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RESEARCH ARTICLE

Seasonal Variation in Concentration of Some Heavy Elements in Surface Water at the Lower Region of Galma Dam, Zaria, Nigeria

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Abstract

The aim of this study is to examine the seasonal variation in concentration of Pb, Cr, Fe, Cd, Co, Ni, Zn and Cu in surface water at the lower region of Galma dam Zaria, Nigeria. The main source of data for the study was surface water at the lower section of the dam. The water samples were collected and prepared in the laboratory according to standard method and the Atomic Absorption Spectrophotometry (AAS) technique was used to analyze the data. The results of the analysis showed that the concentration of Cr and Fe is higher in the lake during the rainy season, and the concentration of Zn is higher in the dry season. There is no significant difference in concentration of Pb, Cd, Co and Cu between the two sampling periods. The results showed that the concentration of Ni is below detectable limit in the dam. The results of analysis generally revealed that heavy elements such as Cr and Fe whose sources are related to human activities and geologic formation and are transported by surface and base flows tend to show higher levels of concentration in the dam during the rainy season. The pattern of temporal variation observed is explained by the influence of human activities and weathering processes which are driven by surface and subsurface flows.

Introduction

The interest in the environmental levels of heavy metals is a global one because of the potential hazards of these elements to the health of animals, humans and plants when they exist at elevated levels (Oyekunle *et al.*, 2012). Heavy metals are dangerous because they bio-accumulate (Goyer, 1991: Sawyer *et al*., 2006). Heavy metals are those metallic elements with high atomic weight that is at least five times greater than that of water and several elements have been listed in this group (Ada *et al.,* 2012). The presence of heavy metals in the aquatic environment in trace concentration is important for normal development of the organisms (Kori – Siakpere and Ubogu, 2008) however, some are completely deleterious and need to be monitored continuously. Heavy metals could be detected in aqueous medium and in sediment.

When heavy elements enter aquatic environment, a great portion settles and is absorbed by the bottom mud (Ayotunde *et al.,* 2012). They could be recycled by chemical, physical and biological processes such that some quantity remains dissolved in the water column and some part is being absorbed in the inhabitants (Rayins – Keller *et al.,* 1998; Kori – Siakpere and Ubogu, 2008). Heavy metals or chemical elements are easily introduced into aquatic system as a result of chemical weathering of soil and rocks from volcanic eruptions and from a variety of human activities involving processing or use of metals and substances that contain metals (Butu and Iguisi, 2013; Butu, 2013). Heavy metals may come from many different sources in urbanized areas, including vehicular emissions, industrial discharges and other activities (Thornton, 1991).

The rate of increase in level of concentrations of metal contaminants in domestic water is highly worrisome, this is because pollution greatly reduces the quality of water available for most purposes, and it is also very dangerous to both man and aquatic animals (Butu, 2012). The greatest challenges confronting the water supply agencies today are the

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control and removal of poisonous chemical contaminants from water; this is because of abundance of these chemicals in our environment. Water may be everywhere, but its use has always been constrained in terms of availability, quantity and quality. The scarcity of water globally has lead to intense political pressures often referred to as "water stress" (Molobela and Sinha, 2011). Many challenges regarding water management continue to face the world and in order to adapt to water shortages some changes are needed that will maintain or improve the ability of a system such as the municipal water supply to continue to serve its purpose (Ivey *et al.,* 2000). Water is absolutely essential for life; it is undoubtedly the most precious natural resource that exists on our planet (Abowei and George, 2009). The quality of water available and accessible to a community has tremendous impact on their living standard and well being; thus global and local efforts are wide spread at ensuring adequate provision of clean and safe water to the growing world population (DWAF, 2003). The Galma dam was constructed in 1975 by Kaduna state government to provide portable water to Zaria community (WAPDECO, 1991). Population growth coupled with agricultural activities, industrial and commercial processes have resulted in the accumulation of wastes and pollutants which end up in this water body and other similar sources of water, thereby altering the water quality, species composition and biodiversity.

Several studies have revealed the distribution of various heavy metals in water bodies; the Galma dam is a good reference of a site where human pressures and natural values compete with each other especially at the lower region under different seasonal conditions and where the degree of metal contamination in relation to seasonal variation has not been subjected to detail assessment. For instance, changes in precipitation patterns are likely to increase flooding and as a result mobilize more contaminants into the water ways. This study therefore aims at assessing the seasonal variation in concentration of selected heavy elements in the surface water at the lower region of Galma dam, Zaria Nigeria.

The study area

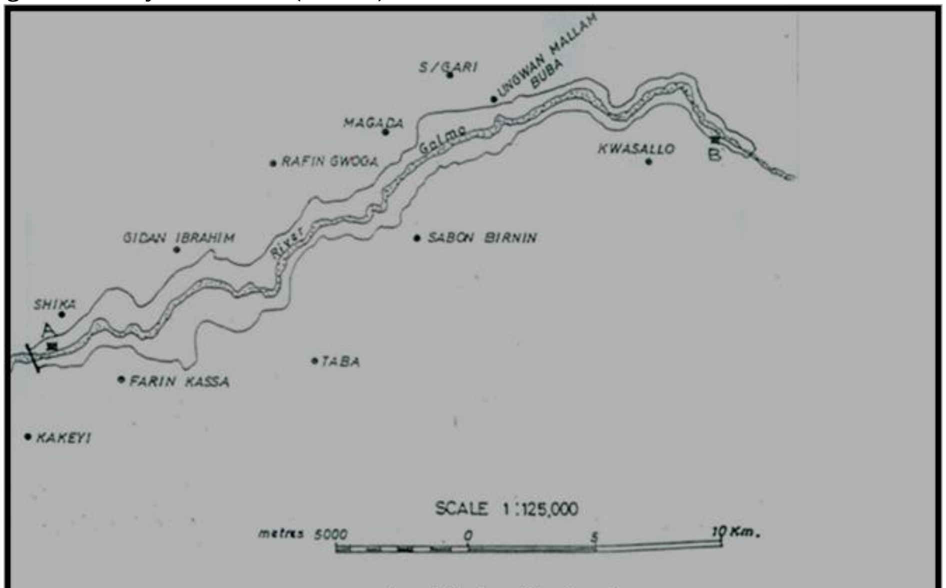
The study area belongs to the north eastern part of Kaduna River basin which borders the Chad basin to the north. The Galma River is one of the main tributaries of River Kaduna. It has its headwaters near the north western edge of the Jos Plateau and falls near the Magami village into Kaduna plains. 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 extends to about 32 – 35km at maximum flood water level, covering about 18.8 hectares of land, the catchment area is 3200 km^2 and gross storage capacity is 16.0 x 10^6 m^3 (WAPDECO, 1991).

Zaria city is situated close to River Galma and its tributary Shika which are the main sources of water in the reserviour. 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.

Materials and Method

Materials. The water samples were collected from the lower region of the dam as shown on Figure 1. The samples were collected at the banks and the middle of the lake (across the lake profile) and mixed in a pre washed 300ml plastic sample bottle. 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 (grab method). 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 levels 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 six months between the months of July to September (rainy season) and January to March (dry season). The samples were stored in the refrigerator till the time of laboratory analysis.

Figure 1. Study area Zaria (Galma) Dam



A: Sampling location.
Source: Adopted from WADPCO (1991)

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 pipette 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.

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.

Results and Discussion

The results of the analysis as shown on Table 1 showed that there is higher concentration of Pb at the lower region of Galma dam in the rainy season. The statistical test confirmed that there is no significant difference in concentration of this element between the rainy and dry seasons. The minor variation observed from the raw data could be as a result of precipitation of the element in the sediment during the dry period. The level of concentration of Cr is higher in the wet season than the dry seasons. The student t-test confirmed that there is significant difference in concentration of Cr between the rainy and dry seasons. The reasons for higher concentration of Cr in the lower part of the dam in the rainy period could be explained by the fact that during the rainy season a lot of debris containing Cr are been washed into the dam by storm runoff and the metal is released into the surface water from these debris. In the dry season most of this metal that has been released into the reservoir must have precipitated into the bottom mud (sediment) of the dam, there by showing less concentration in the surface water in dry season.

Table 1. Concentration of some heavy elements at the lower region of Galma dam during the rainy and dry seasons.

Heavy metal	Rainy Season (Jul - Sep)		Dry Season (Jan - Mar)		Calculated t-values and significant of the difference between the two seasons	
Metal (ppm)	**Concentration (ppm)**	**Standard Deviation**	**Concentration (ppm)**	**Standard Deviation**	**t-Cal**	**Significance**
Lead Pb	0.142	0.121	0.113	0.071	0.600	Not significant
Chromium Cr	0.373	0.289	0.219	0.173	1.770	Significant
Iron Fe	2.414	0.574	1.829	0.518	2.896	Significant
Cadmium Cd	0.00066	0.00023	0.00053	0.00045	0.54	Not significant
Cobalt Co	0.273	0.175	0.306	0.084	0.256	Not significant
Nickel Ni	-0.0187	-0.0391	-0.0174	- 0.0363	-	Not tested
Zinc Zn	0.117	0.036	0.301	0.035	2.665	Significant
Copper Cu	0.203	0.106	0.212	0.110	0.282	Not Significant

Note: The critical (t-test) value for all the compared values is 1.70, the degree of Freedom is 28 at 0.05 level of significance.

The results as shown on Table 1 also revealed that the concentration of Fe in the surface water at the lower region of dam is higher during the rainy season than in the dry season. The statistical test also confirmed that there is statistical evidence to show that there is significant difference in concentration of Fe in the lower section of Galma dam between the rainy and dry seasons. Fe is one of the most common metals that are easily released from the soil regolith during weathering processes in the Galma catchment area. The soil of the catchment area is classified as ferruginous tropical soil which is rich in Fe content (Wright and McCurry, 1970). The Galma basin contains a lot of biotitic rocks which release Fe through weathering process into the drainage basin (Thorp, 1970). The Fe that is released from the weathering process in the catchment area is been transported into the dam through base and surface flows during the rainy season thereby accounting for high concentration of the metal in the surface water of the dam. Another possible source of this element in the lake during the rainy period could be from the chemical fertilizers containing Fe that are constantly applied on the vast farm lands in the catchment area to improve agricultural yield. The chemical fertilizers are also washed into the dam through surface flow in the rainy season thereby increasing the Fe content in the surface water of the dam. During the dry season most of the Fe concentration in the dam is suspected to have undergone reduction and oxidation reactions thereby forming different compounds in the lake sediment or must have precipitated thereby resulting to low concentration in the dry season.

Generally, the concentration of Cd at the lower region of the dam is very low in both rainy and dry seasons. The statistical test also confirmed that there is no significant difference in concentration of Cd between the two seasons, although the raw data showed a slight higher value in the wet period which could be explained by constant loading of Cd containing debris such as used batteries and oils into the lower section of the dam in the wet season. The concentration of Co is higher in the surface water of the dam in the dry season. The statistical test confirmed that there is no significant difference in concentration of this metal. Co is a natural earth metal present in trace amount in the soil, rocks, surface and underground water and usually occurs in association with other elements such as Cu, Ni, Mn and As (MOE, 2001). Co is therefore been released into the lake through base flow from the regolith system and since the main source of Co is the geologic formation through the sediment of the dam, the element concentration is the same in dry and wet seasons. The levels of concentration of Ni at the lower section of Galma dam are both negative during rainy and dry seasons, meaning that the metal is far below detectable level, therefore there was no basis for comparison.

The concentration of Zn in the surface water at the lower region of Galma dam is higher in the dry season than the wet season. The student t-test also confirmed that there is strong evidence to proof that the concentration of this metal is higher in the lake during the dry season. Zn is a common metallic element in the lower Galma catchment area. It is commonly found in Zn pipes, rain pipes, car tyres, motor oils, Zn components in fungicides and insecticides which finally end up in water (Lentech, 2009). Gamboa – Rodriguez, *et al* (2012) observed that the presence of Zn and Pb in Tabasco Lagoon, Mexico was as a result of pluvial discharges from the city around the lagoon that washed rusted metal roofs and carry domestic discharges, paints and roof of insulation debris from building as well as oil and combustion particles from automobile combustion. This source of Zn is applicable to the Galma catchment area. The bulk of Zn into the lower part of the dam is suspected to be from pluvial discharges during the rainy period and this metal must had been released from this debris in the wet period and concentrated in the sediment to be released back into the surface water of the Lake in higher concentration.

The levels of concentration of Cu in the surface water at the lower part of Galma dam is almost the same in the wet and dry seasons. The statistical test also confirmed that there is no significant difference in concentration of this metal between the two sampling periods. This therefore means that there is common source of Cu at the lower section of the Lake. Cu is also a common metallic element in the environment. Cu plated debris which is drained into the lower dam in the wet season must have been released into the surface water and precipitated into the dam sediment to maintain sediment – water column equilibrium in the dry season.

Conclusion

The study showed that all the selected heavy elements analyzed at the lower region of Galma Lake showed high concentration throughout the sampling periods except Ni which is below detectable limit and Cd which has low concentration. It is clear from the findings of the study that the concentration of the selected heavy metals in the surface water at the lower course of the dam reflected the pattern of pollution that takes place in the Galma catchment area in the two seasons. Elements which are linked to overland flow carrying huge debris and base flow draining elements that are released from regolith system tended to be more concentrated at the lower section of the dam in the rainy season, while chemical elements that are bond up in the Lake sediment showed higher concentration in the dry season. Generally, the main source of these metals in the lower section of the dam is from the anthropogenic activities and weathering processes from the Galma catchment area.

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