P-ISSN: 2305-6622; E-ISSN: 2306-3599

International Journal of
Agriculture and Biosciences

www.ijagbio.com; editor@ijagbio.com

Research Article

Regression of Heavy Metal Bioaccumulation on Age and Body Weight of Fishes in Ameka Dam of Ebonyi State, Nigeria

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Article History: Received: February 21, 2019 Revised: July 24, 2019 Accepted: September 01, 2019

ABSTRACT

Heavy metals studied include: Cadmium (C_a), Nickel (Ni), Mercury (Hg), Chromium (Cr), Lead (Pb) and Arsenic (As). Experimental data was collected from Ameka Dam. Data on the body weight and age of fish was collected for about 2 (two) years that is 24 (twenty four) months, result obtained were presented and interpreted in Tables 1 -5 on each of the water body studied. The result of simple regression on the effect of heavy metals on body weight and age of fishes in Ameka Dam showed that cadmium exerted negative influence on the age and body weight of the fishes as indicated by their negative co-efficients. The extent of influence was measured by the co-efficient of multiple determination R^2 of 46% and 3.9% for body weight and age respectively; which means that about 46% of the total variation that occurred in their body weight was caused by the presence of cadmium in the Dam. But, only 3.9% of the change in age was explained by cadmium availability. Significant impact of Cadmium on fish weight was observed at the second year of study, with Cadmium explaining 25% variations in the weight of fish. Nickel had no significant impact while the impact of mercury was seen in year one and two. In conclusion, it was observed that the presence of heavy metals like cadmium, nickel, mercury, chromium, lead and arsenic all exerted more positive influence on both the age and body weight of the fishes. The low values of the Durbin Watson constant in all the heavy metals signified the absence of autocorrelation in the regression model, showing that the model was well specified and no relevant variable was omitted.

Key words: Regression, Age, Body weight, Fish, Heavy metals

INTRODUCTION

The biodiversity of inland aquatic ecosystem is increasingly threatened by a variety of factors all of which are related to humans (Gopal, 2005). Available data suggest that 30% of fish species are threatened by human activities (Reveque *et al*., 2005). Metals such as mercury, cadmium, copper and zinc form major types of toxic compounds that are released into many water courses by the mining industry (Mason, 2002). Both air emissions and wastewaters are sources of metal pollution. Ebonyi State being naturally endowed with several mineral resources which range from lead, gypsum, calcium carbonate, copper, zinc, mercury, etc is seen to be blessed by nature. These resources have as well attracted several investors in the area of mining. Heavy metals are components of the earth crust. They cannot be destroyed or degraded. To a small extent, they enter our bodies via food, drinking water, and air as trace elements. Same heavy metals eg. (copper, selenium and zinc) are essential to maintain the metabolism of the human body, However, at higher concentrations, they can lead to poisoning (Mason *et al*., 2000). Heavy metal poisoning could result, they tends to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical concentration in the environment. Compounds accumulate in living things anytime they are taken up and stored faster than they are broken down (metabolized) or excreted. Heavy metals can enter a water supply by quarrying, industrial waste, consumer waste and or even from acidic rain; breaking down soils and releasing heavy metals into streams, rivers, lakes and groundwater (Nadal *et al*., 2004).

The deteriorating conditions of surface water resources by heavy metal pollution have led to the study of Ivo River in Ishiagu area of Ebonyi State Nigeria. Most pollutions result from uncontrolled discharge of untreated effluent from mining companies and industries in the area. Rashed (2001) and Vinikour *et al.* (1980) reported that

Cite This Article as: Nwabunike MO and GVC Igwe, 2019. Regression of heavy metal bioaccumulation on age and body weight of fishes in ameka dam of ebonyi state, Nigeria. Inter J AgriBiosci, 8(6): 294-298. www.ijagbio.com

metal pollutants in water are not .degraded, rather they are deposited, and some of them are assimilated by the aquatic animals posing serious threats to human health when they are consumed. Some heavy metals such as Zn and Fe are essential micronutrients for animals and plants but are dangerous at high levels, whereas Pb have no well defined physiological functions but are detrimental at certain limits (Nadale t*al.,* 2004; Ochieng *et al.,* 2007; Kar *et al.,* 2008; Aktar *et al.,* 2010). The concentration of Pb may cause neurological impairment and central nervous system malfunctioning. The detection of toxic level of these pollutants in the aquatic organisms observed in this vicinity in recent times necessitated this study and this has attracted the attention of various non-governmental organizations and researchers. Fish diagnoses are often used to detect and monitor these heavy metal contaminations in aquatic ecosystem. This study was embarked upon to determine the levels of heavy metals in fish samples from Ivo River in Ishiagu Ebonyi State, Nigeria. Most inhabitants in Ishiagu depend on the fish for consumption, rearing and trading due to the fact that they are abundant and affordable. Water pollution has been observed for Alayi-Ovim area a nearby area and this was attributed to proximity to lead (Pb)-zinc (Zn) and Chloride (Cl) formations of the Turanian Eze-Aku and the Albian Asu River group (Ibe and Akaolisa, 2011). This study was very important since the Ivo River in this study area is underlain by the Ezeaku Formation (Reyment, 1965). The surface drainage in the study area was irregular and consisted of a number of small streams forming a dendritic pattern. The streams generally flowed in the north-south direction into the Ivo River. Ivo River is the main drainage channel in Ishiagu area and environs. The river basin is a booming fish farming area during dry and rainy seasons. Most industrial activities in the area include: stone crushing, metal mining (Pb-Zn) and smelting. These are located near the river and they discharge their wastes directly into the river. When fish bioaccumulates these pollutants, it becomes a threat to human health since consumers depend heavily in the fish for their dietary. In addition, the streams also become undrinkable since it endangers human health.

MATERIALS AND METHODS

Determination of heavy metals Cd, Ni, Hg, Cr, Pb, and as was done using Buck 211VGP AAS made by Buck scientific, Inc., East Norwalk. The digest of the ash of each sample above as obtained in calcium and potassium determination was washed into 100ml volumetric flask with distilled water and made up to mark. This diluent was aspirated into the Buck 211VGP Atomic Absorption Spectrophotometer (AAS) through the suction tube. Each of the trace mineral elements was read at their respective wavelengths with their respective hollow cathode lamps using appropriate fuel and oxidant combination.

Analytical procedure: Data collected from the laboratory analyses of fish for the body burden of heavy metals identified from the three sampling locations and controls, were subjected to statistical analysis. Both descriptive and inferential statistics were used. Descriptive statistics in form of line tables were used to represent the bioaccumulation of the heavy metals as the fish grow from age one to two years. But, inferential statistics in the form of ordinary least square simple regression analysis and correlations of the various parameters were determined to indicate similarities or differences on the impact of heavy metals on the fish population of the Ebonyi river systems. The simple regression model is specified below:

Y = (A, B, Ut)…………Implicit form

$Y = Bo+A_1X_1+B_2\, X_2+ Ut$……Explicit form

Where:

Y = Heavy metals concentration/bioaccumulation

B0 = Constant

A = Age of fishes (months)

B = Body weight of fishes (g)

Ut = Error term

Correlation model

Model Specification for Spearman Correlation Analysis

$$1 - \frac{6 \sum d^2}{N (n^2 - 1)}$$

Where

N = No of Occurrence

D = Standard deviation

∑ = Summation

RESULTS

The result of the effects of bioaccumulation of heavy metals on fish tissues over two years

Simple regression analysis was done to determine the effect of heavy metals on the body weight and age of fishes in Ebonyi State. Body weight was measured in grams while age was measured in months. These were the two dependent variables which were regressed separately against independent variables. The independent variables were the heavy metals. Heavy metals studied include: Cadmium (C_a), Nickel (Ni), Mercury (Hg), Chromium (Cr), Lead (Pb) and Arsenic (As). Experimental data was collected from Ameka Dam. Data on the body weight and age of fish was collected for about 2 (two) years that is 24 (twenty four) months, obtained were presented and interpreted in Tables 1-3 on the water body studied.

The result of simple regression on the effect of heavy metals on body weight and age of fishes in Ameka Dam showed that cadmium exerted negative influence on the age and body weight of the fishes as indicated by their negative co-efficients. The extent of influence was measured by the co-efficient of multiple determination R^2 of 46% and 3.9% for body weight and age respectively; which means that about 46% of the total variation that occurred in their body weight was caused by the presence of cadmium in the Dam. But, only 3.9% of the change in age was explained by cadmium availability. This implied that cadmium exerted greater influence on the body weight than the age of the fishes in the Dam. Cadmium influence on the body weight was statistically significant at 1% level of significance while that of age was not significant.

Effect of tissue heavy metals on body weight of fish: a two years impact

Significant impact of Cadmium on fish weight was observed at the second year of study, with Cadmium explaining 25% variations in the weight of fish. Nickel had

Table 1: Regression Result on the Effect of Heavy Metals on Body Weight and Age of Fishes in Ameka Dam, Ebonyi State

Heavy Metals	R^2 (%)	AdR^2 (%)	S.E.E	F- Ratio	Constant Coefficient	Constant Standard Error	Variable Coefficient	Variable Standard Error	Durbin Watson
Cadmium									
BW	46.0	43.6	3.851	18.766	46.122	4.302	- 8.644	1.995*	0.991
A	3.9	-0.5	7.088	0.887	19.830	7.917	-3.458	3.672$^{N.S}$	0.038
Nickel									
BW	32.1	29.0	4.321	10.386	93.895	20.528	-2.075	0.644*	1.312
A	1.8	2.7	7.166	0.394	33.853	34.042	-0.670	1.068^{NS}	0.031
Mercury									
BW	18.4	14.7	4.736	0.865	75.793	21.586	-1.307	0.587*	0.865
A	5.3	1.00	7.037	1.222	47.909	32.070	-0.964	0.872^{NS}	0.044
Chromium									
BW	19.5	15.8	4.705	5.318	115.641	38.105	-1.147	0.497**	0.918
A	1.2	3.3	7.187	0.263	42.316	58.207	-0.389	0.760^{NS}	0.028
Lead									
BW	57.0	55.1	3.437	29.196	85.477	10.697	-2.703	0.500*	1.490
A	17.2	13.4	6.579	4.565	-31.161	20.479	2.046	0.957**	0.145
Arsenic									
BW	3.3	-1.1	5.155	0.755	37.106	10.763	-0.273	0.315^{NS}	0.638
A	38.1	35.3	5.688	13.540	-59.827	19.690	2.080	0.565*	0.209

Source: Data Analysis, 2013.

Table 2: Effect of Heavy metals on Age of catfishes

	Age of fishes (Months)					
	Cadmium	Nickel	Mercury	Chromium	Lead	Arsenic
Ameka dam						
R	0.275	0.043	0.036	0.232	0.012	0.068
R^2	0.055	0.002	0.001	0.054	0.000	0.005
y=a + bx	Age=11.67-2.47Cd	Age=2.9+0.11Ni	Age=3.74+0.08Hg	Age=9.46-0.42Cr	Age=5.83+0.03Pb	Age=2.49+0.16As
P value	0.059	0.770	0.808	0.112	0.934	

R=coefficient of correlatiom, R^2=coefficient of determination; y=a+bx is the linear regression equation; * significant at p<0.05, ** significant at p<0.01

Table 3: Effect of Heavy metals on Age of catfishes

	Age of fishes (Months)					
	Cadmium	Nickel	Mercury	Chromium	Lead	Arsenic
Ameka dam						
R	0.275	0.043	0.036	0.232	0.012	0.068
R^2	0.055	0.002	0.001	0.054	0.000	0.005
y=a + bx	Age=11.67-2.47Cd	Age=2.9+0.11Ni	Age=3.74+0.08Hg	Age=9.46-0.42Cr	Age=5.83+0.03Pb	Age=2.49+0.16As
P value	0.059	0.770	0.808	0.112	0.934	

R=coefficient of correlatiom, R^2=coefficient of determination; y=a+bx is the linear regression equation; * significant at p<0.05, ** significant at p<0.01

no significant impact while the impact of mercury was seen in year one and two. It impact in year one and two were relatively similar. Chromium impacted on fish weight only in the first year and was responsible for 35% changes in fish weight at this time. Lead impacted on fish weight only in year two, with its ability to causes changes in fish weight as 13.5%. Arsenic had similar impact on fish weight as Mercury but its impact on fish weight in year one (40.9%) was higher than its impact in year two (25.4%) (Table 2).

Effect of tissue heavy metals on body weight of fish: a two years impact

Significant impact of Cadmium on fish weight was observed at the second year of study, with Cadmium explaining 25% variations in the weight of fish. Nickel had no significant impact while the impact of mercury was seen in year one and two. It impact in year one and two were relatively similar. Chromium impacted on fish weight only in the first year and was responsible for 35% changes in fish weight at this time. Lead impacted on fish weight only in year two, with its ability to causes changes in fish weight as 13.5%. Arsenic had similar impact on fish weight as Mercury but its impact on fish weight in year one (40.9%) was higher than its impact in year two (25.4%) (Table 3).

Regression result on the effect of heavy metals on body weight and age of fishes in ameka dam

The result of regression on nickel showed that nickel accumulation in the dam negatively influenced both body weight and age of the fishes in the dam as was indicated by their negative coefficients. A co-efficient of multiple determinations R^2 of 32.1% and 1.8% were obtained for body weight and age of fishes respectively. This shows that about 32.1% of the variation in the body weight and 1.8% of variation in age of the fishes were caused by the presence of nickel. The result on body weight showed statistical significance at 1% level while that of age was not statistically significant.

Similarly, mercury negatively influenced both age and body weight of the fishes as shown by the negative co-efficients which they possess. The extent of influence was indicated by coefficient of multiple determinations R^2 of 18.4% and 5.3%.This implies that about 18.4% of the total variation in body weight and 5.3% variation on age was caused by mercury. The effect on body weight was statistically significant at 5% level of significance while that of age was not statistically significant.

In addition, chromium bore negative coefficients which showed negative influence on both body weight and age of the fishes in the dam. The level of influence was indicated by R^2 of 19.5% and 1.2%; meaning that about 19.5% of the total variation in body weight and 1.2% of variation in age resulted due to the influence of mercury. However, the effect on body weight showed statistical significance at 5% level while that of age was not statistically significant.

Also, lead showed negative relationship to the body weight and age of the fishes as was shown by the negative coefficient of the independent variable for body weight and negative coefficient of the constant in case of age. Both were statistically significant at 1% and 5% levels of significance respectively. The extent of the negative influence was high on body weight due to high coefficient of multiple determinations R^2 of 57%; which means that about 57% variation in the body weight of the fishes was due to the presence of lead in the dam.

Arsenic negatively influenced both body weight and age of the fishes in the dam as shown by the negative coefficients of the body weight and constant of age. But, a low R^2 of 3.3% and a high R^2 of 38.1% were obtained for body weight and age respectively. This indicates that about 3.3% and 38.1% of the variation in body weight and age of the fish were due to the influence of arsenic.

In Ameka dam lead, cadmium seem to be more abundant in the dam as indicated by the high R^2 of 57%, 46% and 32% which showed the percentage of their influence on the body weight of fishes in the Dam. The influence of these metals on the body weight was greater than on their age except arsenic which exerted greater influence on age than body weight. The low values of Durbin-watson constant obtained from all the heavy metals indicates the absence of autocorrelation in the regression model showing that the model was well-specified as relevant variables were not omitted. Thus, the result is statistically reliable. The final regression equations are indicated below. march 2011 to February 2013

DISCUSSION

Cadmium and Mercury concentrations were statistically similar (P>0.05) in fin of fishes collected from Enyigba river and Ameka Dam while the concentration of this heavy metal in other study areas differed significantly (p<0.05). There was no significant difference (p>0.05) in the concentration of Nickel in the fin of catfishes collected from Ameka dam, Enyigba and Mkpume rivers but the concentration differed significantly from those of Ebonyi and Pond water. Chromium and Arsenic concentration in the fin of catfishes collected varied significantly, with those from Enyigba and Mkpume rivers having significantly higher concentration (p<0.05), respectively while those from pond had low concentrations (p<0.05). Lead concentration was statistically similar (p>0.05) in fishes collected from Ameka dam and Mkpume river. The lead concentration of fishes from Ebonyi river was significantly lower (p<0.05) than that of pond water and these differed significantly (p<0.05) from those of other study areas (Tablea 3). which agreed with (Nadalet*al*., 2004; Ochieng*et al.,* 2007; Kar*et al.,* 2008; Aktar*et al.,* 2010). The concentration of Pb may cause neurological impairment and central nervous system malfunctioning.

Except for Lead and Arsenic, heavy metals were more concentrated in the fins of either Ameka or Enyigba catfishes than on that of Mkpume in dry season. The concentrations of heavy metals were least in pond water catfishes fin followed by Ebonyi river catfishes. Their heavy metals concentrations were significantly lower (p<0.05) than those of other study areas, with significant difference (p<0.05) between the fin concentration of heavy in Ebonyi river and pond water catfishes. In rainy season, concentrations of heavy metals in Mkpume were only high for Nickel, Lead and Arsenic. The concentrations of heavy metals was consistently low in the fin of catfishes collected from the pond and Ebonyi river although in some cases (Cadmium and Nickel) there was no significant difference (p>0.05) between pond water and Ebonyi river catfish fin heavy metal concentration. Most heavy metals did not differ significantly (p>0.05) in fin concentrations when dry and season concentrations were compared (4)

Nickel also exerted positive influence on both the body weight and the age of the fishes since they both had positive coefficients. The coefficient of simple determination, r-square of 84.0% and 28.0% were obtained for both body weight and age of the fishes respectively. This implies that about 84.0% of the observed variation in the body weight and 28.0% variation that were observed in the age of the fishes both were as a result of the presence of nickel in the fish fin. It was also observed that though body weight was not statistically significant, age of fish was statistically significant at 1% level of significance. Same heavy metals eg. (copper, selenium and zinc) are essential to maintain the metabolism of the human body, However, at higher concentrations, they can lead to poisoning (Mason *et al*., 2000). Heavy metal poisoning could result, as they tends to bioaccumulate.

Similarly, mercury also exerted positive influence on both the body weight and the age of the fishes since they both have positive coefficients. The coefficient of simple determination, r-square of 19.8% and 14.9% were obtained for both body weight and age of the fishes respectively. This implies that about 19.8 % of the observed variation in the body weight and 14.9% variation that were observed in the age of the fishes both were as a result of the presence of mercury in the fish fin. It was also observed that whereas body weight was statistically significant at 5%, age of fish was statistically significant at 10% level of significance.

Furthermore, chromium also exerted positive influence on the body weight and a negative influence on the age of the fishes since they both have positive and negative coefficients respectively. The coefficient of simple determination, r-square of 28.0% and 14.0% were obtained for both body weight and age of the fishes respectively. This implies that about 28.0 % of the observed variation in the body weight and 14.0% variation that were observed in the age of the fishes both were as a result of the presence of chromium in the fish fin. It was also observed that in as much as body weight was statistically significant at 1%, age of fish was statistically significant at 10% level of significance.

Lead, was observed to have exerted positive influence on both the body weight and the age of the fishes since they both have positive coefficients. The coefficient of simple determination, r-square of 20.0% and 14.4% were obtained for both body weight and age of the fishes respectively. This implies that about 20.0 % of the observed variation in the body weight and 14.4% variation that were observed in the age of the fishes both were as a result of the presence of Lead in the fish fin. It was also observed that though body weight was statistically significant at 5%, age of fish was not statistically significant at any level of significance.

Arsenic also from the analysis exerted negative influence on both the body weight and the age of the fishes since they both have positive coefficients. The coefficient of simple determination, r-square of 2.8% and 12.8% were obtained for both body weight and age of the fishes respectively. This implies that about 2.8% of the observed variation in the body weight and 12.8% variation that were observed in the age of the fishes both were as a result of the presence of Arsenic in the fish fin. It was also observed that both body weight and age were not statistically significant at any significance level.

In conclusion, it was observed that the presence of heavy metals like cadmium, nickel, mercury, chromium, lead and arsenic all exerted more positive influence on both the age and body weight of the fishes. The low values of the Durbin Watson constant in all the heavy metals signified the absence of autocorrelation in the regression model, showing that the model was well specified and no relevant variable was omitted.

- The provision of retention pond for pre-treatment of mining effluent is an effective physical treatment method.
- Neutralization of effluent water is recommended as a modern treatment practice such as lime precipitation of effluent water.
- Microbial activities and biodegradation is one of the most important biotechnology that emerged recently for treating and processing of tailing solutions for precious metal mining factories.
- Discharge of mining effluents should be monitored strictly by relevant agencies in order to prevent environmental pollution and reduce health hazards caused by the activities of miners.
- Swift intervention by government and other stakeholders in putting in place effluent treatment facilities will go a long way to curb environmental health risk posed by these hazardous effluents from miners.
- World health/bank should please assist the state Government in making available good quality refined urban tap water to the villages and subborbs so as to save the lives of both Urban and Rural dwellers.

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