Research Journal of Applied Sciences, Engineering and Technology 4(23): 5040-5047, 2012
ISSN: 2040-7467

Submitted: March 16, 2012 Accepted: April 08, 2012 Published: December 01, 2012

Preliminary Studies on Bioconcentration of Heavy Metals in Nile Tilapia from Tono Irrigation Facility

[1]Apori Ntiforo [1]Sam-Quarcoo Dotse and [2]Maxwell Anim-Gyampo
[1]Department of Applied Physics,
[2]Department of Earth and Environmental Science, Faculty of Applied Sciences, University for Development Studies, P.O. Box 24, Navrongo, Upper East Region, Ghana

Abstract: The present study has identified and measured the concentrations of heavy metals in the body tissue of Nile Tilapia from the Tono Irrigation facility located in the Kassena-Nankana East District of the Upper East Region of Ghana. Using Neutron Activation Analysis (NAA), Arsenic, Cadmium, Chromium, Copper, Iron, Manganese, Nickel, Vanadium and Zinc were identified and their mean concentrations were 0.23, 0.02, 0.2, 1.03, 45.95, 19, 0.21, 0.27 and 12.76 µg/g, respectively. The order of mean concentration of heavy metals in fish samples was Cd<Ni<As<V<Cr<Cu<Zn<Mn<Fe. The mean concentrations of Arsenic, Cadmium, Chromium, Nickel, Iron, as well as Zinc concentrations were below the maximum contaminant levels of 0.27, 0.05, 53.80, 107, 0.7 and 34.2 µg/g, respectively in fish set by WHO (1986). However, the mean concentrations of Copper and Manganese exceeded the maximum contaminant levels of 1 and 5 µg/g, respectively. A correlation between age and the accumulation of heavy metals in fish samples was also established. There is the need for a more comprehensive investigation into the accumulation and distribution of heavy metals in water, sediments and fish samples from the facility.

Keywords: Accumulation, contaminant, heavy metals, irrigation facility, NAA, tilapia, tono

INTRODUCTION

Heavy metals are natural components of the Earth's crust. They occur in the soil, air and water. They are easily released when the soil is loosen and leach or runoff into water bodies. The metals in the air can also be deposited in water bodies to add up to those occurring in the water and from leaching and runoffs. Increase in anthropogenic activities such as agricultural and industrial activities continuously increase the amount of heavy metals in the environment, especially in aquatic ecosystem. Pollution of heavy metals in aquatic ecosystem is growing at an alarming rate and has become an important worldwide problem (Malik *et al*., 2010).

Heavy metals in aquatic environment are a major concern because of their toxicity and threat to plant and animal life, disturbing the natural ecological balance. The specific problem associated with the heavy metals in the environment is their accumulation through food chain and persistent in nature (Dimari *et al*., 2008). Uptake of heavy metals such as Copper, Nickel, Manganese, Lead, Cadmium, Iron and Cobalt through the food chain in human being may cause various physiological disorders like hypertension, sporadic fever, nausea and renal damage (NRC, 1999-2000). As trace elements, some heavy metals like copper, selenium, zinc and iron are essential in maintaining the metabolism of the human body. Metals such as Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Thallium (Tl) and Lead (Pb), are considered as major environmental pollutants. Small amounts of these heavy metals are common in our environment and serve as micronutrient for plants, animals and humans in our diet. These make them essential for good health. But large amounts of these metals in organisms such as fishes and humans may cause acute or chronic toxicity. World Health Organisation (WHO) and other organizations such as United States Environmental Protection Agency (USEPA), among others have set maximum permissible levels of heavy metal concentrations in the environment and for that matter in food such as fish.

The sources of these heavy metals include sediments, soil erosion, quarry and agricultural activities (Rauf and Ubaidullah, 2009). They are released through leaching and weathering into water bodies such as rivers, streams and dams. In agriculture, heavy metals are released during land preparation such as ploughing, ridging and hallowing among others. Also agrochemicals such as fertilizer (phosphate fertilizer, N-P-K fertilizer) and herbicides contain heavy metals that easily accumulate in the soils, carried by run-off or leach into water bodies around farm lands (Modaihsh *et al*., 2004).

One major source of food is fishery products which contain proteins, fatty acids and other elements that are

Corresponding Author: Apori Ntiforo, Department of Applied Physics, Faculty of Applied Sciences, University for Development Studies, P.O. Box 24, Navrongo, Upper East Region, Ghana

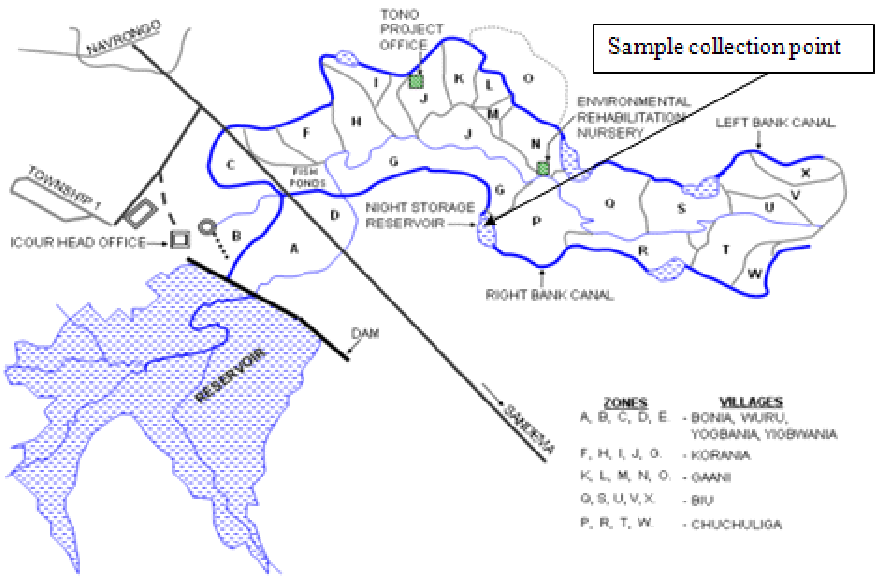

Fig. 1: Map of Tono irrigation facility (Okrah, 2010)

essential to humans as well as some other organisms. The Tono irrigation dam is a facility that supplies the people of Navrongo and adjacent communities with fishery products. Fishes in their habitat have the ability to accumulate heavy metals (Edem *et al.*, 2009). The accumulation is as a result of the intake of these metals from their polluted habitat via food or non-food particles, gills, oral consumption of water and the skin. Heavy metals from various source that get into the water in the dam, is passed up the food chain as organism in it make use of water. Since they are non-degradable, organisms ingest them into their body and accumulate them with time. As an organism continuously feed, it accumulates these chemicals in a process called bioaccumulation. With each step up in the food chain, the concentration of these metals increases (USGS, 2011). If the accumulations of these heavy metals exceed certain threshold values that are considered unsafe for human consumption, it may pose a threat to those communities whose livelihoods depend on the facility. Hence, it has therefore become necessary to assess the concentrations of heavy metals in the fishery products from the Tono irrigation facility to ascertain their safety for human consumption.

Agricultural activities also contribute to the accumulation of heavy metals in water bodies around farmlands and for that matter Tono Irrigation Facility. The Tono irrigation facility has being in existence for about two decades now. The facility has been used by farmers since its existence which is used in the production of tomatoes, rice and other vegetables. Knowledge of heavy metal concentrations in fish is important with respect to nature of management and human consumption of fish. Fish are often at the top of aquatic food chain and may concentrate large amounts of heavy metals from the water which is easily passed up on the food chain to higher organisms like humans (Rauf and Ubaidullah, 2009).

The main aim of the present study, which is a preliminary investigation, is to qualitatively and quantitatively analyse heavy metals in the body tissue of Nile Tilapia from Tono Irrigation Facility. This if necessary will pave way for a more comprehensive investigation of the distribution of heavy metals in water, sediments and fish samples from the facility. In this case, various organs (muscle, liver, gills and kidney tissues) of fish samples will be considered.

MATERIALS AND METHODS

Study area-tono irrigation facility: Tono Irrigation facility was built in the late 70's and early 80's to promote the production of food crops by small scale farmers within organized and managed irrigation scheme. The scheme covers an area of 3860 ha with about 2490 ha developed for irrigation. The Dam has a total catchment area of about 650 km^2 with a maximum surface area of 1860 ha and a maximum storage of $93x10^3$ m^3 (Fig. 1). The irrigation scheme serves about 4000 small-scale farmers with holdings between 0.2-2 ha per famer living in 9 villages located at the periphery of the Tono irrigation facility (Wedjong, 2004).

The major crops cultivated on the project are tomato, rice, soya bean among others. The facility was build purposely for irrigation; it has also become a source of fishery products for the inhabitants of Kassena-Nankana

Districts. There are different species of fishes found in the dam but Nile Tilapia is the commonest species.

The topography is low-lying with an average height of 100 m above sea level. The landscape is generally undulating with isolated hills rising up to about 300 m in the western parts of the District. The Savannah ochrosols are porous, well drained, loamy and mildly acidic and interspersed with patches of black or dark-grey clay soils. This soil type is suitable for cultivation and hence accounts for the arable land sites including most parts of the Tono Irrigation Project sites where both wet and dry season farming activities are concentrated (Kassena-Nankana, 2011).

Sample and sampling: *Oreochromis niloticus* commonly known as Nile tilapia were collected from local fisherman at a reservoir on the right canal at Chuchuliga on March, 2011 (Fig. 1). The Nile tilapia was chosen because of its high dominance at the different fishing locations. For varying length with weight, ten different sizes of tilapia samples were selected from a large number of fishes for analysis. The length and weight of Nile tilapia increases as the age increase (Gómez-Márquez *et al*., 2008).

The samples were packed in new polyethylene bags obtained from the local market. The packed samples were kept in well cleaned thermo insulator flask. In order to preserve the fish samples, they were place in ice in the flask. The samples were then transported to the Neutron Activation Analysis laboratory at Ghana Research Reator-1 centre (GHARR-1), Ghana Atomic Energy Commission for analysis.

Sample preparation: Sample preparation was carried out in the sample preparation room of the GHARR-1. Weights and lengths of the samples were recorded. The ten samples were grouped into five based on their recorded weight and then labeled. The fish samples were washed several times with de-ionized water. The intestines of the samples were removed. The scales, head, tails, fins and bones were separated from the body tissue or fillet using a stainless steel knife.

The body tissue samples were freeze dried for 48 h. The samples were grounded into powder using a stainless steel agate mortar and pestle into finer particles to obtain a homogenous fish samples suitable for irradiation.

Two hundred mg of each of the five samples were weighed into clean polyethylene sheets, wrapped and heat sealed. The sealed samples were then packed into 7 mL polyethylene vials and the vials were capped and heat sealed for irradiation, to determine heavy metals and their concentration by Neutron Activation Analysis (NAA). Three replicate sub-samples were prepared for each sample. The samples were then packed into 7.0 mL volume polyethylene irradiation vials capped and heat-sealed.

Table 1: Concentrations of heavy metals in samples

	Concentration (μg/g)				
Element	S1	S2	S3	S4	S5
Cu	1.42	0.93	0.54	0.89	1.39
Ni	0.27	0.13	0.05	0.21	0.38
V	0.69	0.11	0.13	0.08	0.35
Fe	34.72	24.73	46.92	54.89	68.47
Mn	13.84	18.21	11.01	3.07	48.87
Zn	4.27	16.02	7.33	11.09	25.11
Cd	0.04	0.02	0.01	0.02	0.03
As	0.12	0.46	0.23	0.1	0.22
Cr	0.12	0.16	0.23	0.37	0.45

Analysis of heavy metals: Neutron Activation Analysis (NAA) stands at the forefront of techniques for the quantitative multi-element analysis of major, minor, trace and rare elements. It is preferred because of its sensitivity and accuracy especially in respect of some trace elements. It is also a non-destructive method (Simonits *et al*., 1974).

The samples and the elemental comparator standard were irradiated in the inner irradiation site of the Ghana Research Reactor-1 (GHARR-1) facility operating at half power of 15 kW at a neutron flux of 5.0×1011 neutrons/cm^2/s.

The scheme for irradiation was chosen according the sample matrix. After the irradiation, induced radioactivities in the samples were counted using an Ortec HPGe detector with a relative efficiency of 25% and an energy resolution of 1.8 keV at 1332.5 keV gamma-rays of ^{60}Co. The gamma-ray acquisition system consists of MAESTRO Multi-Channel Analyser (MCA) emulation software card, coupled to the detector via electronic modules. The accumulated spectra intensities were analysed both qualitatively and quantitatively to determine the heavy metals and their concentrations. For quality assurance, IAEA-530 Trace element in tuna fish homogenate, Certificate of analysis standard material 1566b Oyster Tissue (National Institute of Standards and Technology) prepared in the same manner as the study samples were included. The Standard Reference Materials were treated the same way as the samples.

RESULTS AND DISCUSSION

The heavy metals detected using Neutron Activation Analysis were Arsenic, Cadmium, Chromium, Copper, Iron, Manganese, Nickel, Vanadium and Zinc as shown in Table 1

The concentration of heavy metals ranged from a minimum of 0.01 μg/g in cadmium to maximum of 68.47 μg/g in iron (Table 1). The mean concentration of heavy metals ranged from a minimum of 0.02 μg/g in cadmium to 45.95 μg/g as a maximum in iron. The order of mean concentration of heavy metal in fish samples was Fe>Mn>Zn>Cu>Cr>V>As>Ni>Cd as shown in Table 2.

The Table 3 gives the mean concentrations in the five samples, grouped according to their weights. The mean concentration of heavy metals vary from sample S1 to S5

Table 2: Mean concentrations of heavy metals in the fish samples

Heavy metals	Concentration (µg/g) Min	Max	Mean
Cu	0.54	1.42	1.03
Ni	0.05	0.38	0.21
V	0.08	0.69	0.27
Fe	24.73	68.47	45.95
Mn	3.07	48.87	19.00
Zn	4.27	25.11	12.76
Cd	0.01	0.04	0.02
As	0.1	0.46	0.23
Cr	0.12	0.45	0.27

Table 3: Mean heavy metal concentration in fish samples

Element	Concentration (µg/g) S1	S2	S3	S4	S5
Heavy metal	6.17	6.75	7.38	7.861	6.14

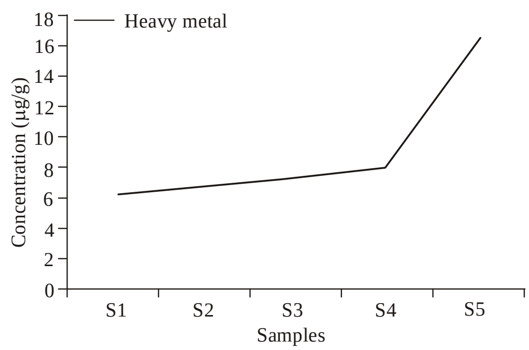

Fig. 2: Heavy metal concentrations in fish samples

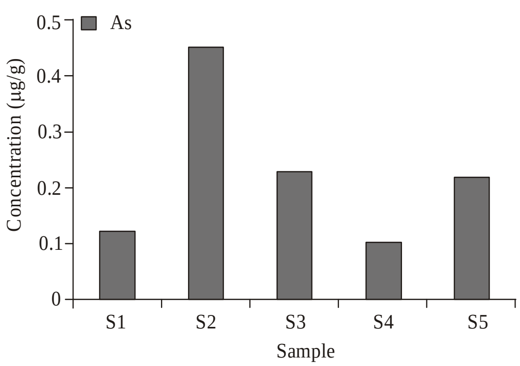

Fig. 3: Accumulation of As in fish samples

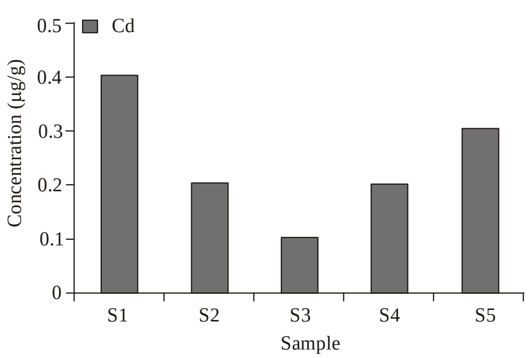

Fig. 4: Accumulation of Cd in fish samples

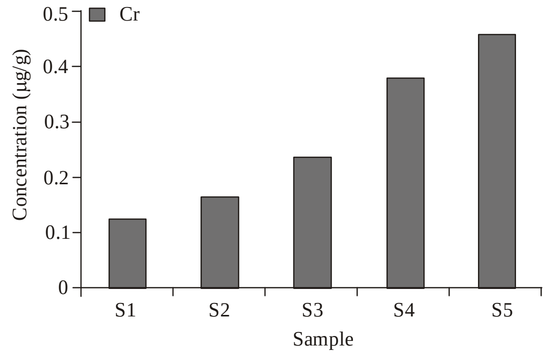

Fig. 5: Accumulation of Cr in fish samples

(Fig. 2), implying a correlation between age and the accumulation heavy metals.

Arsenic (As): Arsenic was detected in all the fish sampled, with concentrations ranging from 0.10 to 0.46 µg/g dry weight. The highest concentration of arsenic was observed in sample S2 followed by samples S3, S5 and S1, while the S4 showed the least concentration (Fig. 3).

The mean concentration of Arsenic in fish sample was 0.22 µg/g. Arsenic level in the Nile Tilapia was below National Contaminant Bio-monitoring Program (NCBP) contaminant level of 0.27 µg/g dry weights (Schmitt and Brumbaugh, 1990). The presence of Arsenic in the fish samples can mainly be attributed to the naturally occurring Arsenic in the soil that leaches into the reservoir.

According to Walsh *et al*. (1977), arsenic concentrations greater than 0.5 µg/g dry weight in fish could cause harm. Based on the mean concentration of Arsenic level of 0.22 µg/g, the Tono irrigation facility contained fish with arsenic concentrations below the potentially harmful threshold.

Cadmium (Cd): The highest concentration of Cadmium 0.04 µg/g was observed in sample S1 while the lowest concentration of 0.01 µg/g was detected in sample S3 as shown in Fig. 4.
The mean concentration of cadmium in the fish samples was 0.02 µg/g. Although Cadmium occurs naturally in the environment, the accumulation of cadmium in fish samples can be as a result of agricultural activities such as land preparation, application of agro-chemicals and other activities.

According Modaihsh *et al*. (2004), fertilizers such as phosphate fertilizers and other types averagely contains 13.4 µg/g of cadmium which accumulates as fertilizers are applied annually on farmlands. Cadmium is a non essential trace metal that is potentially toxic to most fish and wildlife, particularly freshwater organisms (Robertson

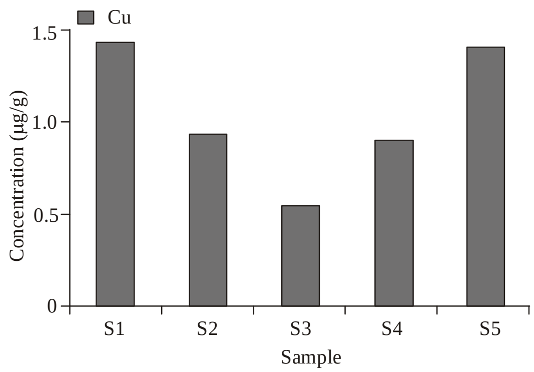

Fig. 6: Accumulation of Cu in fish samples

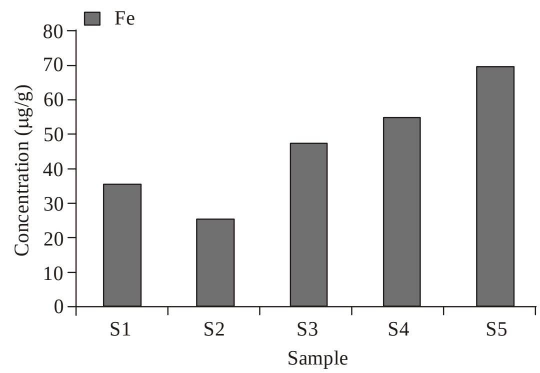

Fig. 7: Accumulation of Fe in fish samples

et al., 1992). The highest concentrations of cadmium in the fish sample were below the 0.5 µg/g threshold considered harmful to fish and predators (Walsh *et al*., 1977).

Chromium (Cr): The concentrations of chromium in the sample varied from 0.12 to 0.45 µg/g. The minimum level was in sample S1 and the maximum in S5 as represented in Fig. 5.

It was found that the concentrations of chromium increase from sample S1 to S5. This means the concentration of chromium increases with increase in age of Nile tilapia from the facility. Agricultural activities such as application of Agro-chemicals like fertilizers and pesticides may be the source of chromium in the fish samples.

Chromium is an essential trace element in humans but in excess, it could have lethal effects on fish and wildlife (Robertson *et al*., 1992). No guideline value is available for chromium as the maximum permissible level in fish (Akan *et al*., 2009). Chromium concentration in the fish samples was far below the level validated by United States Environmental Protection Agency (USEPA) to be contaminant (53.8 µg/g) in fish.

Copper (Cu): The levels of copper in the fish samples ranged between 0.54 and 1.42 µg/g as illustrated in Fig. 6.

The highest concentration of copper (1.42 µg/g) was detected in sample S1 while the lowest detected limit (0.54 µg/g) was found in sample S3. (1.03 µg/g) was the mean concentration of copper in the samples. In 1989, World Health Organisation reported that copper toxicity in fish is taken up directly from the water via gills and ingested into the body tissue. The study showed that accumulation of copper in the body tissue was high. Effects of high concentrations of copper in fish are not well established; however, there is evidence that high concentration of copper in fish can lead to toxicity (Woodward *et al*., 1994).

Copper can combine with other contaminants such as ammonia, mercury and zinc to produce an additive toxic effect on fish and predators (Herbert and Vandyke, 1964; Rompala *et al*., 1984). However, the accumulation of copper (1.03 µg/g) in the fish sample was a little above the maximum contaminant level of 1.0 µg/g reported by Schmitt and Brumbaugh (1990). Copper levels exceeding the permissible levels in the fish sample means it is approaching toxicity levels. Although Copper as a micro nutrient is essential to the human body, high levels of it can be harmful. Ingesting high levels of copper can cause nausea, vomiting and diarrhoea. Very-high doses of copper can cause damage to the liver and kidneys and can even cause death (ATSDR, 2011). This high level of Copper in fish sample can be attributed to leaching as well as runoff of naturally occurring copper in the soil.

Iron (Fe): The highest accumulation of iron was 68.47 µg/g which was found in sample S1 as in Table 2 and Fig. 7.

Also the lowest was 24.73 µg/g in sample S1. (45.95 µg/g) was the mean concentration of iron in the samples. Although agricultural activities may be a source of iron in fish samples, the main source is as a result of naturally occurring iron present in the soil. The level of iron in the samples was below the permissible level of 107 µg/g set by World Health Organisation (WHO, 1986). Iron deficiency in the human body come with a lot of complications such as Anemia, among others. However when iron exceed certain threshold value in the body as a result of accumulation from food such as fish it become toxic to the body. Since the concentration of iron in fish sample is below the permissible level it means iron accumulation does not pose any health risk.

Manganese (Mn): Manganese occurs naturally in the soil and may be released into water bodies through runoff or leaching facilitated by agricultural activities such as ploughing, ridging and harrowing. Also agro chemicals such as pesticide and herbicides release manganese which contributes to the accumulation of manganese in fish

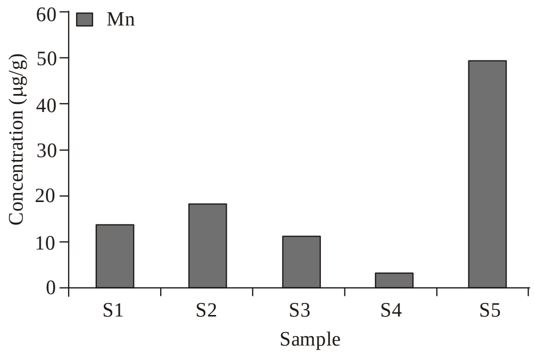

Fig. 8: Accumulation of Mn in fish samples

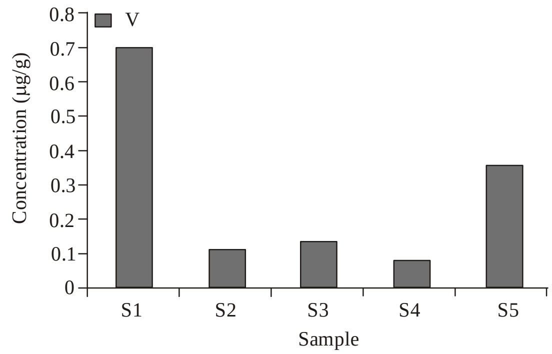

Fig. 10: Accumulation of V in fish samples

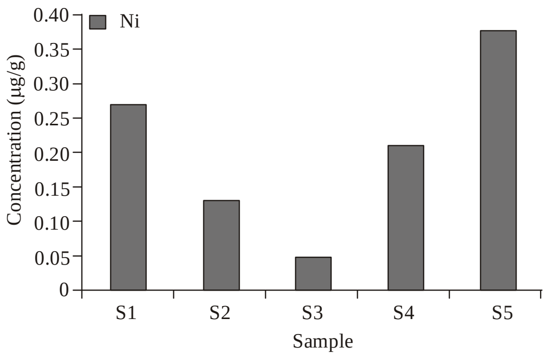

Fig. 9: Accumulation of Ni in fish samples

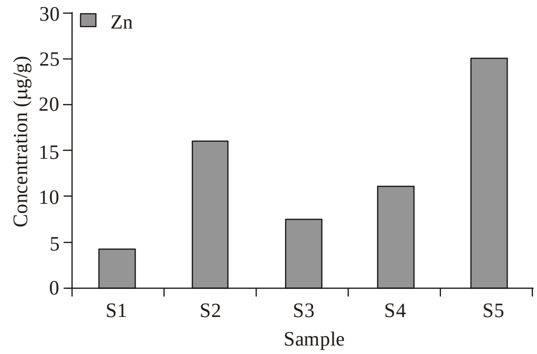

Fig. 11: Accumulation of Zn in fish samples

samples. The concentration of Manganese in the samples ranges from 3.07 to 48.87 µg/g as indicated on the figure (Fig. 8). The mean concentration of Manganese was 19.00 µg/g. According to the World Health Organisation (WHO, 1986), acceptable level of manganese in tilapia is 5 ug/g. Manganese concentration in this study was higher than acceptable level.

Manganese is one of the essential trace elements necessary for human survival. Its deficiency in the body poses health problems such as skin diseases, blood clotting, neurological symptoms, among others. Manganese in high concentration result to manganese poisoning that causes hallucinations, forgetfulness and nerve damage. Manganese can also cause Parkinson disease, lung embolism and bronchitis. When men are exposed to manganese for a longer period of time they may become impotent.

Nickel (Ni): The concentration of Nickel in the samples is represented in Fig. 9.

Averagely the mean concentration of nickel in the fish samples was 0.21 µg/g. The maximum accumulation level was 0.38 µg/g which was observed in sample S5 and also the minimum in sample S3 with value 0.05 µg/g. The application of agro-chemicasl such as fertilizers, pesticides and herbicides contribute nickel to add up to the naturally occurring nickel in the soil that leaches and runoff into the reservoir to accumulate in fish.

Nickel concentration of 0.7 µg/g in fish is considered potentially harmful to fish and humans that consume them (Baumann and May, 1984). None of the concentrations of nickel in the samples in this study approached these levels of concern. Hence, nickel concentrations in the entire fish do not constitute any threat upon the consumption of these species of fish from the facility.

Vanadium (V): Vanadium accumulation ranges from 0.08 to 0.69 µg/g with the maximum and minimum in samples S4 and S1 respectively which is illustrated in Fig. 10.

Source of Vanadium in fish samples can be attributed to natural occurrence in the soil. The mean concentration of vanadium in the fish samples was 0.27 µg/g. There is little evidence that vanadium in high concentration is toxic. Vanadium has not been classified by the United State Environmental Protection Agency (USEPA) or World Health Organisation (WHO) to have a permissible level; however the recommended dietary allowance is less than 1.8 mg per day.

Zinc (Zn): The highest concentration of Zinc was observed in sample S1 followed by sample S5, S2 and S4.

The least concentration was observed in sample S3. The concentration of Zinc in the samples ranged from 4.27 to 25.11 μg/g as shown in Fig. 11.

The concentration of Zinc in the samples was below the National Contaminant Bio-monitoring Program (NCBP) maximum contaminant level of 34.2 μg/g. Fish can accumulate zinc from both the surrounding water and from their diet (Eisler, 1993). Although zinc is an essential element, at high concentrations, it can be toxic to fish, cause mortality, growth retardation and reproductive impairment (Sorenson, 1991). Zinc is capable of interacting with other elements to produce antagonistic, additive or synergistic effects (Baumann and May, 1984). Zinc does not appear to present a contaminant hazard to fish and its consumers. Zinc is an essential element that occurs naturally in organisms and in the earth crust.

CONCLUSION AND RECOMMENDATIONS

Conclusion: The results of this study supply valuable information on the heavy metal contents in fish from a reservoir within the Tono facility. The concentrations of heavy metals determined in fish samples did not follow a specific trend. However, it was identified that heavy metal accumulates in fish as they grow.

From the results of this study, the average concentration of arsenic (0.23 μg/g), cadmium (0.02 μg/g), chromium (0.27 μg/g), iron (45.95 μg/g), nickel (0.21 μg/g) and zinc (12.76 μg/g) in Nile Tilapia investigated revealed that the concentrations of these metals did not exceed the maximum contaminant levels of 0.27 μg/g for Arsenic, 0.05 μg/g for Cadmium, 53.80 μg/g for chromium, 107 μg/g for iron, 0.7 μg/g for Nickel and 34.2 μg/g for zinc as prescribed by WHO (1986). However the average concentrations of copper (1.03 μg/g) and manganese (19.00 μg/g) exceeded the acceptable levels of 1 and 5 μg/g respectively of WHO (1986). Hence, these can be a major health risk because they could bioaccumulate and biopersist in Tilapia.

Although, the results in this study did not clearly show the manifestation of toxic effects, except copper and manganese, there could be the possibility of deleterious effects after a long period of consumption of tilapia from the facility. Factors such as leaching and runoff of heavy metals that lead to heavy metal accumulation in fish continue to exist. This will continue to affect the integrity of the ecosystem of this facility.

Recommendations: Considering the results obtained in this research and the concerns raised by international bodies such as WHO (1986), among others on the health risk associated with the increase heavy metals contamination in fish, it may be prudent to:

- Create afforested buffer zones to reduce or prevent the leaching as well as running off of heavy metals into the reservoirs within the facility.
- Conduct a more comprehensive investigation of the distribution of heavy metals in water, sediments and fish samples from the facility. In this case, various organs (muscle, liver, gills and kidney tissues) of fish samples will be considered.
- Monitor heavy metals accumulation within the facility.

REFERENCES

Akan, J.C., F.I. Abdulrahman, O.A. Sodipo and P.I. Akandu, 2009. Bioaccumulation of some heavy metals of six fresh water fishes caught from Lake Chad in Doron Buhari. J. Appl. Sci. Env. Sanitat., 4(2): 103-114.

ATSDR (Agency for Toxic Substances and Disease Registry), 2011. Toxic Substances Portal-Copper. Retrieved from: http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=205&tid=37(Accessed on: May 14, 2011).

Baumann, P.C. and T.W. May, 1984. Nickel residues in fish from inland waters of the United States. Workshop Proceedings, the Effects of Trace Elements on Aquatic Ecosystems. Electr. Pow. Res. Instit. Palo Alto, CA, 7: 1-16.

Dimari, G.A., F.I. Abdulrahman, J.C. Akan and S.T. Garba, 2008. Metals concentrations in tissues of tilapia *Gallier*, *Crarias Lazera* and *Osteoglossidae* Caught from Alau Dam, Maiduguri, Borno State, Nigeria. Am. J. Env. Sci., 4(4): 373-379.

Edem, C.A., V. Osabor, G. Iniama, R. Etiuma and J. Eke, 2009. Distribution of Heavy Metals in Bones, Gills, Livers and Muscles of (Tilapia) *Oreochromis Niloticus* from Henshaw. Department of Pure and Applied Chemistry, University of Calabar, Cross River State, Nigeria.

Eisler, R., 1993. Zinc hazards to fish, wildlife and invertebrates: A synoptic review. U.S. Fish Wildl. Serv. Biol. Rep., 85(1.10): 90.

Gómez-Márquez, J.L., B. Peña-Mendoza, I.H. Salgado-Ugarte and J. Luis, 2008. Age and growth of the Tilapia, *Oreochromis Niloticus* from a tropical shallow lake in mexico. Rev. Biol. Trop. 56(2): 875-884, ISSN: 0034-7744.

Herbert, D.M. and J.M. Vandyke, 1964. The toxicity to fish of mixtures of poisons. Ann. Appl. Biol., 53: 415-421.

Kassena-Nankana, 2011. Kassena/Nankana District, About This District, Economy. Retrieved from: http://kassenanankana.ghanadistricts.gov.gh/?arrow=atd&_=105&sa=1271, (Accessed on: May 5, 2011).

Malik, N., A.K. Biswas, T.A. Qureshi, K. Borana and R. Virha, 2010. Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. Environ. Monit. Assess., 160: 267-267.

Modaihsh, A.S., M.S. Al-Swailem and M.O. Mahjoub, 2004. Heavy metals content of commercial inorganic fertilizers used in the Kingdom of Saudi Arabia. Sultan Qaboos Univ. Agric. Marine Sci., 9(1): 21-25.

NRC (National Research Council), 1999-2000. Dogfish liver (Dolt-2), Dogfish Muscle (Dolt-2), Non Defatted lobster Hepatopancreas (LUTS-1) and Marine Lobsters Hepatopancreas (Tort-2) Reference materials for Trace Metals. In: Chemical Metrology, introduction to NRC Certified Reference Materials (CRMS)-Institude for National Measurement standard (INMS). Catalogue Number and Date sheet: DOLT-2 INMS CRMs. Institute for Marine Biosciences, Halifax, Government of Canada.

Rauf, J.M. and M. Ubaidullah, 2009. Heavy Metal Levels in Three Major Carps (Catla Catla, Labeo Rohita and Cirrhina Mrigala) from the River Ravi, Pakistan. Fisheries Research Farms, Department of Zoology and Fisheries, University of Agriculture, Faisalabad, Pakistan.

Robertson, S.M., L.R. Gamble and T.C. Maurer, 1992. Contaminant Survey of La Sal Vieja. U.S. Fish and Wildlife Service, Corpus Christi, Tex.

Rompala, J.M., F.W. Rutosky and D.J. Putnam, 1984. Concentrations of Environmental Contaminants from Selected Waters in Pennsylvania. U.S. Fish Wildl. Serv. Rep. State College, Pennsylvania, pp: 102.

Schmitt, C.J. and W.G. Brumbaugh, 1990. National Contaminant Biomonitoring Program, Concentrations (NCBP) of arsenic, cadmium, copper, lead, mercury, selenium and zinc in U.S. freshwater fish, 19761984. Arch. Env. Contaminat. Toxicol., 19: 731-747.

Simonits, A., F. De Corte and J. Hoste, 1974. Single-comparator methods in reactor neutron activation analysis. J. Radioanal. Chem., Institute for Nuclear Sciences, Rgksuniversiteit, Proeftuinstraat, 9000 Ghent, Belgium, 24(1975): 31-46.

Sorenson, E.M., 1991. Metal Poisoning in Fish. CRC Press Inc., Boca Raton, Florida, pp: 119-174.

United state Geological Survey (USGS), 2011. Toxic Substances Hydrology Program, Biomagnification. Retrieved from: http://toxics.usgs.gov/definitions/biomagnification.html, (Accessed on: April 20, 2011).

Walsh, D.F., B.L. Berger and J.R. Bean, 1977. Mercury, arsenic, lead, cadmium and selenium residues in fish: 1971-1973-national pesticide monitoring program. Pesticide Monitor. J., 11: 5-134.

Wedjong, P., 2004. ICOUR Tono Dam. Retrieved from: http://mysite.verizon.net/vze827ph/tono.htm, (Accessed on: April 12, 2011).

World Health Organization (WHO), 1986. Environmental health criteria 108. International Programme on Chemical Safety World Health Organization. Retrieved from: http:\\www.inchem.org/documents/ehc, (Accessed on: April 26, 2011).

Woodward, D.F., W.G.A. Brumbaugh, J. Deloney, E.E. Little and C.E. Smith, 1994. Effect of contaminant metals on fish in the Clark Fork River in Montana. Trans. Am. Fisher. Soc., 123: 51-62.