Assessment and Distribution of Metal Pollutants in the Water of River Ngadda and Alau Dam Used for Irrigation Farming in Maiduguri, Borno State, Nigeria

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Abstract

The present study was carried out to assess levels of heavy metals namely; iron, manganese, zinc, Nickel, cadmium, lead, cobalt, chromium and copper in water samples obtained from River Ngadda and Alau Dam which were extensively used for irrigation during dry season farming. The analysis was carried out using Atomic Absorption Spectrophotometer (AAS).The results indicated that the maximum concentrations of Cd (0.044)ppm, Co (0.392)ppm, Fe (10.48)ppm, and Ni (0.37)ppm from samples obtained at various point from River Ngadda exceed the recommended safe limit in water used for continuous irrigation while the concentration of Aluminium and Copper were below the recommended safe limit at all the sampling points. However, the concentration values of all the metals were below the recommended maximum tolerable levels by USEPA. The similarity distributions of the various elements determined in the various sites were analysed using mathematical tool of cluster analysis employing hierarchical procedure and using WARD's method. The result obtained produce three clusters groups labeled Clusters I, II, and II consisting of five, four and four sites with percentage similarity of the element concentrations and or sources of the clusters being 96.8%, 78.6% and 75.5% respectively.

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Introduction

Over the last three decades, there has been much interest in the geochemical distribution and fate of heavy metals in the environment, including both water and sediments fraction with the factors that enhances heavy metals in the environment which include urbanization, agricultural and

industrial activities and improper waste disposal system (Tijani, 2004). Heavy metal contamination of stream and river water ecosystem is a worldwide environmental problem (Sekabira, 2010). Trace amount of heavy metals are always present in fresh waters from the weathering of rocks and soils (Muwanga,, 2006, Babel and Opiso, 2007, Samaghandi *et al* 2007, Igwe *et al* 2008, Al-Juboury, 2009). Runoff, atmospheric deposition and domestic and industrial effluent discharges are the major sources of aquatic pollution (Wasswa,1997, Linnik, and Zubenko, 2000, Campbell, 2001, Luwanga, *et al*, 2003 and Lomniczi *et al*, 2007) Industrial or Municipal wastewater is mostly used for the irrigation of crops mainly in periurban ecosystem, due to its easy availability, disposal problems and scarcity of fresh water but irrigation with wastewater is known to contribute significantly to the heavy metal content of soil.(Arora Monu, 2008, Mapanda *et al* 2005). Wastewater contains substantial amount of toxic heavy metals, which create problems (Cheng Wang 2002, Wang, 2005; Singh *et al*, 2004, Singh 2010, Sinha and Dalwami, 2006).. Excessive accumulation of heavy metals in agricultural soils through waste water irrigation may not only result in soil contamination, but also affect food quality and safety (Muchuweti, 2006).

Food and water are the main source of our essential metals; and these are also the means through which we are exposed to various toxic metals. Study has shown that long term irrigation with waste or contaminated water may lead to the accumulation of heavy metals in agricultural soils and plants (Singh, 2010). The generation of solid waste has become an increasing environmental and public health problem everywhere in the world (Akoteyon, 2011). The fast expansion of urban, agricultural and industrial activities spurred by rapid population growth and the change in consumer habit has produced vast amount of solid wastes which may contain metal pollutants and be transported to nearby stream through erosion or leaching to contaminate the water hence when the water is used for irrigation purposes it can be transferred to the soil and be absorbed by the plats cultivated on the soil. River Ngadda is important because it is being used for fishing, farming, washing and in some cases as drinking water. This study was conducted with the following objectives to assess the heavy metals concentrations of (iron, manganese, zinc, Nickel, cadmium, lead, cobalt, chromium and copper) in river Ngadda water and to establish the similarity distributions of the various contaminants in the various study sites using cluster analysis.

Materials and Methods

River Ngadda originates from River Yedzaram and Gadombole which meet at Sambisa both in Nigeria and flows as River Ngadda into Alau Dam and stretches down across Maiduguri Metropolis then emptied into Lake Chad. The river being that it transcends the Maiduguri town it receives all sorts of wastes from residential houses. Maiduguri, like other cities in developing countries there are few sanitary landfill sites. The waste dump sites are usually haphazardly located without careful consideration of environment and public health (Agunwamba, 2007). The study area lies between latidude 11^{o} $15^{'}$ N and longitude $30^{o}05^{'}$ E at an altitude of 345m above

sea level and is located on sheet 90 North West on scale 1:50,000 Nigerian survey topographical map.

Sample Collection and Preparation

Representative samples were collected from Alau Dam, and at various points along the bank of river Ngadda where farming activities were carried out at the time of sampling. The water samples were collected using a 1.5litre polyethylene bottles from the body of the stream at various irrigation points. Each container to be used for sampling the water was washed and rinsed with the water at the sampling point three or four times before collection. The water used in rinsing the bottles was disposed outside the water body so that it does not mix with the water to be sampled. The sample bottle was held by the base and plunged below the surface. It was then turned slowly upward and the mouth was directed towards the water current where there was current or else moved slowly away from the hand. Precaution was taken to avoid contact with the bank or stream bed. The bottles were filled to the top and Analar grade Concentrated HCl were added and then tightly sealed with the cap. The samples were then taken to the laboratory for further preparation for the AAS analysis.

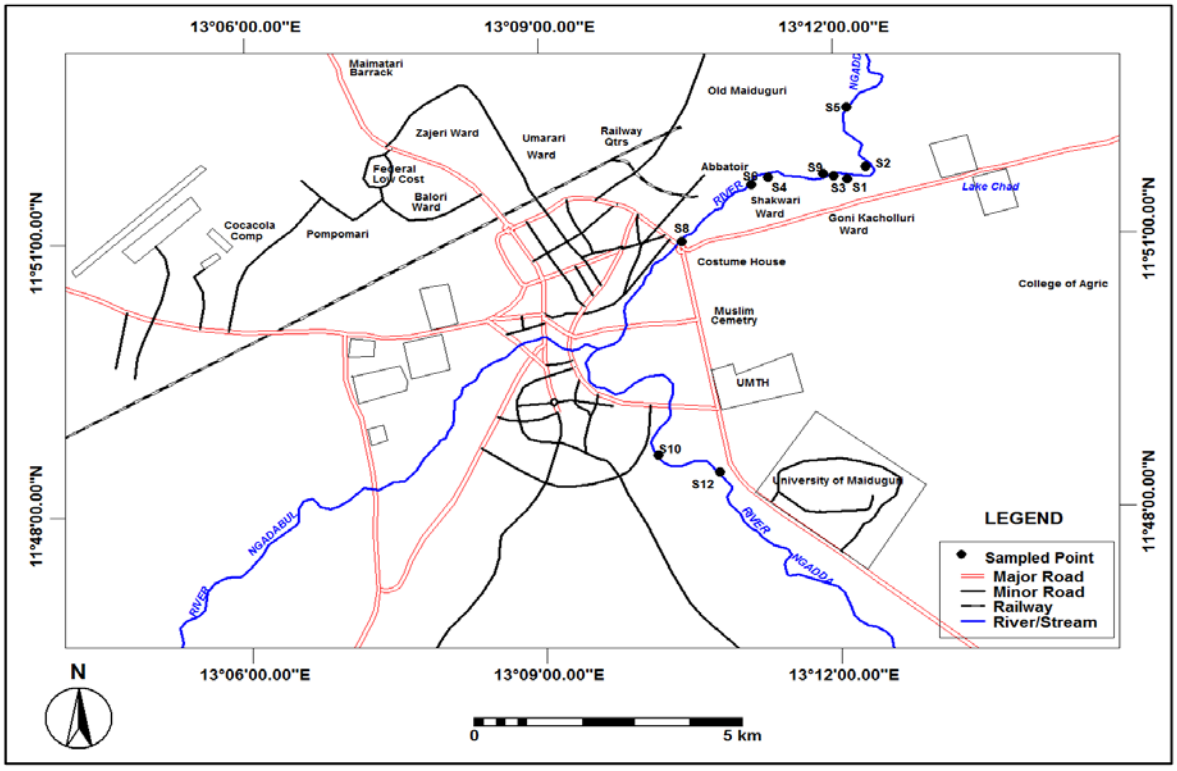

Fig. 1b : Maiduguri Township Map Showing the Sampling Points on River Ngadda

Result

The data obtained was subjected to cluster analysis procedure using Ward's method so as to obtain the distribution of the various elements determined in the various site according to their similarity.. The Ward's method of clustering commence with the number of cluster equal to the number of samples and fuses together until only one cluster remains. The criteria for linking clusters are minimization of the error sum of squares (Oladipo, 1992) given as

$$SS = \sum_{clusters(A)} \sum [L_{ij} - L_{ij(s)}]^2 \text{ samples(i) elements(j)} \quad (4)$$

where Lij(A) = mean value of j for cluster say (A) to which i is assigned. WARD's method calculates the increase in SS with both joining samples to clusters and merging clusters. The cluster analysis was carried to show the similarity in the distribution of the various sites in terms of the content of the samples from each site which was the elements. The resulting hierarchical treatment is displayed in form of a dendrogram as shown in Figure 2.

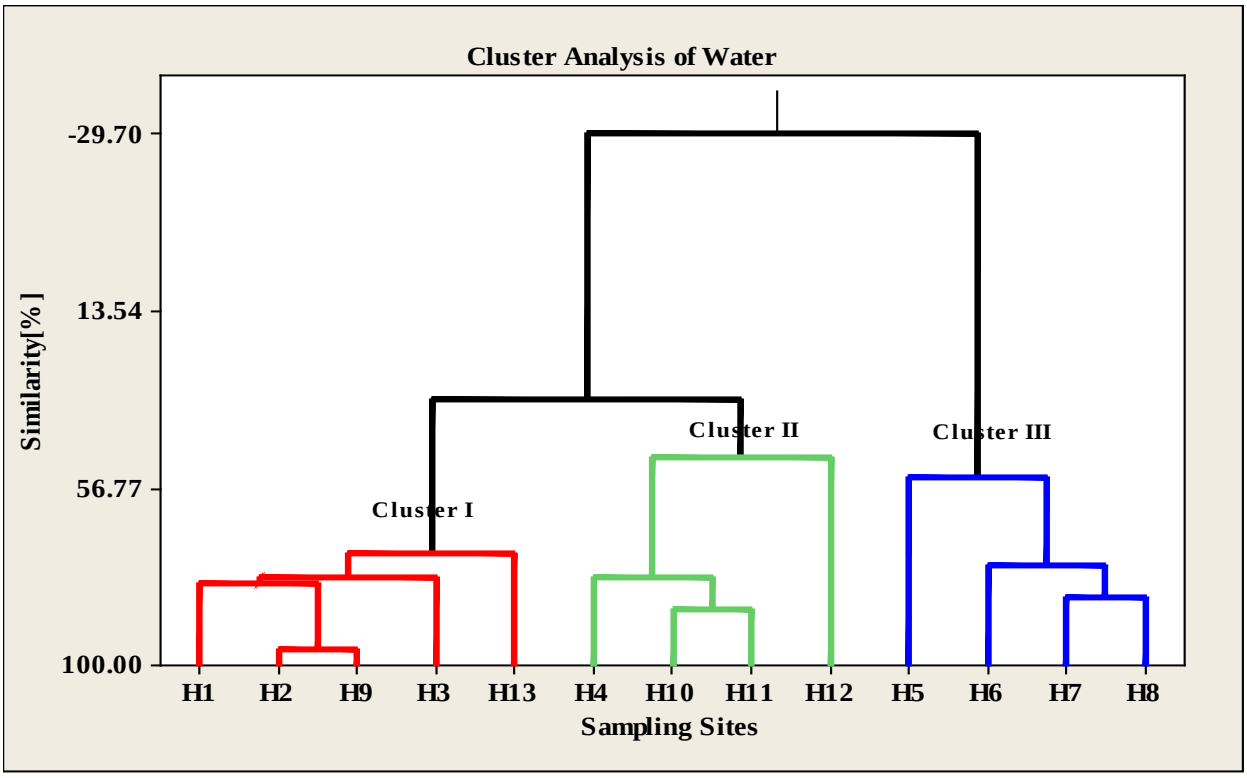

Figure 2: Dendrogram for Cluster Analysis of water Samples Data.

Figure 2 showed the dendrogram for cluster analysis of water samples data. It clearly shows that the sampled sites have been divided into three major groups and for convenience; the groups have been labeled as cluster I, II and III. The clusters produced represent the similarity in sources and or content of the variables in the samples that were grouped together as clusters. The first cluster constitutes sites H1, H2, H3, H9 and H13 which suggests that the content of the samples from these sites i.e the elements in the samples have common or similar sources and it can be

observed from the dendrogram that the similarity was about 96.2%, the second cluster consists of sites H4, H10, H11 and H12, with similarity at about 78.6% in their sources and content while the third cluster constitutes sites H5, H6, H7 and H8.with similarity at about 78.5%.

To obtain the structure of the dendrogram, normalised concentration values of the elements were plotted as shown in figure 3.

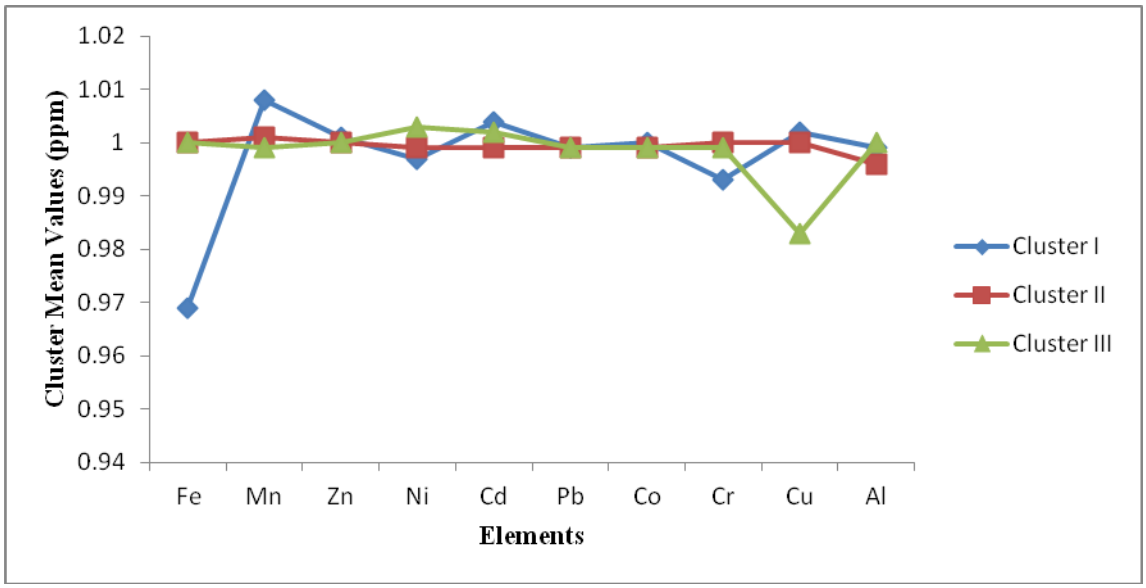

Fig 3: Normalized Concentration Profile Obtained from the Cluster Analysis of the Water Samples.

Figure 3 displayed the structure of the water dendrogram. The deviating elements in cluster I were Fe, Mn, and Cd, for cluster III was Cu. This deviation of the different elements i.e the content of the samples from either cluster I or cluster III were due to increase or decrease in the content of the samples from the mean values in the various sites i.e. high concentrations for values above the normalized value or low concentrations for values below the normalized value. The increase or decrease in values of these elements in the water could be due to different factors such as natural or human activities which enhance or reduce deposition/accumulation of element at a particular site; for example wind storms which transport some of these elements in particulate form from one point to the other since the study area is closed to desert area, effect of erosion from rain water during rainy season, storms from the municipal, farming activities such as continuous application of chemical fertilizers that contain some of these elements which may be roded into the river landfill processes with solid waste from the Metropolis for land reclamation which contained metal pollutants.

The concentrations of some of the elements determined in this research work was compared with the standard guideline for safe limit of heavy metals in water given by Food and Agricultural Organization (FOA) as indicated in Figure 4a – 4f.

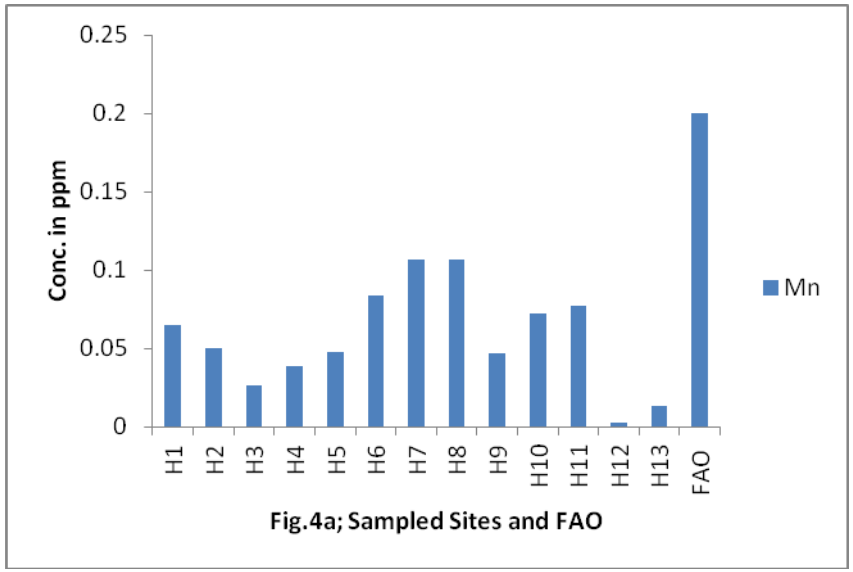

Fig.4a; Sampled Sites and FAO

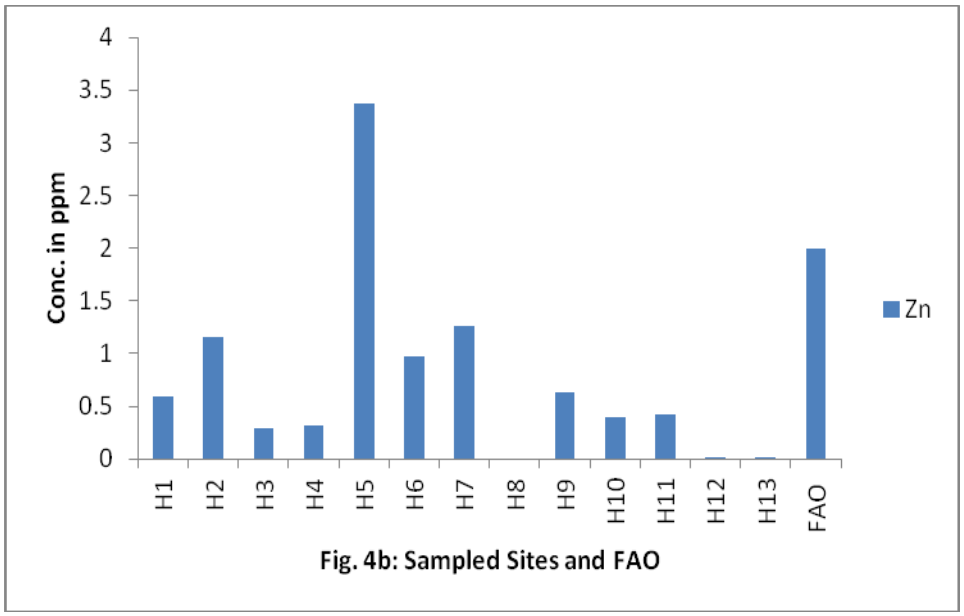

Fig. 4b: Sampled Sites and FAO

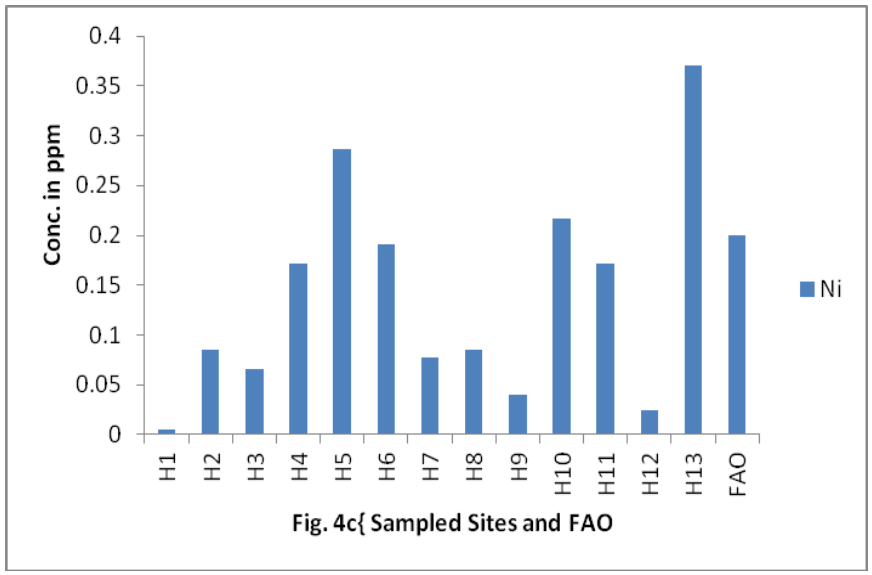

Fig. 4c{ Sampled Sites and FAO

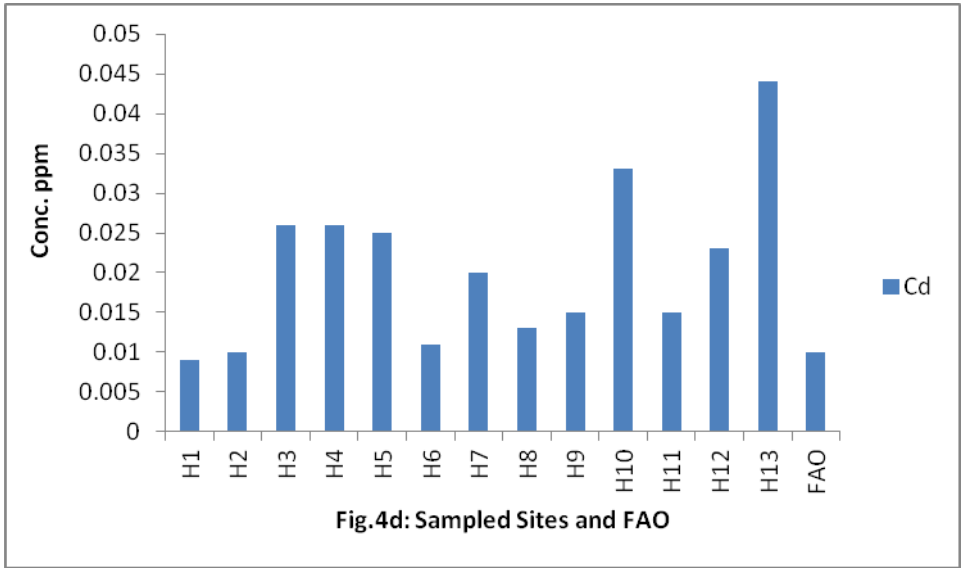

Fig.4d: Sampled Sites and FAO

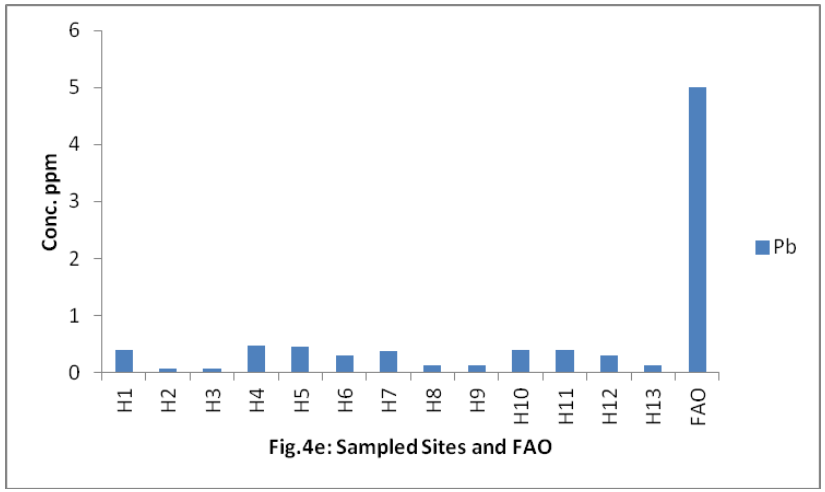

Fig.4e: Sampled Sites and FAO

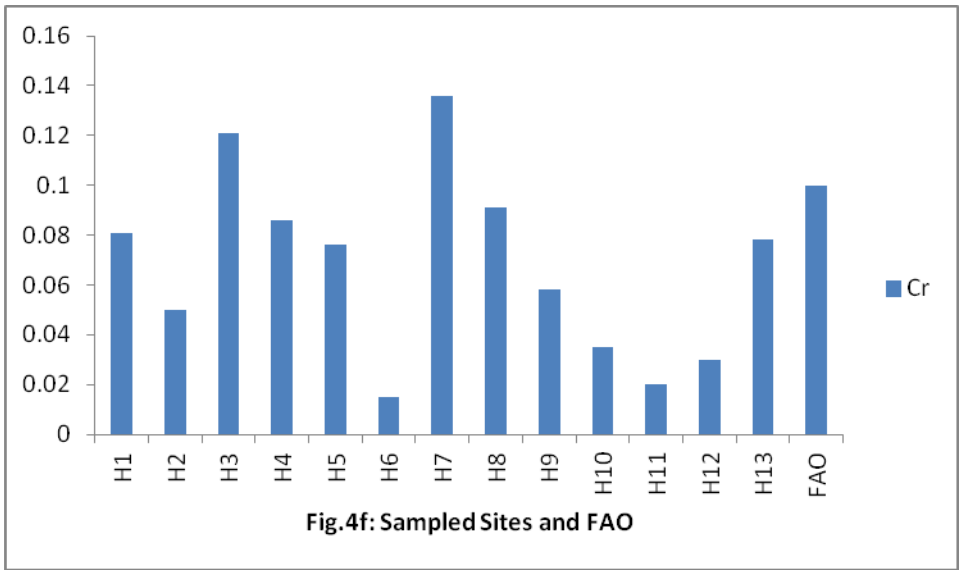

Fig.4f: Sampled Sites and FAO

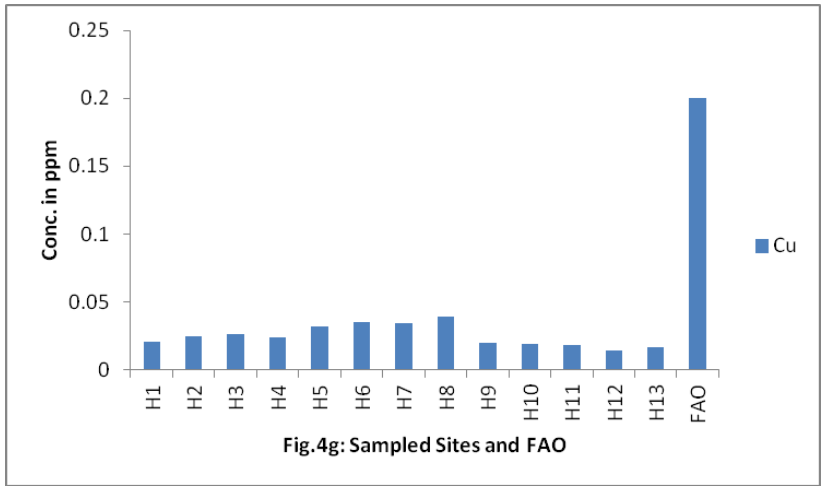

Fig.4g: Sampled Sites and FAO

Discussion

. The result of the cluster analysis of the water samples data divide the study area into three clusters, cluster I, cluster II and cluster III to form a dendrogram as shown in Figure 2..The dendrogram indicates the similarity in the distribution of the various elements in the samples obtained from the various points in River Ngadda and Alau Dam in terms of the concentration of the elements in the water and/or the origin of the sources of the elements. Cluster I showed a similarity of 96.2% for the content of the samples obtained at the point while cluster II showed a similarity of 78.6% for the content of the samples in the sites and cluster III showed a similarity of 75.5%. It can also be observed from Figure 2 showed that, the first cluster consist of sampled sites H1, H2, H3, H9 and H13 which constitute sampled sites from both Alau Dam area (H9 and H13) and sampled sites from Gongulon area (H1, H2 and H3). The second cluster consist of sampled sites H4, H10 and H11 with those sites around Alau Dam area constituting sampled sites H10 and H11 while the sampled site around Gongulon area consist of site H4. The third cluster consist of sampled sites H5, H6, H7 and H8.with all these sites predominantly around custom area. This clustering of the water collection point from the same area appearing in different clusters could be attributed to the fact that the metal pollutants sources were heterogeneous implying that they are from more than one source which may include sources from town storm, erosion from surface soil along roadside, windstorm that transport particulate element from one place to another and application of chemical fertilizer which may introduce some elements into the soil.

It can be clearly seen from Figure 4(a – g) that the concentrations of manganese, lead and copper stated by FAO guideline for safe limit of water for agricultural irrigation were higher than the concentrations determined at all the sampled points. The concentration of Zinc determined at most of the sampled points were less than the FAO value except at points H5 which was a point by the Shukwari ward an area after the Custom bridge downward. Concentration of Nickel exceed FAO value at points H5, H10 and H13 which points by Shukwari ward, by new G.R.A. around Lagos bridge, by Alau dam main water body respectively. The concentration of Cadmium determined in this study exceeded FAO value at all the sampled points except at point H1which was Gongulon farming area. The concentrations of Chromium determined in this study were less than the FAO value at most of the sampled points except at points H3 and H7, which were points behind Maiduguri College of Agriculture and adjacent Gomburu Market near Custom bridge respectively. It is therefore required that for safe agricultural practice, thee usage of the water of river Ngadda and Alau Dam for irrigation purposes need to be investigated periodically so as to know the level metal pollutants concentration in the water and be aware whether it is safe and guide for agricultural purposes so as to avoid health implications that can be posed to man due to consumption of crops cultivated with such water.

Conclusion

From the results presented, it can be observed that the concentrations of some of the toxic metal pollutants determined in this research were above the guide for safe limit of heavy metals in water used for irrigation given by FAO. Therefore, since the water were used for cultivation of agricultural food crops it is expedient that such investigation be carried out periodically so as to ascertain the levels of this metal toxicants and the suitability of the water for agricultural purposes since the plants may absorb the element and it will accumulate above threshold level.

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