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Assessment of some heavy elements in Galma dam, Zaria, Nigeria

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Abstract

The study was carried out to assess the levels of concentration and distribution of Pb, Cr, Fe, Cd, Co, Ni, Zn and Cu in Galma dam, Zaria, Nigeria which spanned to 35Km. The main source of data was the surface water from the lower and the upper regions of the dam. The samples were collected and prepared in the laboratory according to standard method, Atomic Absorption Spectrophotometry (AAS) technique was used to analyze the data. The results showed concentration of Pb, Cr, Fe, Cd, Co, Zn and Cu at various levels and the concentration of Ni below detectable level. The results also showed the distribution of these elements at lower and upper regions of Galma dam. The enrichment of these heavy elements in the dam could be explained by the loading of the dam with debris and effluents produced by various human activities within the dam catchment area through overland and base flows and the release of elements from geologic processes. The concentration of Pb, Cr and Fe were observed to be slightly above NIS and WHO standards for drinking water. To minimize pollution of the reserviour, it is strongly recommended that there should be reduction in levels of some unhealthy practices such as indiscriminate discharge of effluents like, engine oil, lubricants, used batteries, electric bulbs/fluorescent tubes, electronic and electrical appliances and high level use of chemicals on the farms are recommended to be discouraged.

Keywords: Catchment area, Carcinogenic, Concentration, Distribution, Enrichment, Galma dam, Heavy elements, Human activities, Lower region, Toxic, Upper region

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1. Introduction

Heavy elements are those metallic elements with high atomic weight that is at least five times greater than that of water (Ada et al., 2012b). Heavy elements include; lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag), chromium (Cr), copper (Cu), iron (Fe) and the platinum group elements (Dorherty et al., 2012). They are non-biodegradable and persistent environmental contaminants which may be deposited in water bodies. The presence of heavy metals in the aquatic environment in trace concentration is important for normal development of the organism (Kosi – Siakpere and Ubogu, 2008). They could be detected in the aqueous medium and in the bottom. Some heavy metals are completely toxic and need to be monitored continuously in the bodies of organisms as they are capable of bioaccumulation, resulting to mobility and often mortality of the organisms (Ayotunde et al., 2011)

Ayotunde et al., (2011) observed that when heavy metals enter aquatic environment a great portion settles and is absorbed by the bottom mud (sediment). They could also be recycled by chemical and biological processes such that some quantities remain dissolved in the water column and some part is being absorbed by the inhabitants (Ada et al., 2012a). Interest in the environmental levels of heavy elements is a global one because of the potential hazards of these metals to the health of humans, animals and plants when they exist at elevated levels. Sawyer et al., (2006) is of the opinion that heavy elements are dangerous because they bioaccumulate and interfere with biochemical processes in the living issues.

High levels of heavy metals in soil, water and atmosphere vis-à-vis the biota are often related to industrial activities, burning of fossil fuels, chemical dumping, application of agro-allied chemicals such as fertilizer and certain pesticides (Oyekunle et al., 2012). The knowledge of the levels of heavy elements in our environment is necessary for the purposes of setting background values of these elements, monitoring their accumulation in the biota regularly and estimating the amount of the metals that may possibly get translocated across the compartments in the entire ecosystem (Oyekunle et al., 2012). Harrison (1996) observed that with increasing industrial activities, what were once pristine habitats of organisms are becoming increasingly exposed to environmental pollution by heavy metals.

Water quality and the risk to waterborne diseases are critical public health concern in many developing countries. UNICEF/WHO (2012) observed that close to a billion people most living in the developing world do not have access to safe and adequate water. Most water sources in developing countries are polluted by both organic and chemical pollutants which include heavy elements (Haylamicheal et al., 2012). The Galma dam in Zaria which was constructed to provide portable water to Zaria metropolis is also suspected to be affected by pollution through heavy elements. Therefore, the knowledge of the changing concentrations and distribution of heavy elements and their compounds in Galma dam becomes imperative. The enrichment of heavy metals in the water body can result from both anthropogenic activities and natural processes which are on daily increase in the catchment area. Christopher (2012) observed that as long as human-induced generation of heavy metals continues in industrial and domestic activities, sustained measurement will be needed to assess the effectiveness of the set limitation standards and facilitate the identification and quantification of the state of environmental degradation attributable to the discharged-heavy metals. Therefore, the aim of this study is to assess the levels of concentration and distribution of Pb, Cr, Fe, Cd, Co, Ni, Zn and Cu in surface water of Galma dam and to assess the contamination status of these elements using NIS and WHO guidelines for drinking water.

2. The Study Area

The Galma river catchment area belongs to the north eastern part of Kaduna river basin which borders the Chad basin to the north. The Galma river is one of the main tributaries of River Kaduna. It has its headwaters near the north western edge of the Jos Plateau and falls near the Magami village into Kaduna plains. The main tributaries of Galma river are Shika river in the middle course and the River Kinkiba and Likarbu in its lower course. The Galma dam which is popularly called Zaria dam was constructed across the Galma river in 1975. The lake has the following characteristics (WADPCO, 1991);

a. It covers 18.8 hectares of land.

b. Dam catchment area = 3200Km^2.

c. Gross storage capacity = 16.0 x 10^{6}m^3.

d. Maximum Dam height = 14.9m.

e. Length of the Dam Crest = 640m.

f. Length of the Lake = 32Km – 35 Km at maximum flood water level.

g. Water Supply Capacity = 872 million litres.

Zaria city is situated close to River Galma and its tributary Shika which are the main sources of water in the reserviour. The dam is the zoned type. The water from this dam is passed into treatment plant where biological pollutants are removed by chlorination and other sediments removed by filtration and then pumped through network for public consumption. The geology of the study area is composed mainly of fine grain gneisses and magnetite with same coarse-grained granitic outcrops in few places. The gneisses are moderately to weakly foliated, principally made up of quartz and oligoclase, depth of weathering is irregular but thorough the depth ranges from 10m to deep pockets occasionally extending to about 60m (WAPDECO, 1991). The Galma river catchment lies within the tropical wet and dry climatic zones, characterized by strong seasonality in rainfall and temperature distribution. The catchment area lies in the natural vegetation zone known as northern guinea savannah. The zone is characterized by vegetation but cultivation, grass burning and grazing activities have greatly modified the natural vegetation cover and composition. The soil has been classified as leached ferruginous tropical soil developed on weathered regolith rich in fine grain quartz and oligoclase (Wright and McCurry, 1970). The major rural land use activities in the catchment area is farming and animal rearing.

3. Materials and method

3.1. Materials

The raw water sample was collected from the dam which spanned to about 35Km. Two sampling points were used; one in the upper and another in lower regions of the dam as shown on Figure 1. In each of the sampling points the raw water was collected at the banks and the middle of the lake (across the lake profile) and mixed in a pre washed 300ml plastic sample bottom. The samples were treated immediately on site with Nitric acid (HNO_3) at PH of 2 to preserve them before laboratory analysis. The samples were collected by dipping the plastic bottle into the water and collecting the surface water. Heavy elements are known to be more concentrated in sediments and aquatic animals (Rognerad and Fjield, 1993; Caccia et al*.,* 2003; Pekey, 2006; Marchand et al*.,* 2006). However, the need to assess the actual level of concentration of these heavy elements that are directly pumped out to the end users necessitated the choice of surface water for the study. The samples were collected for a period of 24 weeks fortnightly between the months of October to March. The samples were stored in the refrigerator till the time of laboratory analysis.

3.2. Sample preparation

Each sample was filtered in the laboratory using Watman Brand filter paper of 0.45um to remove clay and other suspended colloids in the water sample. 100ml of the filtered sample was collected and stabilized with Nitric acid in each sample. The standard curves of Pb, Cr, Fe, Cd, Co, Ni, Zn and Cu were prepared bearing in mind that these elements occur in trace concentration. Standard solutions were prepared from 1000 parts per million (ppm) stock solutions. 1ml of the 1000 ppm was pipetted into 100ml volumetric flask and made up with distilled water. This solution was 10 ppm of the solution. From this solution, standard solutions of 0.2, 0.4, 0.6, 0.8 and 1 ppm were prepared by taken 0.2, 0.4, 0.6, 0.8 and 1ml portions into 10ml volumetric flasks and made to mark. These were then run in the Air Acetylene flame and standard curves for the various elements were obtained.

3.3. Data analysis

To analyze the samples, 100ml of the digest in each sample was run one after the other on the UNICAM 969 Atomic Absorption Spectrophotometer (AAS) which uses air acetylene flame. By choosing the correct wavelength of the various elements and running a known standard curve of the various elements, the absorbance values of the chemical elements present in the samples were determined. Using the standard absorbance of the various elements, the absorbance from the various heavy elements as contained in the samples was converted to ppm values as their levels of concentration. This was repeated three times for every element in every sample and the mean concentration was taken as the actual level of concentration of the heavy element in ppm. Finally, the entire data generated by laboratory analysis of the water samples were summarized by some simple descriptive statistics.

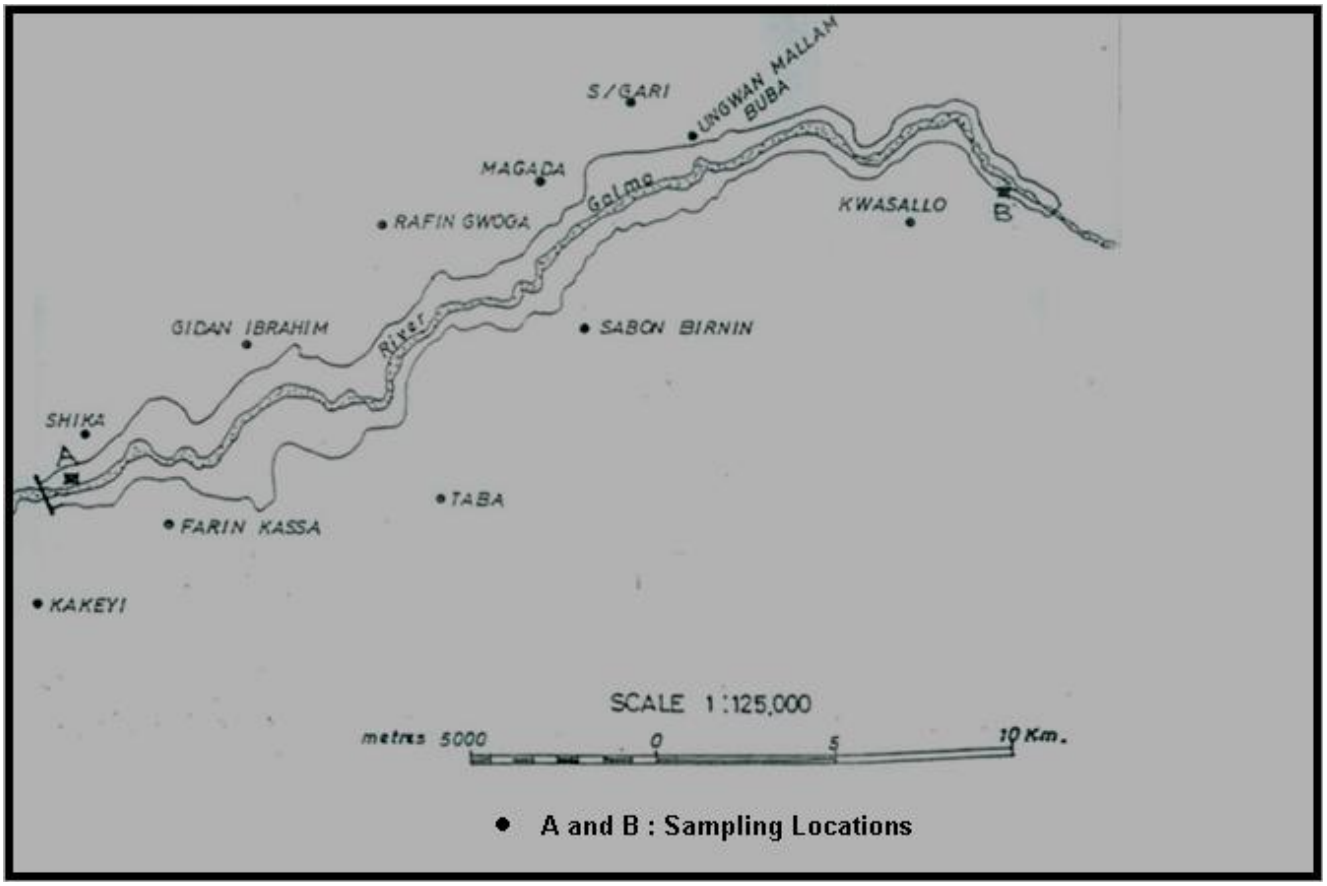

Figure 1. Study area Zaria (Galma) Dam (Source: Adopted from WAPDECO, 1991)

4. Results and discussion

The results of the analysis as shown on Tables 1 and 2 showed the levels of concentration and distribution of some heavy elements in Galma dam. The result showed that the levels of concentration of Pb at the lower and upper regions of the dam are both high with low standard deviation and coefficient of variation and slightly above the WHO and NIS guidelines limit for drinking water quality as shown on Table 3. Lead is a chemical element in the carbon group. Excessive intake of Pb can damage nervous system and cause brain disorder. Pb is a neurotoxin that accumulates both in soft tissues and the bones (Wikipedia, 2013). Lead poisoning has been documented in six villages in Zamfara State, Nigeria where it claimed 355 people across the six villages (Ibrahim and Aliyu, 2010).

The level of concentration of Cr in the entire Galma dam is high as shown on Tables 1 and 2, both the standard deviation and coefficient of variation in the upper region are low, however they are high in the lower region. The mean concentration at both regions is above WHO and NIS guidelines for drinking water as shown on Table 3. Cr is one of the trace elements that occurs as an abundant element in the earth crust, its compounds are found in the environment due to erosion of chromium containing rocks and from other man made sources. Excessive exposure to Cr is suspected to be carcinogenic because of it bioaccumulation nature (NIS, 2007). The concentration of Fe in Galma dam is high, both the standard deviation and coefficient of variation at the lower region are low, but high at the upper region. The mean concentration at both regions is slightly above NIS guideline although there is no current WHO standard for comparison. The Galma catchment area contained a lot of biotitic rocks which release Fe through weathering into the drainage basin (Thorp, 1970). High concentration of Fe in drinking water may cause turbidity or stain in plumbing fixtures, laundry and cooking materials; Fe has little direct and adverse health implications to humans but rather plays a vital role in biology (Butu, 2012).

The concentration of Cd in the entire dam is low with very low CV. The concentration in the dam is far below the NIS and WHO standards for drinking water implying that the dam is not polluted by Cd. Cd occurs as a minor component in most Zn ores and therefore a by-product of Zn production. It is a rare element, it is used as pigment and corrosion resistant plating, it could also be used as nickel-cadmium batteries. Cd has no biological function in humans, but it could be toxic to the kidney when consumed in quantities above permissible limits (Wikipedia, 2013).

The level of concentration of Co in the dam is relatively high considering the fact that Co is a trace element that occurs only in combination with other minerals in the soil. Both the standard deviation and the coefficient of variation at the lower region are high, but low in the upper region. Although there are no guidelines limits for Co in drinking water, MOE (2001) reports that the toxicity of Co is quite low compared to other elements in the soil, however exposure to higher levels can be carcinogenic to humans because of the bioaccumulation nature of Co in the human tissues.

The level of concentration of Ni in Galma dam is far below detectable level. Therefore, the dam is free of Ni contamination. The results of the analysis showed a low concentration of Zn with low standard deviation and coefficient of variation in entire Galma dam, the mean values at both regions are lower than the WHO limit, although there is no NIS guideline for comparison. The level of concentration of Cu in Galma dam is low with low standard deviation and coefficient of variation in the lower region, but higher standard deviation and coefficient of variation in the upper region. The concentration of Cu in the entire lake is below NIS and WHO standards for drinking water, this means that the dam is not contaminated by Cu.

The results of the analysis as shown on Tables 1 and 2 clearly indicated that Pb, Cr, Fe, Zn and Cu showed some levels of enrichment in both the upper and the lower regions of Galma dam. The reasons for this enrichment are attributed to the fact that these elements are free earth metals which occur abundantly in the earth crust and also exist in household appliances. Pb is used in batteries as electrodes and in ceramics, Cr is used in metal alloys and pigments for paints and Zn is a common household material for roofing. The presence of these heavy metals in Galma dam can be explained by pluvial discharges from Sabon Gari, Zaria and other rural settlements around the dam that washed rusted metal roofs and carry domestic discharge, paint and roof insulation debris from building as well as oil and debris from the rural area containing agro-allied chemicals into the reserviour. The result as shown on Table 3 clearly revealed that the levels of concentration of Pb, Cr, and Fe are slightly above NIS and WHO permissible limit for domestic water. Although Fe is not known to pose direct harmful effects on humans, Pb and Cr have been implicated in the etiology many ailments peculiar to humans. Therefore, their continuous grow in water bodies for human consumption deserved a close monitoring. Ni is completely below detectable level in Galma dam, this therefore means that anthropogenic activities which could release Ni into the water body are unrampant or absence. The concentration of Cd is also very low and this can be explained by non human activities that related to release of Cd into the stream directly such as effluent and sewage or waste water.

Table 1. Concentration of Selected Heavy Elements in the Lower Region of Galma Dam

Heavy elements	Maximum Concentration (ppm)	Minimum Concentration (ppm)	Mean Concentration	Standard Deviation	CV (%)
Lead (Pb)	0.243	0.000	0.127	0.052	40.94
Chromium (Cr)	0.653	0.002	0.286	0.066	23.10
Iron (Fe)	3.543	0.857	2.123	0.606	28.54
Cadmium (Cd)	0.001	0.000	0.0005	0.000001	0.03
Cobalt (Co)	1.031	0.059	0.261	0.147	56.3
Nickel (Ni)	-0.022	-0.008	-0.018	-0.0004	-1.76
Zinc (Zn)	0.397	0.012	0.151	0.027	17.9
Copper (Co)	0.373	0.088	0.209	0.093	44.50

Table 2. Concentration of Selected Heavy Elements in the Upper Region of Galma Dam

Heavy elements	Maximum Concentration (ppm)	Minimum Concentration (ppm)	Mean Concentration	Standard Deviation	CV (%)
Lead (Pb)	0.299	0.070	0.126	0.048	38.09
Chromium (Cr)	0.834	0.039	0.340	0.208	60.30
Iron (Fe)	6.836	0.588	2,730	1.794	65.71
Cadmium (Cd)	0.001	0.000	0.0001	0.00001	1.0
Cobalt (Co)	0.957	0.002	0.169	0.142	0.08
Nickel (Ni)	-0.029	-0.010	-0.021	-0.004	-2.10
Zinc (Zn)	0.450	0.011	0.126	0.048	38.1
Copper (Cu)	0.322	0.038	0.139	0.085	61.15

Table 3. Comparison of observed values of concentration of selected Heavy elements in Galma dam with Nigerian and World Health Organization (WHO) standards

Heavy elements	Mean Values in ppm		NIS (2007) Standard	WHO (2011) Standard
	Lower Region	Upper Region		
Lead (Pb)	0.127	0.126	0.01	0.01
Chromium (Cr)	0.286	0.340	0.05	0.05
Iron (Fe)	2.123	2.730	0.0	NG
Cadmium (Cd)	0.0005	0.0001	0.003	0.003
Cobalt (Co)	0.261	0.169	NG	NG
Nickel (Ni)	-0.018	-0.021	0.02	0.02
Zinc (Zn)	0.150	1.26	NG	3
Copper (Cu)	0.209	0.139	1	2

Source: WHO (2011): NIS (2007) NG = No guideline

5. Conclusion

The result of the study showed that there is significant amount of Pb, Cr, Fe, Co, Zn and Cu which occurred at different levels of concentration and are distributed at both the upper and lower regions of Galma dam, a very low concentration of Cd also exists in the dam and the level of Ni at both regions of the dam is below detectable limit.. Pb, Cr and Fe showed a slightly high enrichment levels above permissible standard and this may pose some health complications if the concentration increases above these levels in the long run. This is because heavy elements are known to be non biodegradable, they bioaccumulate progressively in aquatic organisms and human cells when expose to them over a long period. The presence of these heavy elements in the dam can be explained by pluvial processes which washed man-made debris that contained these metals into the dam during rainy season as well as release of some elements from geologic processes.

In light of the results obtained, the following recommendations are considered necessary:

a. The indiscriminate dumping of refuse which littered the built up area of the Galma catchment area and other water sources be discouraged because most of these metal pollutants have their origins from the decay of substances in the dump. Government should provide necessary vehicles for regular evacuation of all dumped refuse. An acceptable method of sanitary land fill should be introduced.

b. The use of toxic chemicals for farming especially the use of pesticides and herbicides should be controlled. It is possible to obtain optimum agricultural yield within the drainage basin without contaminating the reserviour with chemical elements.

c. The unhealthy practices such as discharging of oil of all kinds, petrol, used batteries, grease, used bulbs/fluorescent tubes, electrical and electronic appliances, training effluents and salon effluent into public drains which finally end up into rivers/reserviours should be discouraged. Government should rather organize collection system of waste lubricants which can be recycled.

d. The location of industries, research institutions should be far away from water bodies. For already existing factories and research institutions, necessary steps should be taken to remove some of the poisonous and harmful chemicals from the effluents before discharging them to the remote areas. Also a permissible limit of effluents from the factories should be set and monitored by the government; this should include outlawing discharge of industrial liquid water direct into public drains without preliminary treatment.

e. The government should re-introduce and enforce the compulsory Environmental Sanitation Day every last Saturday of the month. This will assist in keeping the environment clean.

f. The sanitary section of Health department of every Local Government Area should train and retrain sanitary officers (Dubagari) to enlighten the general public within their areas on the need for cleanliness and clean environment and also to enforce compliance with standards.

g. Towns and cities should have simple and effective sewage treatment. Raw sewage should not be discharged into public drains or water bodies.

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