were taken from a local fish vendor who manages the fish ponds located in Basiri quarters of Ado-Ekiti, Ekiti State, Nigeria in the month of December in year 2022. Grass was planted around the pond to prevent erosion and in-wash of muddy water.

Grab samples were taken below the water surface at two different locations in the pond using 1-1 acid-leached polyethylene bottles. The water samples were pooled together. The samples were stored at 2.8^0C. An auger was used to take soil sediments from the surface down to a depth of about 15cm at two different locations and these samples were pooled together and stored in polyethylene bags in a laboratory freezer pending analysis. Four fresh fish of *Clarias gariepinus* were caught from the pond with the assistance of the pond attendant. Each fish was briefly washed with distilled de-ionised water to remove any adhering contamination and then drained under folds of filter paper and then wrapped in aluminium foil and deep-frozen.

Sample treatment

pH: The pH of water samples was determined by the use of pH meter. The meter was calibrated by using the buffer solutions of 4.0, 7.0 and 9.02 to cover the acidic, neutral and alkaline regions. The probe was immersed in the solution and after the stable readings, the values were recorded. pH was measured with a KENTEIL 7020 (Kent industrial measurement limited, Surrey England).

Temperature: the temperature of the water sample was measured by employing the glass bulb thermometer in the range of 0^0C -100^0C.

Electrical conductivity: electrical conductivity is a measure of the ability of an aqueous solution to carry an electric current. Electrical conductivity was measured in water samples using standard conductivity meter after it was calibrated with appropriate standard solutions. Electrical conductivity was measured with CDM 83 conductivity meter (By Radiometer A/S Copenhagen, Denmark) after standardization with KCl solution.

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Biological oxygen demand (BOD): Apparatus [200ml bottle capacity, pipettes of different sizes, burettes]; reagents, [manganese II suphate, sodium hydroxide, potassium iodide, sodium azide, alkali-iodine-azide solution, phosphoric acid]. Procedure: two sets of samples were prepared for the determination of the DO on a:

1. Suitable portion that was freshly sub sampled and
2. Suitable portion in the incubation bottle placed in the dark for 5 days.

200ml capacity bottle was filled to the brim and minimized the contact with air. 1ml of the manganese solution was added to the bottom of the bottle and followed by 1ml of alkali-iodine-azide solution. The bottles were stoppered and shaken well. After the precipitate had settled, 2ml of the concentrated phosphoric acid was added to dissolve precipitate. The released iodine was titrated with 0.025M thiosulphate at the recorded temperature. The dissolved oxygen was calculated and difference between the DO of day 1 and day 5.

Nitrogen forms (Nitrite): Measurements of nitrogen were carried out in samples as total nitrogen. The form of nitrogen measured in water was nitrate and nitrite. The analyses of the various forms relied on chemical reaction of the samples with catalyzing agents. The extract then reacted with colour agents (for example sulfanic acid in nitrite analysis) to form specially coloured complexes and/or compounds. Measurements of the concentrations of the nitrogen form were then made spectrophotometrically at specific wavelengths against standard concentration curves.

Chloride: Chloride in the samples was measured by the titrimetric methodology. Standardized silver nitrite solution was titrated against the solution of the sample in the conical flask. Standard curves were prepared by titrating the standard of different concentration of chloride ions with the silver nitrite solution. The results were read out from the calibration curves prepared from the standard curves.

Sulphate: Determination of sulphate in the samples was based on the barium chloride turbidity method equivalent to APHA 4500-Si (STD Method).[37] Barium chloride was added to sulphate solution and turbidity caused by barium sulphate suspension which is proportional to sulphate concentration was measured spectrophotometrically.

Phosphate: The water samples were analyzed for forms of phosphorus. Phosphorus analyses employing APHA 4500-PE (STD Method) (37) consist of two general procedural steps: (a+) conversion of the phosphorus form of interest to dissolved orthophosphate, and (b) spectrophotometric determination of dissolved orthophosphate. The primary forms determined in this programme were reactive phosphorus and total phosphorus. Phosphates that respond to colorimetric test without preliminary hydrolysis or oxidative digestion of the samples are termed “reactive phosphorus”. While reactive phosphorus is largely a measure of orthophosphate, a small fraction of any condensed phosphate present usually was hydrolyzed unavoidably in the procedure. Reactive phosphorus occurs in both dissolved and suspended forms.

Mineral analysis

Fish: 1.0g of the sample was weighed in the petri dish on the laboratory bench before the analysis. The sample in the petri dish was emptied into the murfle furnace pot. The pot with its content was placed in the furnace at 550^0C for 4 hours. The sample in the pot was allowed to cool in the desiccator. It was repeated until constant weight was obtained.

Fish: (Digestion): 0.1g of the ashed sample was weighed into the pre cleaned borosilicate 250ml capacity beaker for digestion. 20ml of nitric acid was added into the weighed sample in the beaker. The sample with the digesting solvent

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was placed on the hot plate for digestion in the furnace cupboard. The beaker and its contents after digestion were allowed to cool. Another 20ml of the digestion solvent was added and digested further in the fume cupboard and the mixture was allowed to cool to the room temperature. The mixture was filtered into the 250ml volumetric capacity borosilicate container. The filtrate was made up to the mark with the de-ionised water.

Sediment: (Digestion): 1.0g of soil samples was weighed into the pre cleaned borosilicate 250ml capacity beaker for digestion. 20ml of nitric acid was added into the weighed sample in the beaker. The sample with the digesting solvent was added and digested further in the fume cupboard and the mixture was allowed to cool to the room temperature. The mixture was filtered into the 250ml volumetric capacity borosilicate container. The filtrate was made up to the mark with the de-ionised water.

Water: (Digestion): 10ml of water sample was measured into the pre cleaned borosilicate 250ml capacity beaker for digestion. 20ml of nitric acid was added into the measured sample in the beaker. The sample with the digesting solvent was placed on the hot plate for digestion in the furnace cupboard. The beaker and its contents after digestion were allowed to cool. Another 20ml of the digestion solvent was added and digested further in the fume cupboard and the mixture was allowed to cool to the room temperature. The mixture was filtered into the 250ml volumetric capacity borosilicate container. The filtrate was made up to the mark with the de-ionised water.

All the digested samples were sub-sampled into pre-cleaned borosilicate glass containers for atomic absorption spectrophotometer analysis (AAS).

Standards of sodium, calcium, potassium and magnesium solutions of 0.2, 0.4, 0.6, 0.8 and 1.0mg/l were made from each of metals solution of 1000mg/l stock solutions of the analytes. The set of standard solutions and the filtrate of the digested samples were analysed by AAS. The detection limit of the metals in the sample was 0.0001mg/l by means of the UNICAM 929, London, Atomic Absorption Spectrophotometer powered by the SOLAR software. Calcium, potassium, sodium and magnesium cathode lamps were used for the analysis of the respective minerals ions in the standards and the filtrate of the samples. Gas mixtures of compressed air and acetylene were used in the generation of the flame for the minerals.

Phosphorus: 25mg of the sample was weighed into the Schoniger flask and burnt in excess of oxygen gas. The product was digested with nitric acid. The content was boiled for a minute to ensure complete conversion of phosphorus pentoxide to orthophosphate. The solution was passed through a 10cm long resin column, and the filtrate was collected. In a 10ml pyrex test tube, 2ml of the colour development reagent was added for the absorbance reading at 650nm for both the standards and the sample filtrate.

Some calculations from the analytical generated data

Percentage compositions: The mineral parameter percentage composition over the overall mineral composition for each sample was calculated for fish muscle, head, liver: soil sediments and ambient water.

Ratios calculation: Ratios of HPAF: MPAF: LPAF: SED: WAT were calculated where H=head; M=muscle; L=liver; SED= sediment; WAT=water; PAF=fish pond in Ado-Ekiti.

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Correlation statistics: Statistics, both descriptive and inferential methods were used in the calculation of the analytical data as appropriate. Pairs of correlation statistics used were M/H, H/L, M/L and S/W calculating for inferential statistical parameters of correlation coefficient (r_{xy}), variance (r_{xy}^2), regression coefficient (R_{xy}), coefficient of alienation (C_A) and index of forecasting efficiency (IFE). The r_{xy} calculated was compared to the standard (critical) value at n-2(df) and setting the r_{xy} value at $r_{xy=0.01}$. In conjunction with inferential model were the descriptive statistics of mean, standard deviation (SD) and the coefficient of variation in percent (CV%).[38,39] Further statistics comparisons were made between M/S, M/W, H/W, L/S and L/W (M=muscle; S=sediment; W=water; L=liver; H=head).

Mineral differences: Mineral differences (and their percentage differences) were calculated between their pairs: M-H, H-L, M-L and SED-MAT (with their corresponding percentages).

Calculation of mineral safety index (MSI): Mineral safety index values were obtained for Na, Ca, Mg, P (no standard MSI for K). The calculated MSI values were compared with standard MSI values, differences found and their percentage differences calculated.

Bio-concentration factors (BFs): The BFs were calculated for Na, K, Mg, Ca, P and total sample mineral load; also calculated BF was for soil sediments.

Finally, comparisons were made in the major minerals in the present fish samples with published literature values; this also occurred for the bio-concentration factors.

RESULTS AND DISCUSSIONS

The physicochemical properties of the ambient water had been depicted in Table 1. The pH was 6.9 at 26.8^{O}C. A fish natural pH is 7.4, hence, it is wise to keep pond pH to be close to this level as possible. Although fish can tolerate slight fluctuations in the acidity or alkalinity of the water; however, only 6.8 and up to 8.6 will be tolerable.[18]

The pH (standard) values for a warm water fisheries had been put at 6.50-9.00 units[40] at 29.9^{O}C. Also, Adeyeye[36] had reported pH of 7.16 units at 27.5^{O}C in a fresh water pond that contained *Clarias gariepinus.* Warm water fish grow best at temperatures between 25^{O}C and 32^{O}C. In an American survey of 409 locations, it was found that the pH range of those containing a good fish population was 6.3 to 9.0, with the majority if water-courses being within the range 6.7 to 8.6.[41] The measured electrical conductance for the water was 211.10 µS/cm^3. This is much higher than the report in Adeyeye[36] where such value was 20.20µS/cm^3. Gulp et al.[40] have reported the level of conductance required for the fresh warm water aquaculture as 150 to 550µS/cm^3 which is the range of 100 to 350 ppm of total dissolved solids. The chloride level in the water was 16.3963mg/l. The chloride value in the report of Adeyeye[36] was 46.09 mg/l whereas Gulp et al.[40] reported a standard of 0.002mg/l. The amount of chloride in water is a useful measure in water sample. Chloride can range from <10ppm to >25000ppm (in sea water).[42] High level of chloride is not known to be injurious to fresh water organisms.[36]

Phosphate level in Table 1 was 0.0218mg/l. High levels of phosphate are a major cause of green water and blanket weed in a pond. If the phosphate level are kept low, algae growth will be limited within a pond. Phosphate in ponds should be about 0.05ppm;[18] this meant the phosphate level in the present report was fine. The lowest oxygen level in pond freshwater should be 6.0mg/l,[18] the present value was much less at 1.8982mg/l. However, some fish will be able to tolerate lower oxygen levels than this;[18] this could be the case for *Clarias gariepinus* with its specialized gill arches.

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In the report of Adeyeye,[36] another *Clarias gariepinus* pond had oxygen level of 2.00mg/l which was close to the present report. The analyzed water sample was taken in the morning. Reported lethal concentration of dissolved oxygen for common carp (*Cyprinus carpio L*) is 0.2 to 0.8mg/l.[43] It is expected that photosynthesis will always increase during the day light, meaning that the pond water dissolved oxygen will likely increase during the day thereby raising the level of dissolved oxygen above 1.8982mg/l. Both nitrate and sulphate values were low at respective values of 0.1206mg/l and 24.15mg/l. The nitrate level was lower than the recommended minimum of 20-60mg/litre.[18] On the whole the pond was suitable for the fish development.

Table 1: Physicochemical parameters of the pond water in *Clarias gariepinus* fish pond.

Parameters	Units	Water
pH	-	6.9
Temperature	^{O}C	26.8
Electrical conductivity	($\mu S/cm^3$)	211.10
Nitrate	mg/l	0.1206
Sulphate	mg/l	24.115
Phosphorus	mg/l	0.0218
Chloride	mg/l	16.3963
Biochemical oxygen demand (BOD)	mg/l	1.8982

The major minerals (Na, K, Mg, Ca, P) in the soil sediments and ambient water had their levels depicted in Table 2; their percentage levels were also calculated as presented in Table 2. In the sediments, P was the most concentrated at 179.12ppm (wet weight) and 62.21%. This was distantly followed by Ca at 65.77ppm (wet weight) and 22.84% of total mineral weight in the soil. The mineral concentration trend in sediment was total >P>Ca>Na>Mg>K. Literature values for Na and K in soil sediments were: Na(0.02mg/litre) (dry weight) and 3.02mg/litre (dry weight) in K;[34] 11.67mg/litre (dry weight) in Na and 1.56mg/litre (dry weight) in K [36]; in three ponds, the following were reported : sediments, mg/l(dry weight), 2.15-8.06 (Ca), 0.15-0.79(Mg), 2.30-4.70(Na) and 3.50-6.40(K).[35] All this literature values were less than the present reported values all on pairwise comparisons. Fish pond sediments had also been reported to be rich in nutrients like nitrogen, 1.08-7.03g/kg; carbon,18.3-92.43g/kg; phosphorus, 0.22-2.07g/kg; magnesium, 0.62-2.93g/kg and potassium 0.62-2.25kg.[44] The most concentrated mineral in the water was sodium at a value of 101.42ppm and 83.27% and phosphorus was the least value at 0.014ppm and 0.011%. The second most concentrated mineral was potassium at a value of 14.61ppm at 112.00%. Value of magnesium was<1.00(0.908ppm, 0.746%) whereas calcium was <5.00(4.841ppm, 3.975%). The total water mineral concentration was 121.79ppm thereby giving a ratio of WAT: SED as 1.00:2.364. Literature values were : 0.55ppm(Na) and 8.33ppm(K) (34); 0.16ppm(Na) and 0.02ppm(K); in three fish ponds:0.18-1.07ppm (Ca), 0.43-0.55ppm(mg), 4.70-5.80ppm and 5.70-6.00ppm(K)[35]. High variations existed between the soil sediment minerals and those of the water as demonstrated by the coefficient of variation percent (CV%) which ranged between 41.72 and 141.39. Na, K had their values more concentrated in water than their corresponding values in soil. The high aqueous solubility of Na and K salts might have contributed to their relatively high concentration in the water samples. Since K is a well-known constituent of plant [45], its level in the soil would be enhanced by dead plant residues and this would enrich the associated water in K. Low Mg and Ca concentrations were reported in the water samples despite the fact that Mg is supposed to be among the earth's most common elements with many soluble salts, this may in turn affect the hardness of the pond water.[46] Na and K are the 6^{th} and 7^{th} most abundant elements in the earth's crust.[47] The solubility of most salts of Group I elements in water decreases on descending the group.[47] The results in Table 2 show that the concentration of Na was higher than K both in the soil sediments and the pond water. At pH levels greater than 5.0, influx and outflux are approximately equal and

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the body Na is maintained, < pH 5.0 the influx is increasingly reduced, and the efflux is increased. While the influx is most sensitive to acid pH values the efflux is more responsive to Ca concentration of the water, it is thought that lack of Ca increases cell membrane permeability.[41]

Table 2: Major mineral composition (wet weight) [Na, K, Mg, Ca, P] of soil sediments and water in *Clarias gariepinus* fish pond.

Mineral	Sediments (ppm) (%values)	Water (ppm) (%values)	Mean	SD	CV%
Na	22.96 (7.974)	101.42 (83.27)	62.19	55.48	89.21
K	7.955 (2.763)	14.61 (12.00)	11.28	4.706	41.72
Mg	12.12 (4.209)	0.908 (0.746)	6.514	7.928	121.71
Ca	65.77 (22.84)	4.841 (3.975)	35.31	43.08	122.01
P	179.12 (62.21)	0.014 (0.011)	89.57	126.64	141.39
Total	287.93 (100)	121.79 (100)	204.86	117.48	57.35
Ratio:	SED: WAT 2.364:1.00				

SED = sediments; WAT = water

Depicted in Table 3, were the major mineral concentrations (wet wt.) in muscle, head and liver all at mg/100g level. The concentration values were also accompanied by their corresponding percentages. The distribution of the minerals in the fish anatomical parts was highly varied except K whose CV% was (least varied). This distribution could be ranked as follows: Phosphorus [1st in H, L, 2nd in M =14/45 or 31.11%] > Potassium [1st in M, 2nd in L, H = 13/45 or 28.89%] > Na [3rd in H, 4th in M, L = 7/45 or 15.56%] ≡ Ca [3rd in M, L, 5th in H =7/45 or 15.56] > Mg [4th in H, 5th in M, L =4/45 or 8.89%] totalling 100.0% distribution. This highly varied values had led to high CV% that varied between 26.63 and 104.37. The samples total mineral trend was (mg/100g wet wt.): muscle (402.19) < liver (855.38) < head (1630.94). The various mineral ratio distributions were, MPAF: LPAF (1.00:2.127); MPAF: HPAF (1.00:4.06) and HPAF: LPAF (1.00:1.907) where PAF (=Ado-Ekiti fish pond), M=muscle, L=liver, H=head. Some literature values on dry weight basis had the following values: *Cyprinus carpio* [Na, 62.8(head), 48.1(muscle), 0.833(liver)], [K,12.7(head), 16.9(muscle), 0.460(liver)]; *Clarias gariepinus* [Na, 46.0(head), 12.5(muscle), 5.79(liver)], [K, 12.5(head), 13.5(muscle), 1.37(liver)]; *Oreochromis niloticus* [Na, 31.1(head), 63.1(muscle)][34]. Further previous report on *clarias gariepinus* had these values: [Na, 63.5(head), 35.2(muscle), 3.50(liver)], [K, 19.2(head), 10.8(muscle), 1.24(liver)](36). Finally in *Illisha africana* in ponds 1,2,3: [Ca, head(1.37-2.47), muscle(1.36-1.81)]; [Mg, head(0.050-0.181), muscle(0.138-0.164)]; [Na, head(10.4-19.0), muscle(6.22-14.8)]; [K, head(2.30-6.20), muscle(6.40-8.70)].[33] These present results were generally better than in *C. carpio, C. gariepinus*, better than head of *O. niloticus*[34]; better previously reported *C. gariepinus*[36]; and in *Illisha africana.*[36] These differences could have been due to the differences in the fish species, environment, age of the fish, sex of the fish, season of capture, etc.

Table 3: Major mineral composition (wet weight) [Na, K, Mg, Ca, P] of *Clarias gariepinus* muscle, head and liver.

Mineral	Muscle mg/100g (%value)	Head mg/100g (%value)	Liver mg/100g (%value)	Mean	SD	CV%
Na	36.73 (9.132)	79.81 (4.893)	42.88 (5.013)	53.14	23.30	43.85
K	168.01 (41.77)	166.87 (10.23)	258.68 (30.24)	197.85	52.68	26.63
Mg	18.95 (4.712)	78.97 (4.842)	37.71 (4.409)	45.21	30.70	67.91
Ca	66.08 (16.43)	2.974 (0.182)	136.41 (15.95)	68.49	66.75	97.46
P	112.42 (27.95)	1302.32 (79.85)	379.70 (44.39)	598.14	624.30	104.37
Total	402.19 (100)	1630.94 (100)	855.38 (100)	473.84	351.24	74.13
Ratios:	MPAF:LPAF; 1.00:2.127;	HPAF:LPAF 1.00:1.907	MPAF:HPAF 1.00:4.06			

% = percentage; SD = standard deviation; CV% = coefficient of variation percent; MPAF = fish muscle at Ado-Ekiti pond; LPAF = fish liver at Ado-Ekiti pond; HPAF = fish head at Ado-Ekiti pond

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The Table 4 combined the analytical data for the minerals in the fish sample parts, soil sediments and water. The major aim of the Table was to observe the concentration dispersion of the minerals in the various matrices as depicted in the CV% values. The second aim was again to look at the ratio type in the matrices. Table 4 showed that all the CV% were high at 89.18-150.87, whereas the Na had the least CV% (89.18), P had the highest CV% (150.87). The ratios were; M:H(1.00:4.055); M:L(1.00:2.127); L:H(1.00:1.907); W:S(1.00:2.364); M:S(13.97:1.00); M:W(33.02:1.00). Further ratios were; H:S (56.65:1.00); H:W(133.90:1.00); L:S(29.71:1.00); L:W(70.23:1.00).

Table 4: Major mineral composition (wet weight) [Na, K, Mg, Ca, P] of *Clarias gariepinus* muscle, head and liver; ambient water and soil sediments compared.

Mineral	Muscle (M) (mg/100g)	Head (H) (mg/100g)	Liver (L) (mg/100g)	Sediments (S) (mg/100g)	Water (W) (mg/100g)	Mean	SD	CV%
Na	36.73	79.81	42.88	2.296	10.14	34.37	30.65	89.18
K	168.01	166.87	258.68	0.796	1.461	119.16	114.01	95.68
Mg	18.95	78.97	37.71	1.212	0.0908	27.39	32.67	119.28
Ca	66.08	2.974	136.41	6.577	0.484	42.51	59.15	139.14
P	112.42	1302.32	379.70	17.91	0.0014	362.47	546.86	150.87
Total	402.19	1630.94	855.38	28.79	12.18	585.90	677.86	115.70
Ratios	M:H; 1.00:4.055;	M:L 1.00:2.127;	L:H 1.00:1.907;	W:S 1.00:2.364;				
Ratios	M:S 13.97:1.00;	M:W 33.02:1.00;	H:S 56.65:1.00;	H:W 133.90:1.00;	L:S 29.71:1.00;	L:W 70.23:1.00;		

The inferential statistics and the descriptive statistics of the mineral data from the various samples were depicted in Table 5. Compared statistical pairs were muscle/head (M/H), head/liver (H/L), muscle/liver(M/L) and SED/WAT(S/W) and calculated parameters were correlation coefficient (r_{xy}), variance (r_{xy}^2), regression coefficient (R_{xy}), mean, standard deviation (SD), coefficient of variation percent CV%), coefficient of alienation (C_A) and index of forecasting efficiency (IFE). The r_{xy} values were highly varied: M/H (0.3612), H/L (0.8218), M/L (0.8058), S/W (-0.3398). The r_{xy}^2 values were low to slightly high (0.1155 to 0.6753). The R_{xy} depicted the relationship between the pairs of x and y where x represented the first member of each pair (from the left) and y represented the pair value at the right hand side. The value not usually shown in the R_{xy} is the left hand value which is constantly assumed to be 1.00 whereas the value of the R_{xy} shown represented the y value. For example in M/H, R_{xy} could be represented as Rx (1.00): Ry (3.282) showing that for every 1.00 unit increase in the x value, a corresponding increase of 3.282 occurred in y value. This scenario applied for the other pairs. The mean values were low to high ranging from 24.36 to 326.19 leading to similar high trend in the CV% values: 75.07-178.45. The C_A was slightly low to very high (0.5698-0.9405). C_A and IFE work together and their relationships are opposite to each other. Whereas C_A indicates the value of non-relationship between two identical materials, IFE exhibits the level of relationship. C_A represent the error of prediction of relationship between two compared entities, IFE represents the reduction in the error of prediction of relationship between two entities. C_A + IFE =1.00 on fractional basis or C_A + IFE =100% on percentage basis. When C_A is high, IFE is low and vice versa. All the IFE values were low at 0.0595 to 0.4302; these values would make prediction of relationship between any of the pairs difficult or even impossible since in each case, C_A >>IFE. Based on this observation, it meant that no member of a pair could carry out the food properties of the other. When r_{xy} was subjected to standard critical value at $r_{xy=0.01}$ at n-2(df), it was observed that $r_{xy(calculated)} < r_{xy(Table\ value)}$ showing that no significant differences existed in any of the pair groups.

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Table 5: Correlation statistics from the data compiled in Table 2 [as M/H, H/L, M/L where H=head, M=muscle, L=liver] and Table 3 [as SED/WAT where SED=soil sediments, WAT=water]

Statistics	Muscle (M)/Head (H)			Head (H)/Liver (L)			Muscle (M)/Liver (L)			SED (S)/WAT (W)		
	M		H	H		L	M		L	S		W
r_{xy}		0.3612			0.8218			0.8058			-0.3398	
r_{xy}^2		0.1304			0.6753		80.44	0.6493			0.1155	
R_{xy}	80.44	3.282	326.19	326.19	0.2204	171.08	60.39	1.963	171.08	57.59	-	24.36
Mean	60.39		548.75	548.75		147.16	75.07		147.16	71.71	0.2060	43.47
SD	75.07		168.23	168.23		86.02			86.02	124.52		178.45
CV%												
C_A		0.9325			0.5698			0.5922			0.9405	
IFE		0.0675			0.4302			0.4078			0.0595	

r_{xy}=correlation coefficient; r_{xy}^2=variance; R_{xy}=regression coefficient; SD=standard deviation; CV%=coefficient of variation percent; C_A=coefficient of alienation; IFE=index of forecasting efficiency; critical level at n-2 (df)=3 at $r_{xy=0.01}$ was 0.959 showing that no r_{xy} was significant for the four compared pairs

Table 6: Statistical comparisons between muscle/sediments (M/S), muscle/water (M/W), head/sediments (H/S), head/water (H/W), liver/sediments (L/S) and liver/water (L/W) from data in Table 4.

Statistics	M/S	M/W	H/S	H/W	L/S	L/W
r_{xy}	0.2155	-0.3122	0.9128	-0.3049	0.7398	-0.4693
r_{xy}^2	0.0464	0.0975	0.8332	0.0930	0.5473	0.2203
R_{xy}	0.0256	-0.0225	0.0119	-0.0024	0.0361	-0.0139
$Mean_1$	80.44	80.44	326.19	326.19	171.08	171.08
SD_1	60.39	60.39	548.75	548.75	147.16	147.16
$CV\%_1$	75.07	75.07	168.23	168.23	86.02	86.02
$Mean_2$	5.758	2.435	5.758	2.435	5.758	2.435
SD_2	7.170	4.346	7.170	4.346	7.170	4.346
$CV\%_2$	124.52	178.48	124.52	178.48	124.52	178.48
C_A	0.9765	0.9500	0.4084	0.9524	0.6728	0.8830
IFE	0.0235	0.0500	0.5916	0.0476	0.3272	0.1170

The Table 5 was extended in Table 6 to include these pairs: M/S, M/W, H/S, H/W, L/S and L/W. The r_{xy} values in M/W, H/W and L/W recorded negative values, MS was low (0.2155), both H/S and L/S were slightly high but not significant. Values that were slightly high in the r_{xy} were also slightly high in r_{xy}^2. Pairs that were negative in the r_{xy} were also negative in the R_{xy} whereas others recorded low R_{xy} values. Both mean and CV% were high as observed in Table 5. Also the C_A was consistently higher than its corresponding IFE values thereby making the prediction of relationship difficult.

In Table 7, mineral differences (and their percentages) were recorded for these pairs: M-H (%), H-L (%) and M-L (%) and this was repeated in Table 8 between SED-WAT (%). Negative differences were observed between pairs as follows: M-H (%) in Na, Mg, P with the percentage differences ranging between 3.174(Na) and 87.67(P); also negative differences were observed in Na (M-L), K (H-L, M-L), Mg (M-L), Ca (H-L, M-L), and P (M-L). The CV% were high. This further showed the unequal concentration of the major minerals in the various sample parts thereby making the consumption of the parts necessary for balance mineral consumption. In Table 8, SED-WAT (%) were negative in Na and K. However, the K difference was just 1.981% as the positive difference was 0.840% in M-H.

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Table 7: Mineral differences between muscle and head (M-H), head and liver (H-L) and muscle and liver (M-L) and their corresponding percentage differences.

Parameters	M-H (%)	H-L (%)	M-L (%)	Mean	SD	CV%
Na	-43.08 (3.174)	+36.93 (3.012)	-6.150 (1.357)	27.72	19.79	71.39
K	+1.140 (0.0840)	-91.81 (7.488)	-90.67 (20.01)	61.21	52.02	84.99
Mg	-60.02 (4.422)	+41.26 (3.365)	-18.76 (4.140)	40.01	20.66	51.64
Ca	+63.11 (4.650)	-133.44 (10.88)	-70.33 (15.52)	88.96	38.69	43.49
P	-1189.9 (87.67)	+922.62 (75.25)	-267.28 (58.98)	793.27	474.72	59.84
Total	1357.25 (100)	1226.06 (100)	453.19 (100)	1012.17	488.51	48.26

Table 8: Mineral differences between sediments (SED) and water (WAT) with their corresponding percentage differences.

Parameters	SED-WAT (%)
Na	-78.46 (23.32)
K	-6.665 (1.981)
Mg	+11.21 (3.333)
Ca	+60.93 (18.11)
P	+179.11 (53.25)
Total	336.38 (100)

The mineral safety index (MSI) levels were low as compared to the standard MSI in Table 9. However, the differences between the calculated MSI values were high as shown by their CV% values (43.73 – 104.37). In HPAF, the calculated P MSI was 10.81 whereas the standard MSI was 10.0, that is HPAF was 0.81units > MSI for P. In Table 10, the various differences between the calculated MSI and the standard MSI values were reported (with their percentage differences). The value differences were generally high, hence high percentage differences but low CV% of 5.198-8.655 in Na, Ca and Mg but not in P. Because MSI (calculated) > MSI (standard) for P in HPAF, the percentage difference was negative at -8.10. Also unlike the CV% in Na, Ca and Mg that were low (5.198-8.655), that of P was high at 76.65. The observation in the head for P, showed that P might be deleterious to the consumer of the fish head. However, since the difference was minor, it may not be deleterious.

Table 9: Mineral safety index (MSI) values of the *Clarias gariepinus* anatomical parts (muscle, head and liver)

Serial number	Mineral	Conversion factor	RAI	MSI-TV	MPAF	HPAF	LPAF	Mean	SD	CV%
1.	Na	0.0096	500	4.80	0.353	0.766	0.412	0.510	0.223	43.73
2.	Ca	0.0083	1200	10.0	0.548	0.025	1.132	0.568	0.554	97.54
3.	Mg	0.0375	400	15.0	0.711	2.961	1.414	1.695	1.151	67.91
4.	P	0.0083	1200	10.0	0.933	10.81	3.151	4.965	5.182	104.37

RAI = recommended adult intake (mg); MSI-TV = mineral safety index standard value; no standard MSI for K

Table 10: Mineral safety index differences between standard MSI and calculated MSI and difference percentages: TV (MSI) – CV (MSI)%

S/N	Mineral	MPAF (%)	HPAF (%)	LPAF (%)	Mean	SD	CV%
1.	Na	4.447 (92.65)	4.034 (84.04)	4.388 (91.42)	4.290	0.223	5.198
2.	Ca	9.452 (94.52)	9.975 (99.75)	8.868 (88.68)	9.432	0.554	5.874
3.	Mg	14.29 (95.26)	12.039 (80.26)	13.59 (90.57)	13.31	1.152	8.655
4.	P	9.067 (90.67)	-0.810 (-8.10)	6.849 (68.49)	5.575	4.273	76.65

S/N = Serial number

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Table 11: Bio-concentration factors (BFs) of the major minerals (Na, K, Mg, Ca, P) in *Clarias gariepinus* fish muscle, head and liver.

S/N	Mineral	MPAF	HPAF	LPAF	Mean	SD	CV%	WAT (PA)*
1.	Na	3.622	7.869	4.228	5.240	2.297	43.84	10.142
2.	K	115.00	114.22	177.06	135.43	36.06	26.63	1.461
3.	Mg	208.70	869.71	415.31	497.91	338.16	67.92	0.0908
4.	Ca	1365.01	61.43	2817.81	1414.75	1378.86	97.46	0.4841
5.	P	8030.00	930228.57	271214.29	427247.6	445930.99	104.37	0.0014
6.	Total	33.02	133.91	70.23	79.05	51.02	64.54	12.236

*WAT (PA) = pond water value (mg/100g) used to calculate the BF

The bio-concentration factors (BFs) of the minerals in the fish samples were reported in Table 11. Values for Na were the lowest in all the samples (3.622-7.869). Three digit values were recorded for BFs in K (all fish samples) and Mg (all fish samples). Four digit values for BFs were observed in Ca (Muscle, Liver), P (Muscle) whereas six digit values were observed in P for head and liver. Present values of BFs in liver (Na, K), head (K) and muscle (K) were greater than in *C. carpio*; liver (K), muscle (K) and head (K) were higher than in the literature *C. gariepinus*; also in *O. niloticus*, the K values in head and muscle were lower than the present results. These enumerations showed that Na was more bio-concentrated in *C. carpio*, *C. gariepinus*; also in *O. niloticus* then the present *C. gariepinus* values. These observations (now extended to Ca and Mg) were made in the comparison with *Illisha africana* fish, where also only the Na was higher than the present study. There is a striking similarity between CV% values of the mineral composition (Table 3) and the BFs (Table 11). The CV% for the minerals and BFs pairs were (Table 3/Table11 CV %): Na (43.85/43.84), K (26.63/26.63). Mg (67.91/67.92), Ca (97.46/97.46) and P (104.37/104.37). This similarity could have been due to the use of similar values of water value for each type of mineral across the samples; further the water unit was converted from mg/l to mg/100g in conformity with fish sample mineral unit. [See Table 11.] The sediment BFs were shown in Table 12. As in the fish samples, Na BF was low but unlike in the fish samples soil sediment K BF was low (0.544). Mg and Ca (both alkali earth metals) almost had similar BFs: Mg (13.34)/Ca (13.59). As in the fish, P BF in soil sediments was high at five digits (12794.29).

Table 12: Bio-concentration factors due to soil sediments.

S/N	Mineral	SEDBF
1.	Na	0.226
2.	K	0.544
3.	Mg	13.34
4.	Ca	13.59+++
5.	P	12794.29
6.	Total	2.364

SEDBF = sediments bio-concentration factors

Table 13 compared the literature bio-concentration factors in Na and K[34] in *C. carpio*, *C. gariepinus*, *O. niloticus* with the present report. Also Table 13 contained the comparison of BFs from *Illisha africana* in Na, K, Ca, Mg[35] with the present results; further comparisons also occurred in literature *C. gariepinus* with present results[36] as shown in Table 13. In Table 14, BFs comparisons occurred for *C. gariepinus*, *C. carpio* and *O. niloticus* (together) for Na and K,[34] *Illisha africana* (together) from three ponds for Na, K, Ca and Mg,[35] *C. gariepinus* in Na and K[36] and the present BFs in Na, K, Mg, Ca and P.

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Table 13: Comparison of values of Na, K, Mg and Ca from literature with present work (all values in mg/100g) [Ref. 34]

Source	Na	K	Mg	Ca
1. Akure (Nigeria)				
(a) *Cyprinus carpio* (dry wt.)				
Air bladder	2.381	1.961		
Intestine	60.86	19.82		
Liver	0.833	0.467		
Gills	59.65	10.59		
Head	62.81	12.75		
Eyes	20.00	2.353		
Scales	10.88	3.137		
Muscle	48.07	16.86		
(b) *Clarias gariepinus* (dry wt.)				
Sex organs	0.833	1.633		
Gills	19.83	8.556		
Liver	5.789	1.373		
Intestine	11.08	15.71		
Muscle	12.50	13.53		
Head	45.97	12.55		
Eyes	1.167	0.467		
(c) *Oreochromis niloticus* (dry wt.)				
Scales	10.52	3.520		
Gills	5.71	4.113		
Intestine	48.42	4.50		
Eyes	8.175	0.528		
Head	31.05	7.017		
Muscle	63.06	49.12		
2. Ikere-Ekiti (Nigeria) [Ref. 36]				
(a) Pond 1: *Illisha africana* (dry wt.)				
Gills	13.20	2.000	0.105	1.588
Head	19.04	2.300	0.121	2.470
Intestine	9.500	7.200	0.181	0.456
Muscle	10.30	8.700	0.138	1.382
(b) Pond 2: *Illisha africana* (dry wt.)				
Gills	10.36	3.280	0.065	0.970
Head	21.70	6.200	0.168	2.352
Intestine	11.00	6.500	0.119	0.221
Muscle	14.80	7.800	0.164	1.808
(c) Pond 2: *Illisha africana* (dry wt.)				
Gills	14.28	1.920	0.032	0.764
Head	10.36	5.500	0.060	1.367
Intestine	5.500	4.300	0.083	0.338
Muscle	6.220	6.400	0.156	1.356
3. Akure (Nigeria) [Ref. 36]				
Clarias gariepinus (dry wt.)				
Sex organs	3.384	0.588		
Liver	3.500	1.244		
Muscle	35.10	10.78		
Intestine	9.833	5.444		
Gills	13.49	3.059		
Head	63.51	19.22		
Eyes	5.965	1.569		
4. Ado Ekiti (Nigeria): Present study				
Clarias gariepinus (dry wt.)				
Muscle	36.73	168.01	18.95	66.08
Head	79.81	166.87	78.97	2.974
Liver	42.88	258.68	37.71	136.41

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Table 14: Bio-concentration factors (BF) of the literature sources and present results compared.

Source: (A) Akure (Nigeria)	***Cyprinus carpio* (Common carp)**		***Clarias gariepinus* (African catfish)**		***Oreochromis niloticus* (Tilapia)**	
Fish organ	**Na**	**K**	**Na**	**K**	**Na**	**K**
Air bladder	43.3	980.5	-	-	-	-
Intestine	1106.5	9926.5	201.5	7855.5	880.2	2250.0
Liver	10.0	15.2	105.3	686.5	-	-
Gills	47.0	1084.5	360.6	4278.0	103.9	2050.0
Head	44.3	1142.0	835.7	6274.5	564.6	3508.5
Eyes	44.0	363.6	21.2	233.5	148.6	264.0
Scales	44.3	197.8	-	-	191.3	1760.0
Sex organs	-	-	15.2	816.5	-	-
Muscle	44.3	874.0	227.3	6766.5	1146.5	2458.5
Source: (B) Ikere - Ekiti (Nigeria); *Illisha africana*						
Pond (1)	**Na**	**K**	**Mg**	**Ca**		
Gills	22.76	3.51	2.44	44.11		
Head	32.83	4.04	2.81	68.61		
Intestine	16.34	12.63	4.21	12.67		
Muscle	17.76	15.26	3.21	38.39		
Pond (2)						
Gills	20.72	5.66	1.33	53.89		
Head	43.40	10.69	3.43	130.67		
Intestine	22.00	11.07	2.43	12.28		
Muscle	29.60	13.45	3.35	100.44		
Pond (3)						
Gills	30.38	3.20	0.580	7.14		
Head	22.04	9.17	0.91	12.78		
Intestine	11.70	7.17	1.51	3.16		
Muscle	13.23	10.67	2.84	12.67		
Source (C) Akure (Nigeria); *Clarias gariepinus*						
Fish organ	**Na**	**K**				
Sex organs	230.25	294.00				
Gills	842.94	529.50				
Liver	218.75	622.00				
Intestine	614.56	2722.00				
Muscle	2199.81	5392.00				
Head	3969.31	9608.00				
Eyes	372.81	784.50				
Source (D) Ado-Ekiti (Nigeria); *Clarias gariepinus*						
Fish parts	**Na**	**K**	**Mg**	**Ca**	**P**	**Total**
MPAF	3.622	115.00	208.70	1365.01	8030.00	33.02
HPAF	7.869	114.22	869.71	61.43	930228.57	133.91
LPAF	4.228	177.06	415.31	2817.81	271214.29	70.23

CONCLUSION

The research reported on the pollution levels of minerals in an aquaculture in monoculture fish pond that contained *Clarias gariepinus*. Analysed samples were soil sediments, ambient water and some anatomical parts (head, muscle and liver) of the fish on wet weight basis.The ambient water was suitable for the development as the analysed major minerals (Na, Ca, Mg, K and P) were all within the standard range; also the water physicochemical properties were within the aquaculture standards. The soil sediments had non deleterious levels of the major minerals. The ranking of the mineral concentration in the fish body parts showed this trend: Phosphorus (31.11%) > Potassium (28.89%) > Sodium (15.56%) ≡ Calcium (15.56%) > Magnesium (8.89%). Body mineral concentration trend was (mg/100g wet wt.): muscle (402.19) < liver (855.38) < head (1630.94). These mineral results were better than many literature reports in *Cyprinus carpio*, *Clarias gariepinus*, *Oreochromis niloticus and Illisha africana*. Correlated paired groups of H/L,

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M/L, M/H and S/W; M/S, M/W, H/S, H/W, L/S and L/W showed no significant difference in any of the pairs. [M=muscle, H=head, L=liver, S=sediments, W=water.] The unequal concentration distribution of the minerals in the fish sample parts would necessitate the consumption of every part for balance mineral consumption. In the MSI values, only MSI for P was greater than the standard by a value of 0.81 or 8.10% showing that P might be slightly deleterious to the consumer of the fish head. In the bio-concentration values, only P BF was extremely high: 8030.00-930228.57 (fish samples) and 12794.29 (soil sediments) thereby making frequent monitoring necessary.

Conflicts of Interest

None declared.

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