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MINERALS ASSESSMENT IN WATER, SEDIMENT, AND FISH TISSUES OBTAINED FROM EARTHEN POND OF EKITI STATE UNIVERSITY, NIGERIA

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ABSTRACT

This study assesses the mineral levels in water, sediment, and fishes from Ekiti State University pond, Nigeria; and investigates the metal levels in locally made and imported feeds. Four fish samples (tilapia I and II; catfish I and II) from the pond were dissected to obtain livers, gills, and tissues. The water, sediments, feeds, and fish parts were analyzed using a Flame Photometer (Corning 400) and an Atomic Absorption Spectrophotometer (Buck Scientific 210). The levels of Na, K, Ca, Fe, Cu, Zn, and Mn in the pond water are 10.00, 8.89, 3.02, 6.67, 0.03, 0.25, and 0.18 mg/L, respectively. The concentrations of Na, K, Ca, Fe, Cu, Zn, and Mn in the sediment are 2.52, 4.21, 2.72, 29.78, 0.11, 0.95, and 0.42 mg/kg, respectively. The levels of metals in the feed samples (locally made and imported) range as follows: Na (47.56 – 76.06); K (181.06 – 190.05); Ca (95.43 – 244.53); Fe (2.38 – 4.16); Cu (0.17 each); Zn (1.03 – 1.31); Mn (0.59 – 0.83 mg/kg). The concentrations of metals in the liver, gill, and tissue range as follows: Na (4.90 – 54.56); K (5.02 – 69.07); Ca (21.42 – 522.57); Fe (0.72 – 9.54); Cu (0.06 – 0.44); Zn (0.24 – 1.17); Mn (0.02 – 0.52 mg/kg). However, Cd, Pb, Cr, Ni, and Co were not detected in all the samples. The results showed that the mineral levels in the fishes are within the permissible limits of the World Health Organization (WHO) and Standard Organization of Nigeria (SON).

1. Introduction

Heavy metals are toxic elements as a result of their high molecular weigths (Adewumi *et al.*, 2015). Heavy metals which are essential to living organisms only occur in trace amounts, their deficiencies and excesses in living system cannot be overemphasized (Szyczewski *et al.*, 2009). However, there is a close margin between the beneficial and toxic concentrations of some of the essential heavy metals (Tchounwou, 2008). Trace elements could be poisonous if higher concentrations are ingested into the body over a period of time. Heavy metals, such as Hg, Cd and Pb are very stable and not easily metabolized, they therefore bio-accumulate to attain toxic threshold. Most heavy metals do not have any nutritional role to perform in the body system, the more reason for their toxicity. However, essential metals like Fe, Zn, etc. can become toxic if their concentrations fall outside the permissible limits of international standards (Nabrzyski, 2006). Some metalloids such as arsenic are also in this category as they pose toxicity even at low level of exposure (Duffus, 2002).

Fishes totally depend on water for feeding, growth, salinity balance, reproduction, and metabolic activities (Bronmark and Hansson, 2005). Fish activities in aquatic system are controlled by physicochemical parameters such as colour, odour, temperature, total dissolved solid (TDS), pH, temperature, electrical conductivity (EC), acidity, alkalinity, water hardness, etc. each parameter is governed by international standard (James, 2000). A fish pond could be a controlled pool, hand-dug lake, or tank (Burnett, 2008). Fish pond is not a flowing stream but a stagnant pool consisting of sand, decayed materials, and microorganisms. Vital nutrients get into the pond from water source, runoff, or feed supplements. Decomposition of animal and plant materials in the pond facilitates a balanced ecosystem. However, there could be metal toxicity in the pond if the concentration of metallic elements ingested by aquatic lives is higher than the efflux as a result of imbalanced metabolisms (Luoma and Rainbow, 2005).

Sediment is a major reservoir of metals, it has about 99% of the total metal contents that are present in the aquatic system (Demirak *et al.*, 2006; Aderinola *et al.*, 2009; Oztrurk *et al.*, 2009). Rashed (2001) reported that sediment attracts diverse pollutants such as pesticides and heavy metals, it also plays a major role in re-mobilizing contaminants in the aquatic systems under suitable conditions.

Pollutants, such as heavy metals are readily available in sediment and easily dispersed through ion exchange, absorption, and precipitation processes (Yuan *et al.,* 2004). Pollution in the environment has been a major concern in recent times (Zhang *et al.,* 2007). Heavy metals migrate into water bodies from different sources which could be natural or anthropogenic. They include discharged effluents from industries, domestic wastewater, application of pesticide and inorganic fertilizers on farmland, leaching from landfills, shipping, the use of fossil fuels, as well as weathering (Yilmaz, 2003; Marcovecchio, 2004; Nadafi and Saeed, 2006; Raja *et al.,* 2009; Yilmaz, 2009; Kamaruzzaman *et al.,* 2010). Heavy metals at varied concentrations are stored in different parts of fish in the aquatic systems (Dural *et al.*, 2006; Yilmaz *et al.,* 2007). Many parameters (biotic and abiotic) affect metal uptake and bioaccumulation in fish tissues: feeding system, age of fish, fish gender, body weight, pH, temperature, dissolved oxygen, as well as physiological conditions are few examples of such biotic and abiotic conditions (Fernandes *et al.*, 2007; Kamaruzzaman *et al.*, 2010). Fishes are important bio-indicators that are used to establish toxicity of heavy metals, vital information about the levels of heavy metals and their distribution in fish are necessary as they have direct effect on nature as a whole (Malik *et al.*, 2010).

This study is aimed at determining the physicochemical parameters of pond, and assessing the levels of some minerals in pond water and sediment, feed samples, and selected parts of African catfish (*Claria gariepinus*) and Tilapia (*Oreochromis niloticus*) that are being raised in Ekiti State University Farm, Ado-Ekiti, Nigeria.

2. Materials and methods

2.1. Description of the study area

Ekiti State University, Ado - Ekiti is located along Ado-Ifaki road, Ekiti State, Nigeria. Its geographical co-ordinates are 7.714103°N and 5.260058°E. It has an estimated population of 25000 students. The fish farm of Ekiti State University is of earthen type, located at the Faculty of Agricultural Sciences of the University. The geographical co-ordinates of the pond are 7.113200 °N; 5.2463760 °E.

2.2. Collection of samples

Water samples were collected into sample bottles and properly covered using stoppers before analysis. Samples that were meant for metal analysis were nitrified using 5 mL HNO_3. Sediment samples were collected from different points of the pond using a grab and then homogenised. Two pieces of catfish (I and II) and two pieces of tilapia (I and II) were collected from the pond. Two feed samples (locally made and imported) were collected from the farm and prepared for further analysis.

2.3. Analysis of pond water for physicochemical parameters

Water sample was analyzed for various physicochemical parameters such as pH, Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Electrical Conductivity (EC), Free CO_2, Total Hardness, Calcium Hardness, Alkalinity, Acidity, Chlorides, etc. according to standard analytical procedures as described by AOAC (2005). For Mineral analysis, 100 mL water sample, nitrified at the point of collection was transferred into a beaker, 2 mL of concentrated HNO_3 and 5 mL of concentrated HCl were added, and the sample was heated inside a fume cupboard until the volume was reduced to 15-20 mL. The sample was allowed to cool, and thereafter filtered into 100 mL volumetric flask, the filtrate was made up to the mark using distilled water and subsequently analyzed using Flame Photometer (Corning 400) and Atomic Absorption Spectrophotometer (Buck Scientific 210).

Fig. 1. Earthen fish pond of Ekiti State University farm

2.4. Analysis of sediment sample

Sediment sample was oven-dried at 105°C, 2 g was weighed into a crucible followed by the addition of 10 mL of concentrated HNO_3. The mixture was heated up until near dryness, this process was repeated two more times. Distilled water was added to the residual material and the suspension was filtered into 100 mL standard volumetric flask using filter paper (Merck, 0.45 μm). The filtrate was made up to the mark using distilled water.

2.5. Analysis of fish sample

Fish sample was dissected into liver, gill, and muscle. The organs were analyzed according to the method described by AOAC (1990). For the liver, gill and muscle: 1 g of each was transferred into 250 mL beaker followed by the addition of concentrated HNO_3 (10 mL). The mixture was heated for 45 min and cooled, 5 mL of perchloric acid ($HClO_4$) was added to the mixture and heated until white fume was observed. 20 mL of distilled water was added, the mixture was further heated, cooled, and filtered into 100 mL volumetric flask according to Hseu (2004). The filtrate was then made up to the mark using distilled water and analyzed using AAS.

2.6. Analysis of feed sample

Feed sample (2 g) was weighed into a crucible and 20 mL of concentrated HNO_3 added, followed by 4 mL of $HClO_4$. The content was digested in a fume cupboard at 45°C for 15 min. Immediately white fume was observed, the sample was cooled, filtered into 100 mL standard flask, made up to the mark with distilled water, and subsequently analyzed using AAS.

3. Results and discussion

3.1. Physicochemical parameters of pond water sample

The physicochemical parameters of the earthen pond are presented in Table 1 and compared with the water quality standard of Standard Organization of Nigeria (SON, 2007) and World Health Organization (WHO, 2009). The colour of the pond water sample appeared brown. The pH value of the water was 6.51 which was within the standard permissible limits spelt out by WHO (2009) and SON (2007). This was also in line with the report of Boyd (1998) which inferred that the optimum pH for improved production of fish is 6.5 - 9.0. Values of pH outside the standard permissible limits could however cause destabilization of other physicochemical properties such as acidity, alkalinity, hardness, metal solubility, etc. The temperature of the water at the point of collection was 30.0°C. The temperature value fell within the values stipulated by WHO (2009). Ntengwe and Edema (2008) reported that optimum temperature range of 20 - 30°C is good for improved fish production. However, pond temperature depends on the intensity of sunlight or present weather condition as at a particular point in time. Conductivity is often used as an indicator of pollution status in pond water, this could be born out of persistent debris, feed formulation, run-off into ponds, metabolic wastes from fishes, as well as the activities of other living organisms in the pond (Solomon *et al.,* 2013). The value of electrical conductivity of the pond was 112.2 μS/cm, this value was within the maximum permissible limits stipulated by WHO (2009) and SON (2007). Also, WHO/FAO/IAEA acceptable limit for conductivity in aquaculture as reported by DWAF (1996) is 20 - 1500 μS/cm. The earthen pond under investigation is therefore suitable for fish production as far as electrical conductivity is concerned. The value of alkalinity of the sample was 131 mg/L which was in consonance with the permissible limits (<600 mg/L) stated by WHO (2009). Ehiagbonare and Ogunrinde (2010) reported alkalinity values of between 35 mg/L and 135 mg/L for fish pond water in Okada, Nigeria. Njoku *et al.* (2015) on the other hand, reported alkalinity values of 18 - 24 mg/L in earthen ponds within the Niger-Delta region of Nigeria; they suggested the optimum alkalinity for increased fish production to be 20 – 300 mg/L. James (2000), in his submission reported a suitable range of alkalinity for aquaculture to be 50 - 300 mg/L. Total hardness of water is a contribution of dissolved minerals, such as Ca and Mg compounds. Hardness of water determines the suitability of water for either domestic or industrial use as a result of the presence of bi-carbonates, sulphates, nitrates and chlorides (Solomon *et al.,* 2013). The total hardness value of the water samples was 360 mg/L. Sufficient level of hardness can bring down the level of ammonia and pH toxicity in water. Calcium hardness of the water sample was 92 mg/L and was within the limits set by WHO. The chloride content of the pond water was 123.2 mg/L and within the maximum permissible limits set by WHO (2009) and SON (2007). Although, chloride can be found in natural water, but high level of chloride is a pointer to pollution from either industrial or domestic wastes, seepage of saline water into fresh water system (Shyamala *et al.,* 2008). The values of total solids (TS), total dissolved solids (TDS), and total suspended solids (TSS) for the pond water were 4400, 3200, and 1200 mg/L, respectively. In production of fish, James (2000) opined that a maximum TDS value of 400 mg/L is adequate for the production of various species of fish. The pond water had high TS value which could be as a result of heavy downpour a day before sampling. Boyd (1998) suggested that, for total suspended solids, a range of 10 – 50 mg/L is good for optimum fish culture, although he also noted that the values could be higher in highly turbid fish ponds. Also, dissolved feeds that were not picked up by the fish could also contribute to high values of total suspended solids in pond, which will invariably increase the level of turbidity.

Correlation analysis of the physicochemical parameters for the pond water was carried out using a statistical package (IBM SPSS V21) and the results are presented in Table 2.

A strong positive correlation was found between EC and TH (r = 0.999 at p > 0.05). This shows that calcium or magnesium salts are present as dissolved solids (Agarwal *et al.*, 2014), it also shows that increase in one of the parameters would lead to a decrease in the other. High positive correlations were observed between TS and TDS (r = 1.000 at p > 0.01); and TS and free CO_2 (r = 0. 999 at p > 0.05), this implies that increase or decrease in the value of TS would lead to opposite effect in the other two parameters. TDS was also found to have high positive correlation with free CO_2 (r = 1.000 at p > 0.01). A positive correlation was observed between TH and MH (r = 0.998 at p > 0.05), this is because, in most cases, hardness is caused as a result of dissolution of only calcium and magnesium salts present in water body. Strong negative correlation values were observed between alkalinity and TH; and alkalinity and MH (r = -0.999 at p > 0.05; and r = -1.000 at p > 0.01), the negative correlation could be as a result of anthropogenic influence. Strong correlation between MH and Alkalinity showed that magnesium probably exists in the sample as magnesium carbonates and bicarbonate (Agarwal *et al.*, 2014).

Table 1. Physicochemical parameters of water sample from Ekiti State University farm earthen pond

Parameters	Pond water	WHO (2009)	SON (2007)
Colour	Brownish	-	-
Temperature (°C)	30	28-35	ambient
pH	6.51	6.5-8.5	6.5-8.5
Electrical conductivity (µS/cm)	112.2	300	-
TS (mg/L)	4400	-	-
TDS (mg/L)	3200	500	-
TSS (mg/L)	1200	-	10-50
Free CO_2 (mg/L)	15.53	-	-
Alkalinity (mg/L)	131	600	-
Acidity (mg/L)	126	-	-
Total hardness (mg/L)	360	600	-
Ca hardness (mg/L)	92	75-200	-
Mg hardness(mg/L)	268	-	-
Chlorides (mg/L)	123.2	200 -1000	200-600

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Table 2. Correlation coefficient for the physicochemical parameters of the pond water

	Temp (ºC)	pH	EC (µS/cm)	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	Free CO_2 (mg/L)	Alkalinity (mg/L)	Acidity (mg/L)	TH (mg/L)	CH (mg/L)	MH (mg/L)	Chloride (mg/L)
Temp (ºC)	1.000												
pH	-.419	1.000											
EC (µS/cm	-.916	.021	1.000										
TS (mg/L)	-.990	.288	.964	1.000									
TDS (mg/L)	-.994	.317	.955	**1.000****	1.000								
TSS (mg/L)	-.971	.189	.986	.995	**1.000****	1.000							
Free CO_2 (mg/L)	-.995	.331	.950	**.999***	.995	.989	1.000						
Alkalinity (mg/L)	.875	.073	-.996	-.934	**.999***	-.966	-.917	1.000					
Acidity (mg/L)	.617	-.973	-.250	-.500	-.934	-.410	-.539	.159	1.000				
TH (mg/L)	-.900	-.019	**.999***	.952	-.500	.978	.937	**-.999***	-.211	1.000			
CH (mg/L)	.277	.756	-.639	-.410	.952	-.500	-.367	.708	-.585	-.669	1.000		
MH (mg/L)	-.874	-.075	.995	.933	-.410	.965	.916	**-1.000****	-.156	**.998***	-.710	1.000	
Chloride (mg/L)	.719	-.932	-.381	-.615	.933	-.532	-.650	.293	.990	-.344	-.468	-.291	1.000

*- Correlation is significant at 0.05 level; ******-Correlation is significant at 0.01 level. EC- Electrical Conductivity; TS- Total Solids; TDS- Total dissolved solids; TSS- Total Suspended Solids; TH- Total Hardness; CH- Calcium Hardness; MH- Magnesium Hardnes

3.2. Concentrations of minerals in pond water, sediments, and feed samples

The concentrations of minerals in pond water, sediments, and feeds (locally made and imported) are shown in Table 3. Minerals are essential supplements in human diet as they aid body processes such as rebuilding of tissues and maintaining ion gradients. The concentrations of potassium (K) in pond water, sediment, locally made feed, and imported feed were 8.89 mg/L, 4.21, 181.06, and 190.05 mg/kg, respectively. Mutlu and Uncumusaoğlum (2017) reported that one of the inorganic salts that contribute taste to water is K_2SO_4, and that K occurs in water mainly as K_2SO_4. The concentrations of sodium (Na) in water and sediment samples were 10.00 mg/L and 2.52 mg/kg, respectively. It was however observed that the concentration of Na in the water sample was within the standard limits stated by SON (2007) and WHO (2009). The concentration of Mn in the pond water (0.18 mg/L) was within the confines of permissible limits set by SON (2007). Mn in large concentrations can cause series of psychiatric disturbances, termed "Manganism" which have affected people working in production and processing of alloys derived from manganese (Nussey *et al.*, 2000). The concentrations of cadmium (Cd), lead (Pb), chromium (Cr), nickel (Ni), and cobalt (Co) in the pond water were below detection limits (BDL).

Table 3. Concentrations of minerals in pond water, sediment, and feed samples

Sample	Na	K	Ca	Fe	Cu	Zn	Mn	Cd	Pb	Cr	Ni	Co
Water (mg/L)	10.00	8.89	3.02	6.67	0.03	0.25	0.18	BDL	BDL	BDL	BDL	BDL
Sediment (mg/kg)	2.52	4.21	2.72	29.78	0.11	0.95	0.42	BDL	BDL	BDL	BDL	BDL
Locally made feed (mg/kg)	47.56	181.06	95.43	2.38	0.17	1.03	0.59	BDL	BDL	BDL	BDL	BDL
Imported feed (mg/kg)	76.02	190.05	244.53	4.16	0.17	1.31	0.83	BDL	BDL	BDL	BDL	BDL

BDL: below detection limit

The locally made and imported feeds were rich in sodium (Na) with values of 47.56 and 76.02 mg/kg, respectively. The concentrations of iron (Fe) in the locally made and imported feed samples were 2.38 and 4.16 mg/kg, respectively. The Fe content in the feeds is to improve the iron level of the fishes in order to meet up with the minimum iron requirement in fish that will benefit the consumers. However, the amount of minerals, most especially iron in a feed depends on the formulation of the feed. The concentrations of K, Ca, Cu, Zn, and Mn for locally made and foreign feeds were 181.06 and 190.05 mg/kg, 95.43 and 244.53 mg/kg, 0.17 mg/kg each, 103 and 1.31 mg/kg, and 0.59 and 0.83 mg/kg, respectively. The concentrations are within the permissible limits of WHO (2009) and SON (2007) standards.

3.3. Concentration of minerals in the fish samples

The concentrations of minerals in the various parts of tilapia and catfish samples are presented in Table 4. The concentrations of potassium (K) in the gill samples of tilapia I and tilapia II were 50.02 and 41.02 mg/kg; in the liver, 5.02 and 7.23 mg/kg; and in the muscle, 66.23 and 44.56 mg/kg. The potassium contents in the gills, liver and muscle of catfish I and catfish II were: 48.59 and 45.89; 9.10 and 9.56; and 73.47 and 69.07 mg/kg, respectively. The results showed that the highest concentration of K was observed in the muscle, and the lowest concentration was observed in the liver. The highest concentration found in the muscle could be attributed to the fact that K is needed to: improve fish protein; build muscle; maintain normal body growth; control the electrical conductivity; and maintain the acid-base balance. The concentrations of manganese in the fish parts ranged from 0.02 – 0.51 mg/kg, with the gill having the highest concentration. The highest concentration in the gill could be attributed to the fact that, the gills, being the dominant site for contaminants and pollutants uptake due to the anatomical properties that maximize absorption efficiency of minerals from water. Cr, Cd, Pb, Ni, and Co were not detectable in any of the fish parts. Zinc (Zn) was detected in muscle, liver, and gills. The highest concentration (1.23 mg/kg) of Zn was observed in the gills of catfish I, while the minimum concentration (0.24 mg/kg) was observed in the liver of catfish II. In the case of copper (Cu), the results showed that the highest concentration (0.44 mg/kg) was observed in the liver of Tilapia I, while the minimum concentration (0.06 mg/kg) was observed in the gills of catfish II. The concentrations of Zn and Cu were however lower than those reported for a number of species of fishes such as *Tilapia nilotica* (Rashed, 2001); *Clarias gariepinus* and *Labeo umbratus* (Coetzee *et al.*, 2002); *Cyprinus carpio* (Zhang *et al.*, 2007); *Ctenopharyngodon idella* and *Labeo rohita* (Malik *et al.*, 2010). However, the results are in agreement with the reports of some authors whose observations demonstrated that heavy metal bioaccumulation in various tissues of fishes living in the same water body vary according to the species of fish (Canli and Atli, 2003; Mendil and Uluozlu, 2007; Uysal *et al.*, 2008). The concentrations of iron (Fe) in the body parts of tilapia I and tilapia II ranged from 1.07 – 9.54 mg/kg, where the gill (Tilapia II) had the highest concentration, and the minimum concentration (1.07 mg/kg) was observed in the muscle of Tilapia I. The trend of Fe concentration in the two tilapia fishes is as follows: tissue < liver < gills. The concentration of Fe in the body parts of catfish I and II ranged from 0.72 – 4.13 mg/kg. The highest concentration was observed in the gill of Catfish I, while the lowest concentration was observed in the muscle of catfish II. The trend of iron concentration in the two catfish samples is as follows: tissue < liver <gills. Similar reports were submitted on *Claria gariepinus* (Osman and Kloas, 2009) and *Oreochromis niloticus* (Saheed and Shaker, 2008). The levels of Fe in the fish samples are within the limits specified by FAO/WHO (1989). Among all the parts investigated for both catfish and tilapia samples, heavy metals tend to accumulate most in the gills, followed by livers and muscle, this is because fish gills are involved in gas exchange, regulation of ions, acid balance, and waste egestion (Shukla *et al.*, 2007). Fish gill is the major area used for the ingestion of dissolved heavy metals which could lead to lesion and damage of gills (Bols *et al.*, 2001).

Table 4. Concentrations of minerals in fish samples

Sample		Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Co (mg/kg)
Tilapia I	**Liver**	7.52	5.02	21.42	3.99	0.44	0.46	0.20	BDL	BDL	BDL	BDL	BDL
	Gill	50.93	50.02	428.53	8.57	0.37	1.17	0.35	BDL	BDL	BDL	BDL	BDL
	Tissue	46.25	66.23	200.51	1.07	0.10	0.73	0.14	BDL	BDL	BDL	BDL	BDL
Tilapia II	**Liver**	10.01	7.23	186.15	2.49	0.09	0.38	0.15	BDL	BDL	BDL	BDL	BDL
	Gill	54.56	41.02	522.57	9.54	0.16	1.33	0.51	BDL	BDL	BDL	BDL	BDL
	Tissue	44.58	44.56	281.53	1.08	0.22	0.81	0.17	BDL	BDL	BDL	BDL	BDL
Catfish I	**Liver**	14.32	9.10	44.56	3.37	0.07	0.57	0.03	BDL	BDL	BDL	BDL	BDL
	Gill	48.02	48.59	397.52	4.13	0.09	1.23	0.24	BDL	BDL	BDL	BDL	BDL
	Tissue	50.11	73.47	94.06	0.93	0.08	0.71	0.04	BDL	BDL	BDL	BDL	BDL
Catfish II	**Liver**	4.90	9.56	27.78	1.92	0.12	0.24	0.02	BDL	BDL	BDL	BDL	BDL
	Gill	32.16	45.89	360.58	2.35	0.06	0.91	0.45	BDL	BDL	BDL	BDL	BDL
	Tissue	35.24	69.07	59.87	0.72	0.07	0.55	0.07	BDL	BDL	BDL	BDL	BDL

3.4. Transfer Factor

Transfer factor is the ratio of concentration of one specific metal detected in the fish part to the concentration of the same metal in the water or sediment (Rashed, 2001). The transfer factors of fish parts with respect to the pond water and sediment were calculated as follows:

$$\text{Transfer factor } (TF) = \frac{M_{part}}{M_{water\ or\ sediment}} \quad (1)$$

Where M_{part} is concentration of metal in fish part; M_{water} or $M_{sediment}$ is the concentration of metal in water or in sediment. Tables 5 and 6 show the transfer factors between fish parts, pond water, and sediment using potassium (K) as a yardstick.

Table 5. Transfer factor of potassium (K) between fish parts and pond water

Fish body parts	M_{part}	M_{water}	Transfer factor
Tilapia I liver	5.02	8.89	0.56
Tilapia I gills	50.02	8.89	5.63
Tilapia I muscle	66.23	8.89	7.45
Tilapia II liver	7.23	8.89	0.81
Tilapia II gills	41.02	8.89	4.61
Tilapia II muscle	44.56	8.89	5.01
Catfish I liver	9.10	8.89	1.02
Catfish I gills	48.59	8.89	5.47
Catfish I muscle	73.47	8.89	8.26
Catfish II liver	9.56	8.89	1.06
Catfish II gills	45.89	8.89	5.16
Catfish II muscle	69.01	8.89	7.76

Table 6. Transfer factor of potassium (K) between fish parts and sediment sample

Fish body parts	M_{part}	$M_{sediment}$	Transfer factor
Tilapia I liver	5.02	4.21	1.19
Tilapia I gills	50.02	4.21	11.88
Tilapia I muscle	66.23	4.21	15.73
Tilapia II liver	7.23	4.21	1.72
Tilapia II gills	41.02	4.21	9.74
Tilapia II muscle	44.56	4.21	10.58
Catfish I liver	9.10	4.21	2.16
Catfish I gills	48.59	4.21	11.54
Catfish I muscle	73.47	4.21	15.45
Catfish II liver	9.56	4.21	1.80
Catfish II gills	45.89	4.21	10.90
Catfish II muscle	69.01	4.21	16.41

When transfer factor is less than 1, it means that bioaccumulation of metal (K) in the fish is not from the water or the sediment. When transfer factor is greater than 1, it means that bioaccumulation of metal in fish is from both the pond water and sediment. It can be observed from Table 5 that the transfer factors for Tilapia I and II in the liver were less than 1 which shows that bioaccumulation of K in the fish was not from the water or sediment. However, transfer factors for other Tilapia parts and all Catfish parts were greater than unity, which means that the minerals were transferred into the fish parts from either the pond water or the sediment.

4. Conclusions

This study showed that the feed samples contained the highest concentration of potassium since potassium is needed for building fish muscle and to maintain normal body growth, the more reason it is found in high concentration in the fish muscle. The levels of detectable (Na, K, Ca, Fe, Cu, Zn, and Mn) minerals were found to be within the confines of WHO and SON standards. However, Pb, Cd, Cr, Ni, and Co were not detectable in all the samples (fish, water, sediment, and feed) as the metal levels were below detection limit. In general, the fishes from the pond are free from contamination of heavy and toxic metals, hence are safe for human consumption.

5. References

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