POLLUTION LOAD INDEX (PLI), A YARDSTICK FOR ASSESSING THE QUALITY OF WATER IN SHIKA DAM

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Abstract: Eleven sampling sites along Shika Dam, Sabongari LGA, Kaduna State, Nigeria were chosen to collect and assess the levels of As, Cr, Ni, Pb, Co and Cd in the dam water using pollution load index (PLI). Results of the Metal analysis revealed that Cd and As present in the water were above the permissible limits of WHO and FAO, respectively. This clearly showed that the water is highly polluted with respect to these metals. However, the levels of Cr, Pb, and Ni detected in the samples were below the WHO permissible limits of 0.1, 0.05, and 0.05 mg/L, respectively. The Cr, Pb and Ni detected permissible limits across the Dam. The physico-chemical parameters that were analyzed include: DO, BOD, COD, Turbidity, TSS, Colour, EC, pH, NO_3^-–N, PO_4^{3-}–P, and NH_3–N. ANOVA showed that there was a significant difference in the concentrations of the Cd and Ni across the sampling points at 95% confidence limit ($P \leq 0.05$) while Pb, Cr, and As showed no significant difference in the concentrations across the sampling points.Pollution Load Index (PLI) was used as a tool to investigate the level of pollution in the quality of water in the Dam. The PLI recorded revealed and confirmed that Shika Dam water is highly polluted with As and Cd metals as the level recorded were > 1, a clear indication that the water is highly polluted. The trend in the PLI levels were H (7.287) < F (7.310) < D (7.678) < I (8.430) < C (8.821) < K (9.531) < A (10.0770) < G (10.487)< B (12.540) < J (14.728). Also, results of the PLI's indicates that point H is the least polluted while point J is the most polluted of all the sampling points analyzed which was attributed to anthropogenic activities like the use of pesticides and fertilizers containing Cd and As on the farmlands close to the study area.

Keywords: Pollution load index, heavy metals, Dam, Shika, Nigeria

Introduction

Dams are structural barriers built to obstruct or control the flow of water or other materials in river and streams (Nicklow, 2003). They are mainly built for irrigation, power generation, river navigation enhancement, flood control, hydraulic head increase, water supply and water storage to compensate for fluctuations in river discharge (flow) or in demand for water and energy with over 58,000 to 850,000 built all over the world and more than half located in China and India. Some of its parts include the Crest (top), Abutment (the part of the valley that meets the dam), Berm (a nearly horizontal step in the sloping profile of an embankment), Outlet (an opening where water can be released), spillway (a structure that allows water to be released from a reservoir) (Latifah and Met, 2014; Nicklow, 2003).

The existence of heavy metals in water in excess of natural background loads have become extremely hazardous due to their toxicity, persistence and bioaccumulation problems as well as their tendencies to accumulate in vital human organs (Defew *et al.,* 2004; Tam and Wong, 2000). The concentrations of these heavy metals are likely to result in harmful effects of sediment-dwelling organisms. Studies have shown that heavy metals are present at low concentrations in aquatic environment but deposits of anthropogenic activities have raised their concentrations causing environmental problems in lakes (Ntakirutimana *et al*., 2013). However, the widespread contamination of natural waters and sediments by heavy metals such as Arsenic, Mercury, Lead, Chromium, Nickel, Cadmium etc which have hazardous effect on human health are associated with the increased release of this heavy metals from not just anthropogenic sources but also geological sources (Basim and Kushnood, 2016; Nicholson *et al*., 2003). Heavy metals discharge into water systems may be immobilized within the stream sediments by adsorption, flocculation, and co-precipitation (Pekey, 2006; Marchand *et al.*, 2006).

Pollution load index which is an example of the root of product pollution index is calculated as the chemical product concentrations that are measured in water bodies and is used as an index of bioavailability of pollutants for mussels in coaster waters. It represent the number of times by which the metal contents in the sediment exceeds the background concentration and gives a conclusive indication for the overall levels of heavy metals toxicity in a particular sample (Priju and Narayana, 2006). It is also proposed as a standardized system for detecting pollution which permits a comparison of pollution level between different sampling points at exceedingly different times (Angulo, 1996; Barakat *et al.*, 2012). Examples of single indices used include geo-accumulation index (Igeo), while contamination factor (CF) is used to determine the concentration and cause of the contaminants, and enrichment factor is used to check the amount of nutrients in the soil and to determine the anthropogenic impacts of the metal or metals in the water, soil or sediments (Yujun *et al*., 2011).

This paper is aimed at assessing the pollution load index of water in Shika Dam so as to assist the law enforcement agencies such as Kaduna state environmental protection agency with a background data for improving its quality through constant monitoring.

Materials and Methods

Experimental

Sampling

Sample collection: The samples were collected according to the method describe by APHA, (2005).

Sample pretreatment: The samples were pre treated according to the method described by APHA, 2005.

Sample preservation: The samples were preserved according to the method described by APHA, 2005.

Method

Quality assurance

The analytical data quality was guaranteed through the implementation of laboratory quality assurance and quality control methods, including the use of standard operating procedures, calibrating the standards, analyzing of reagent blanks and analysis of replicates. All reagents used were of analytical grades and double distilled de-ionized water was used to carry out the analysis (Todorov *et al.*, 2008).

a) Washing of the glassware: Glassware's and polythene sample bottles were washed with liquid soap, rinsed with water and soaked in 10% HNO_3 for 24 h. They are then rinsed with double distilled de-ionized water and dried. The analytical results obtained were validated with the spiked samples. The analytical precisions were confirmed by the triplicates digestion throughout the study (Todorov *et al.*, 2008).

Determination of the physicochemical parameters of the water

All the physicochemical parameters were determined using APHA, 2005, standard analytical methods.

Water sample digestion for metal analysis

25ml of each sample were taken and mixed with 5ml of a mixture of concentrated H_2SO_4 concentrated HNO_3 (1:1), the solution was boiled on a hot-plate at 120^0C until dense white fume of SO_3 appears. Aliquots of 5ml of concentrated HNO_3 were added and heating was continued until the solution becomes clear and no brown fumes were observed. The solution was heated to dryness and 15 ml of 0.5% v/v were added and boiled to dissolve salts. After cooling, the solution was transferred into 50 ml volumetric flask and the volume was made up to the mark with 0.5% v/v HNO_3 (APHA, 1998).

Sample analysis

The digested samples were analyzed forCd, Pb, Hg, As, Cr, and Ni contents in both the water and sediments sample using the Atomic Absorption Spectrophotometer (AAS) in the Multi-user laboratory of Chemistry Department, Ahmadu Bello University (ABU), Zaria.

Statistical treatment of the water and sediment data

The data obtained for the water samples were subjected to statistical analysis using Microsoft excel spreadsheet and SPSS-package for ANOVA correlations analysis.

Determination of pollution load index (PLI)

Generally pollution load index (PLI) as developed by Tomlinson (1985) was adopted.

Results and Discussion

Physicochemical parameters of water samples

The results of the investigation have been summarized in Tables 1 – 4. The mean values and standard deviations of physicochemical parameters analyzed in the water of Shika Dam was presented in Table 1 while the results for heavy metals, ANOVA and Pollution Load Index were presented in Tables 2, 3, and 4, respectively.

Table 1: Physico-chemical parameters of water in Shika Dam

Sample	DO (m/L)	BOD (mg/L)	TSS	pH	EC (µS/cm)	Turbidity (NTU)	COL (unit)	NO_3 (mg/L)	PO_4 (mg/L)	NH_3 (mg/L)	COD (mg/L)
A	2.10±0.00	1.15±0.07	0.10±0.00	4.89±0.01	95.05±0.07	56.80±0.00	8.00±0.00	30.00±0.00	8.00±0.00	0.12±0.00	120.00±0.00
B	3.25±0.07	2.05±0.07	0.20±0.00	5.06±0.00	125.75±0.35	60.10±0.00	8.00±0.00	30.00±0.00	7.00±0.00	0.12±0.00	100.00±0.00
C	3.25±0.07	2.15±0.07	0.10±0.00	5.33±0.01	106.30±0.00	59.25±0.07	8.00±0.00	32.00±2.83	7.00±0.00	0.12±0.00	49.75±0.35
D	2.50±0.00	1.45±0.07	0.15±0.07	4.99±0.01	96.05±0.64	60.50±0.00	8.00±0.00	31.00±1.41	7.00±0.00	0.12±0.00	122.50±3.54
E	2.10±0.00	1.10±0.00	0.10±0.00	5.64±0.01	221.50±0.71	61.40±0.14	8.00±0.00	40.00±0.00	6.50±0.71	0.12±0.00	210.00±0.00
F	1.75±0.07	0.90±0.00	0.10±0.00	5.05±0.07	100.45±0.07	77.25±0.07	8.00±0.00	40.00±0.00	7.00±0.00	0.12±0.00	110.00±0.00
G	0.65±0.07	0.25±0.07	0.10±0.00	4.06±0.01	94.15±0.07	74.25±0.07	8.00±0.00	40.00±0.00	8.00±0.00	0.12±0.00	190.00±0.00
H	2.40±0.00	1.25±0.07	0.20±0.00	5.06±0.01	106.40±0.71	65.75±0.07	8.00±0.00	40.00±0.00	8.50±0.71	0.12±0.00	215.00±7.07
I	1.05±0.07	0.75±0.07	0.10±0.00	4.85±0.01	91.80±0.00	61.50±0.42	8.00±0.00	30.10±0.14	7.00±0.00	0.12±0.00	150.00±0.00
J	2.05±0.07	0.95±0.07	0.20±0.00	5.07±0.00	131.25±0.07	60.40±0.00	8.00±0.00	30.00±0.00	7.00±0.00	0.12±0.00	49.65±0.49
K	1.60±0.00	0.6±0.00	0.10±0.00	5.19±0.01	113.75±0.07	56.50±0.00	8.00±0.00	30.50±0.71	7.00±0.00	0.12±0.00	70.50±0.71
WHO	**13 – 14**	**6**		**6.5 – 9.2**	**200**	**25**	**5**	**45**	**5**	**0.3**	**10**

The trend of DO (mg/L) value across the sampling points was in the order of G < F < I < K < J < E < A < H < D < B < C across the sampling points, which was in line with the work of Ogeibu *et al.* (2014). The results also showed that the levels of dissolved oxygen across all the sampling points analyzed were below the WHO/FAO standard of 13-14 mg/L. In this study, the lower values of Dissolved oxygen in all the sampling sites indicate the presence of micro-organisms that compete with the aquatic organisms for the available oxygen in the water. Bacteria's decomposes organic materials using dissolved oxygen, thus reducing the DO present for fish. Dissolved oxygen concentrations below 3 mg/L stress most warm water species of fish and concentrations below 2 mg/L will kill some species. Often fishes that have been stressed by dissolved oxygen concentrations in the range of 2 or 3 mg/L will become susceptible to disease.

The trend of BOD (mg/L) across the sampling points was in the order G < K < I < F < J < E < A < H < D < B < C sampling points respectively which corroborates with analysis of Ogeibu *et al.* (2014). These results showed that the BOD value of all the samples sites are way below the WHO standard of 6 mg/L. The low values of Biochemical oxygen demand (BOD) in all the sampling points suggest that the bacteria present in the water consumed the available oxygen while decomposing organic matter under aerobic conditions. This accelerates bacterial growth and diminishes oxygen to levels that are lethal for most fish and many aquatic insects.

Similarly, the trend observed for the Turbidity (NTU) across the sampling points was in the order of K < A < C < D < B < J < E < I < H < G < F while that of TSS values was 0.1 NTU for points A = C = E = F = G = I = K < B < H < J < D. In all the sampling points the water of Shika Dam was found to be highly turbid and full of suspensions which agrees with the findings of Narayanaswamy and Ramachandra (2014) on the Seasonal influence on physicochemical parameters of Yelahanka lake water of Bangalore. The turbidity value in all the sampling points was above the WHO permissible limit of 25 NTU. This clearly indicates that the water in Shika dam was turbid. The higher value of turbidity and TSS showed the presence of anthropogenic contributions especially the improper discharge of wastes from various human activities and the industrial oil sub-sector in the study area. This high level of Turbidity and TSS in the water of Shika Dam thus stresses fish species at prolonged exposures of 25 NTUs or greater. High Turbidity and or TSS reduce light penetration, decreasing algal growth, and low algal productivity which reduces the productivity of aquatic invertebrates that serves as food source of many fish. High turbidity levels affect fish feeding and growth and impair the ability of salmonids to find and capture food. Gill function in some fish may also be impaired after 5 to 10 days of exposure to a turbidity level above 25 NTU.

The trend of pH across the sampling point was in the order of G < I < A < D < F < B < H < K < J < C < E, respectively across the 11 sampling points. The pH of the Shika dam water is similar to the observation of Davies and Tawari for Okpoka Creek, upper Bonny Estuary in Nigeria (Davies and Tawari, 2010). The result of this study showed that the water is below the WHO standard of 6.5-9.2 mg/L, which indicates that the water is acidic. Also, the lower value of pH in Shika Dam may be due to the leaching of heavy metals from plumbing systems around the Dam. This could also lead to an unpleasant aspect of foul-tasting water. Acidic drinking water generally has few negative health effects and can cause serious problems like lead exposure that causes neurological and reproductive problems, such as seizures, hearing loss and miscarriages.

Electrical conductivity (200 µs/cm) value along the dam was in the order of I < G < A < D < C < F < H < K < B < J < E, respectively across the sampling sites. This is in agreement with Klake *et al.,* (2016). The EC in all the sampling sites are low except in sample E where the result is high when compared to the WHO standard of 200 µs/cm. The low electrical conductivity in the water of Shika dam causes aesthetic problems and makes the water taste salty. However, this shows that the kind of water in Shika dam is not suitable for children under the age of 1 and patients on salt-restricted diets such as heart and kidney patients and individuals with chronic diarrhea.

However, the colour of the water was also found to be the same across the dam with value being 8 units. This value is above the WHO permissible limit of 5 unit, which is an indication that the colour of the water is aesthetically displeasing and not pleasant for the survival for aquatic organisms growth and survival (Iwegbue *et al.,* 2007).

The Nitrate (mg/L) values along the dam were all in the range of 30 and 40 mg/L and the trend recorded was in the order of I < K < D < C < A = B = J < E < F < G < H, respectively. The results presented in the table showed that the levels of nitrate in the water of the dam was slightly below the WHO permissible limits of 45 mg/L. Nitrate level in water is an important factor for controlling the occurrence and abundance of phytoplankton maximum values. Varol, (2011) revealed that dam water derived nitrate from allchitinous impact through influx of rain water from catchment area. The lower concentration of nitrate is an indicator of low organic pollutant and eutrophication.

The phosphate (mg/L) levels across the sampling points indicate that they were higher than the WHO permissible limits of 5 mg/L. This corroborates with the work of Priju and Narayana (2006) and indicates that the soil around the sampling points is fertile and that weathering of phosphorus bearing rocks and leaching of the soils in the farmlands is the main sources of phosphorus in the water. Priju and Narayana (2006) also established high level of phosphate as a nutrient element which enhances the growth of microscopic algae which is responsible for the maintenance of dams and lagoons productivity which has been linked to agricultural land use around riverine areas and runoff during the rainy season (Erhunmwunse, 2013).

The Ammonia levels across the sampling points analyzed was found to be uniform with the value of 0.12 mg/L. This value was found to be below the WHO standard of 0.3 mg/L. Ammonia-nitrogen is one of several forms of nitrogen that exist in aquatic environments. Unlike other forms of nitrogen, which can cause nutrient over-enrichment of a water body at elevated concentrations and indirect effects on aquatic life, ammonia causes direct toxic effects on aquatic life (Iwegbue *et al.,* 2007).

When ammonia is present in water at high levels, it is difficult for aquatic organisms to sufficiently excrete the toxicant, leading to toxic build-up in internal tissues and blood, and potentially death. The low level of ammonia is associated with low municipal treatment discharges, and the less stress effects of ammonia on aquatic organisms (Ihenyen, 2001).

The COD (mg/L) value along the 11 sampling sites was in the order of C < J < K < B < F < A < D < I < G < D < H, respectively. The concentrations recorded were extremely high as compared to the WHO standard of 10 and goes in line with analysis of Sekabira *et al.* (2013). The high level of COD across the dam showed that the total quantity of oxygen required to oxidize all the organic material into carbon dioxide and water is extremely high. This affects aquatic life and makes them prone to diseases.

Heavy metal contents

The concentrations of Cd across the sampling points was in the order of H < I < F < E < A < K < G < C < J < B respectively. The concentrations of Cd in all the sampling points were far higher than the WHO tolerable limit of 0.005 mg/L. These levels of Cd recorded did not compare favourably with the mean values obtained by Ihenyen (2001). Cd replaces Zn in the body, and long-term consumption of Cd may lead to bodily disorders. Cd is toxic to both humans and fish and seems to be a cumulative toxicant.

The concentrations of Ni recorded across the sampling points followed the following trend A < B. As for most metals, the toxicity of Ni is based on its solubility and routes of exposure (inhalation, oral and dermal) of the nickel compound (Das *et al.,* 2008). However, points A and B were found to be below the WHO standard of 0.05 mg/L for Ni. The mean concentration of Ni showed similar spatial pattern like others with the highest and lowest values encountered in points A and B, respectively and the range obtained in this study was much lower than the values of Ogbeibu, (2011) in the water at Benin River**.** This result implies that there is mild Ni exposure in points A and B which can cause cancer to humans, skin allergy, immunotoxicity effects, delayed hypersensitivity haematotoxic effect, neurotoxic effect, genotoxic effect, etc. due to bio-accumulation (Das and Dasgupta, 2002).

The trend of As recorded across the sampling points was B < F < E < C < D < G < H < I < A < K < J, respectively. These results agreed with the work of Goher, (2002) who reported that the deposition of As enhanced by the association of metals with clay minerals or by the adsorption of the oxides of other metals on the water. However, in all the sampling points analyzed, the level of As was found to be higher than the WHO permissible limit of 0.01 mg/L. The health implication of this is that As is present in a dangerous concentration and could lead to cancer of the lungs and skin, limb paralysis, muscular weaknesses when this water is consumed. The major source for the metal contamination in Shika Dam might be due to the industrial effluents near this dam, as well as the transport of small fraction of sediment downstream due to the river velocity that contributes to the accumulation of heavy metals in lower parts (Hassouna, 1996).

Co concentration in the water of Shika dam was found to be below detection limit in all the 11 sampling points (A - K) which shows that the water is free of Co. The WHO permissible limit of Co is 0.7 mg/L. This is in contrast with the work of Clyne *et al.* (2001) where the concentration of Co is pronounced. This implies that the water in Shika dam is free of natural and anthropogenic like include phosphate fertilizer application, mining and smelting of cobalt ores, processing of cobalt alloys, cobalt compounds used by industries close the study area. Inhalations of cobalt particles results in deposition in the upper and lower respiratory tract, where they can be retained or absorbed into the blood after dissolution or mechanically transferred to the gastrointestinal tract of humans to cause harm (Andre *et al*., 1989). However, Cobalt dust may cause an asthma-like disease with symptoms ranging from cough, shortness of breath and dyspnea to decreased pulmonary function, nodular fibrosis, permanent disability, and death. Exposure to cobalt may cause weight loss, dermatitis, and respiratory hypersensitivity.

The trend of Pb recorded was in order of C < F < I < A < K < J < B, respectively; although Pb values in points C, D, F and G were below detection limit. However, in all the analyzed samples, the concentration of Pb in sample B tends to be higher than the WHO permissible limit of 0.05 mg/L while points C,F, I, A, K, J and B were below the WHO standard limit. The concentrations recorded was lower than those recorded by Ogbeibu (2011) and Olomukoro and Azubuike (2009) in the water and sediments of Benin River and Ekpan creek, respectively. The high concentration of Pb recorded in sample B might be attributed to the nature of anthropogenic activities associated with pesticides containing lead compounds used by the farmers in Shika community. This also suggests that point B is closer to areas where anthropogenic activities like runoff from cities, discharge of improperly treated waste effluents, sewage sludge, etc. (Radojevic and Bashkin, 1999). Lead can cause a variety of neurological disorders. In children, it inhibits brain cell development. Lead also prevents the uptake of iron, so people ingesting lead often exhibit symptoms of anemia including pale skin, fatigue, irritability, and mile headaches. Copper is also toxic to juvenile fish. Other toxicants that are associated with industrial effluent are mercury and silver. However, when fish are exposed to either of these at certain concentrations, gill tissues are damaged and death by asphyxiation can occur.

The Cr value in the 11 sampling points analyzed (A-K) was in the trend of C < D = E = F = H = I = K < G < A < J < B. The levels of Cr recorded across in the sampling points were far below the WHO/FAO permissible limits of 0.1 mg/L, a clear indication that Cr concentration in the water is low which means that anthropogenic activities around the farmland contains low concentration of Cr (Jacobs and Tests, 2005). Hexavalent chromium [Cr(VI)] is a toxic industrial pollutant that is classified as human carcinogen by several regulatory and non-regulatory agencies However, the values recorded in this investigation were lower when compared to the mean values obtained by Turnland (1988) for the water of San creek. Chromium reaches water bodies primarily from the discharge of industrial wastes and disposal of products containing the metal (Ihenyen, 2001).

Table 2: Metal concentration (mg/L) of water in Shika Dam

Sample	Cd	Ni	As	Co	Pb	Cr
A	0.628±0.792	0.008±0.011	5.027±0.063	BDL	0.019±0.013	0.008±0.002
B	1.474±0.307	0.002±0.003	1.689±0.622	BDL	0.061±0.011	0.020±0.004
C	1.051±0.900	BDL	3.333±0.566	BDL	0.001±0.001	0.005±0.001
D	0.371±0.037	BDL	3.578±0.114	BDL	BDL	0.006±0.000
E	0.591±0.338	BDL	3.086±0.521	BDL	BDL	0.006±0.000
F	0.521±0.115	BDL	3.071±0.212	BDL	0.004±0.006	0.006±0.000
G	0.990±0.563	BDL	4.102±0.144	BDL	BDL	0.007±0.001
H	0.402±0.033	BDL	4.148±0.055	BDL	BDL	0.006±0.000
I	0.570±0.224	BDL	4.527.0.182	BDL	0.018±0.022	0.006±0.001
J	1.022±0.044	BDL	5.211±0.197	BDL	0.048±0.002	0.015±0.000
K	0.737±0.043	BDL	5.151±0.122	BDL	0.026±0.004	0.006±0.000
WHO	0.005	0.05	0.01	0.7	0.05	0.1

Pollution load index of the water samples

The trend of the pollution load index across the sampling points was in the order of H < F < D < I < C < K < A < G < B < J which indicates that the most polluted site was point J and the least polluted site was point H. in consistent with Ogbeibu *et al.* (2014). The evaluation also revealed that the water of the study stretch of Shika Dam was highly polluted as the values of PLI in the water were above the WHO guidelines for water across the sampling points. The PLI in this study were in contrast with the findings of Rabee *et al.* (2011) in a similar study where the PLI were found to be very low, and varied between 0.301-0.970, an indication that the studied stations in Tigris River were unpolluted. The implication of the findings in this work is that the fishes and all other aquatic organisms dwelling in the water would be polluted and prone to disease. It also implies that humans are also at a high risk of these contaminations when they consume these organisms through the food chain (Prater, 1975).

These results also correspond with a recent report published by Abdullah *et al.* (2015) that shows that the pollution load index of samples of surface river sediments of Balok river in Pahang Malaysia have values ranging from 2.4 to 3.7 which of course indicates that all the studied metal in all stations exceeded the background levels and as a result the water and sediment samples have been polluted by different anthropogenic sources. The high pollution of the dam might be attributed to the influence of Agricultural run-offs, industrial activities and other anthropogenic inputs. This largely indicates that the analyzed samples were all contaminated with Cd and As which might lead to serious health problems to consumers of the water and fish species such as cancer and other neurological disorders.

ANOVA

The results obtained for the analysis of variance (ANOVA) showed that there is no significant difference in the concentrations of Cd and Ni at 95% Confidence level ($P \leq 0.05$) as P recorded for Cd was 0.369 and 0.536 for Ni. However, while there was significant difference in the concentrations of Pb, Cr, and As as P = 0, for Pb, Cr, As across the sampling points, there is no correlation in the concentration of Co across the sampling points.

Table 3: ANOVA of water in Shika Dam

Parameter		Sum of Squires	Df	Mean Square	F	Sig.
Cd	Between Groups	2.270	10	0.227	1.228	0.369
	Within Groups	2.033	11	0.185		
	Total	**4.302**	**21**			
Ni	Between Groups	0.000	10	0.000	0.953	0.526
	Within Groups	0.000	11	0.000		
	Total	**0.000**	**21**			
As	Between Groups	23.428	10	2.343	22.381	0.000
	Within Groups	1.151	11	0.105		
	Total	**24.579**	**21**			
Co	Between Groups	0.000	10	0.000	.	.
	Within Groups	0.000	11	0.000		
	Total	**0.000**	**21**			
Pb	Between Groups	0.009	10	0.001	11.498	0.000
	Within Groups	0.001	11	0.000		
	Total	**0.010**	**21**			
Cr	Between Groups	0.000	10	0.000	23.656	0.000
	Within Groups	0.000	11	0.000		
	Total	**0.000**	**21**			

Results are significant at $P \leq 0.05$

Table 4: Contamination factor (CF) and pollution load index of water in Shika Dam

Sample	CFCd	CFNi	CFAs	DFPb	CFCr	PLI
A	62.830	0.162	100.544	0.187	0.162	10.077
B	147.440	0.038	33.778	0.605	0.396	12.540
C	105.080	0.000	66.658	0.008	0.098	8.821
D	37.130	0.000	71.562	0.000	0.124	7.322
E	59.130	0.000	61.726	0.000	0.124	7.678
F	52.120	0.000	61.426	0.000	0.122	7.310
G	98.990	0.000	82.044	0.000	0.142	10.487
H	40.210	0.000	82.956	0.000	0.116	7.287
I	57.040	0.000	90.548	0.000	0.116	8.430
J	102.190	0.000	104.218	0.481	0.300	14.728
K	73.720	0.000	103.026	0.258	0.114	9.531

PLI < 1 indicates a polluted site

Pollution load index

The trend of the pollution load index across the sampling points was in the order of H < F < D < I < C < K < A < G < B < J which indicates that the most polluted site was point J and the least polluted site was point H. in consistent with Ogbeibu *et al.* (2014). The evaluation also revealed that the water of the study stretch of Shika Dam was highly polluted as the values of PLI in the water were above the WHO guidelines for water across the sampling points. The PLI in this study were in contrast with the findings of Rabee *et al.* (2011) in a similar study where the PLI were found to be very low, and varied between 0.301-0.970, an indication that the studied stations in Tigris River were unpolluted. The implication of the findings in this work is that the fishes and all other aquatic organisms dwelling in the water would be polluted and prone to disease. It also implies that humans are also at a high risk of these contaminations when they consume these organisms through the food chain (Prater, 1975).

These results also correspond with a recent report published by Abdullah *et al.* (2015) that shows that the pollution load index of samples of surface river sediments of Balok river in Pahang Malaysia have values ranging from 2.4 to 3.7 which of course indicates that all the studied metal in all stations exceeded the background levels and as a result the water and sediment samples have been polluted by different anthropogenic sources. The high pollution of the dam might be attributed to the influence of Agricultural run-offs, industrial activities and other anthropogenic inputs. This largely indicates that the analyzed samples were all contaminated with Cd and As which might lead to serious health problems to consumers of the water and fish species such as cancer and other neurological disorders.

The distribution patterns of the heavy metals investigated in the water reflected a high significant difference ($P \leq 0.05$) for Cd and Ni. Overall, the correlation coefficient of the physicochemical parameters and heavy metals contents in the water samples of Shika dam were found to be in the range of -1 to +1, this clearly showed that the source of pollution of the dam was actually from different sources (both anthropogenic and natural). Pollution index revealed that the water polluted and consumers would be prone to various health problems such as typhoid fever, gastro-intestinal tract infection, cancer for using the raw water.

Conclusion

The results of this study supply valuable information about some heavy metal contents of water from eleven sampling points along Shika Dam, and it can be concluded that the distribution patterns of the heavy metals investigated in the Dam water reflected a perspicacious high significant difference ($P \leq 0.05$) for Cd and Ni, while Cr, Pb and As across the sampling points were without an exception. Overall, the correlation coefficient of the physicochemical parameters and heavy metals content in the water samples of Shika dam were found to be in the range of -1 to +1. This clearly showed that some of the analyzed parameters across the sampling points were strongly positive correlated while others were strongly negative correlated. Thus, the source of pollution of the dam is actually from different sources. According to the Pollution index for the studied metals and the information's gathered from the contamination factor and pollution load index, it can be concluded that, Shika dam water has a very high pollution across the sampling points, a clear indication of its high pollution and consumers would be prone to various health problems such as typhoid fever, gastro-intestinal tract infection, cancer etc due to bio-accumulation effects.

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Conflict of Interest

Authors declare that there is no conflict of interest.

References

Abdus-salam N, Bale RB, Taoridi R & Olushola O 2013. Studies of water and sediment Quality of Owalla Dam, Osun State, Nigeria. *Fountain J. Natural and Appl. Sci.,* 2(2): 3-9.

Abowei JFN & Sikoki FD 2005. Water pollution Management and control. *Double Trust Publication Company,* 2: 236.

Addis W & Abedaw A 2015. Analysis of selected physicochemical parameters of soils used for the cultivation of Garlic (*Aluminium sativum L*). *Sci., Techn. and Arts Res. J*., 3(4): 1-4.

Addo MA, Affun HA, Botwe BO, Gbadago JK, Coleman A, Adu PS & Mumuni LI 2012. Assessment of water quality and Heavy Metal levels in water and bottom sediment samples from Mokwe Lagoon, Accra, Ghana. *Res. J. Envt. and Earth Sci.*, 4(2): 119-130.

Aikpokpodion PE 2010. Assessment of heavy metal pollution in Fungicide treated cocoa plantations in Ondo State, Nigeria. *J. Appl. Biosci*., 33: 2037-2046.

Al-Lami AA & Al-Jaberi HH 2002. Heavy metals in water, suspended particles and sediment of the upper-mid region of Tigris River, Iraq. *Proc. Int. Symposium on Envtal. Poll. Control and Waste Mgt.,* 8: 7-10.

Angulo E 1996. The Tomllison Pollution Load Index applied to Heavy Metals. 'Mussel watch' Data: A useful Index to assess Coastal Pollution. *Science to the Total Environment.* 187, 19-56.

Anim AK., Duodu GO., Ahialey EK &Serfor-Armah Y 2011. Assessment of surface water quality : The perspective of the Weija Dam in Ghana. *International Journal of Chemistry.*3(2): 32-39.

Andre S, Metivier H, & Masse R 1989. An interspecies comparison of the lung clearance of inhaled monodisperse cobalt oxide particles — Part III: Lung clearance of inhaled cobalt oxide particles in baboons. *Journal of Aerosol Science*, 20(2): 205–217.

APHA 1998. Standard Methods for Chemical Examination of Wastewater. American Public Health Association. Washington DC, 20: 11-13.

Ashby S 2011. Impacts of hydrology and hydropower on water quality in reservoir tailwater in River Basin

Management. VCA Brebbia Ed. *WIT Press Wessex*, UK, pp. 11, 22-29.

Asibor G, Edjere O, Adeniyi F & Ogundele O 2015. Using EF, PLI, and IGEO for the assessment of heavy metal pollution and sediment quality of Asejire Reservoir, Southwest Nigeria. *Int. J. Envt. and Poll. Res.*, 3(4): 77-90.

ASTM International 2003. Animal Book of ASTM Standards. *Water and Environmental Technology,* West Conshohocken. *Pennysylvania*, 11(1): 6-7.

Ayanwale AV, Minnin MA & Olayemi KI 2013. Physico-chemical properties of selected fish ponds in Nigeria. Implication for artificial fish culture. *Webmed Central Biology,* 3(1): 37-51.

Banat KM, Howari FM & Al-Hamada AA 2005. Heavy metals in urban soils of central Jordan: Should we worry about their environmental risks? *Environmental Research,* 97: 258 – 273.

Barakat M, El Baghdadi RJ & Nadem S 2012. Assessment of heavy metals in surface sediments of day river at Beni-Mellal Region, Morocco. *Res. J. Envtal. and Earth Sci.*, 4(8): 797-806.

Bashim Y & Khoshnood Z 2016. Target hazard quotient evaluation of Cadmium and Lead in Fish from CapsianSea. *Toxicology and Industrial Health,* 32: 215-220.

Basta NT, Ryan JA & Chaney RL 2005. Trace element chemistry in residual treated soil: Key concepts and Metal bioavailability. *Journal of Environmental Quality*, 34(1): 49-63.

Bjuhr J 2007. Trace metals in soil irrigated with waste water in Periurban Area Downstream Hanoi city, Vietnam, Seminar Paper, Institutionen for Markvetenskap, Upsala, Sweden, 2: 333-356.

Boskurt E, Eliri O & Kesiktas M 2014. Analysis of Heavy Metals in Sea water samples collected from Beaches of Asian side of Istanbul. *J. Recreation and Tourism Res. (JRTR),* 1(1): 39-47.

Caccia VG, Millero FG & Palanques R 2003. The distribution of trace metals in Florida Bay sediments. *Marine Pollution Bulletin*, 46(11): 1420-1433.

Caeiro S, Costa MH, Ramos TB, Fernandez F, Silveira N, Coimbra A, Medeiros G & Painho M 2005. Assessing heavy metal contamination in Sado Estuary sediment. An index analysis approach. *J. Envtal. Quality,* 5(2): 151-169.

Chaney RL & Oliver DP 1996. Sources, potential adverse effects and remediation of agricultural soil contaminations and the environment in the Austrailia-Pacific region. *Kluwer Academic Publishers Dordrecht,* 323-359.

Clyne N, Hofman-Bang C, Haga Y, Hatori N, Marklund SL, Pehrsson SK & Wibom R 2001 Chronic cobalt exposure affects antioxidants and ATP production in rat myocardium, Scandinavian. *J. Clin. and Lab. Investigation*, 61(8): 609– 614.

Cuculic V, Cukrov N, Kwokal Z & Mlakar M 2011. Distribution of trace metals in anchialine caves of Adriatic sea, Croatia. *Estruarine Coastal and Shelf Science,* 95: 253-263.

D'Amore JJ, Al-Abed SR, Scheckel KG & Ryan JA 2005. Methods of speciation of heavy metals in soils: A review. *J. Envtal. Quality,* 34(5): 1707-1745.

Dan SF, Osamoh UU & Osabor VN 2014. Seasonal variation of enrichment and contamination of heavy metals in the surface water of Qua Iboe River Estuary and adjoining creeks in South – South, Nigeria. *J. Oceanogra. and Marine Sci.,* 5(6): 45-54.

Davies OA & Tawari CC 2010. Season and tide effects on sediment characteristics of trans-Okpoka Creek, upper bonny Estuary, Nigeria. *Agric. Biol. J. N. Am*., 1(2): 89-96.

Das KK & Buchner V 2007. Effect of nickel exposure on peripheral tissues: Role of oxidative stress in toxicity and possible protection by ascorbic acid. *Rev Environ Health,* 22: 133-49.

Das KK, Das SN &. Dhundasi SA 2008. Nickel, its adverse health effects and oxidative stress. *Indian J. Med. Res.,* 128: 412-425.

Das KK & Dasgupta S 2000. Effect of nickel on testicular nucleic acid concentrations of rats on protein estriction. *Biol. Trace Elem. Res.*, 73: 175-80.

Defew LH, Mair JM & Guzman HM 2014. An assessment of water contamination in Mangrove sediments and leaves from Punta mala Bay. *Pollution Bulletin,* 50: 547-552.

Devolder PS, Brown SL, Hesterberg D & Paudya K 2008. Metal bioavalaibility and speciation in a wetland tailings repository amended with biosolids compost, wood ash and sulfate. *J. Envtal. Quality,* 32(3): 851-864.

Duffus JH 2001. Heavy metals – A meaningless term. *Chemistry International,* 23(6), 1-6.

during the third Millenium BC: First regional database. *J. Archeol. Sci.,* 38(12): 3278-3295

Erhunmwunse NO, Dirisu AR & Ogbeibu AE 2013. Managing eutrophication in Nigeria inland waters. *J. Water Res. and Protec. (JWARP),* 5: 743-746.

Fawell J & Nieuwenhuijsen MJ 2003. Impact of environmental pollution on health: Balancing risk. *British Medical Bulletin.* 68(1): 227-242.

Feratti F, Kerolli-Mustapha M & Kraja-Ylli A 2015. Assessment of heavy metal contamination in water and sediment of Trepca and Sitnicariver, Kosovo using pollution indicators and multivariate cluster analysis. *Environmental Monitoring and Assessment,* 187: 338-342.

Godwin AE, Etim IU & Basil NI 2004. Seasonal variation of enrichment and contamination of heavy metals in Qua Iboe River Estuary, Nigeria. *Global J. Pure and Appl. Sci.,* 10(4): 611-617.

Goher ME, Farhat HI, Abdo MH & Salem GS 2014. Metal pollution assessment in the surface sediment of Nasser, Egypt. *Egyptian J. Aquatic Res.,* 40(3): 213-224.

Hamaidi-chergui F, Errahmani MB, Benouaklil F & Hamaidi M S 2013. Preliminary study on physic-chemical parameters and phytoplankton of Chiffa River (Blida, Algeria). *Journal of Ecosystem,* 15: 1-9.

Harikumar P & Jisha P 2010. Distribution patterns of trace metal pollutants in the sediment in an Urban Wetland in the Southwest Coast of India. *Int. J. Envtal. Sci. and Techn.*, 2(5): 840-850.

Hassan R, Schole R& Ash N 2005. Ecosystems and Human wellbeing: Current state and trends, Isalnd Press, Washington DC. 1, 917.

Hawkes SJ 1997. What is heavy metal. *J. Chem. Edu.,* 74(11): 1374.

Helmenstine AM 2014. What is heavy metal. *About Chemistry,* 3(2): 1-7.

Hiremath SC, Yadawe MS, Pujeri US, Hiremath DM & Pujar AS 2011. Physico-chemical analysis of ground water in municipal area of Bijapur (Karnataka). *Curr. World Envt. – An Int. Res. J. Envtal. Sci.,* 6: 265–269.

Hogan CM 2010. Heavy metal. *The Encyclopedia of Earth,* 15: 1-10.

Ihenyen AE 2001. Heavy metals in sediments of the Benin River estuary and its environs, western Niger Delta, Nigeria. *Environ. Sci.*, 6: 551-559.

Inengite AK, Abasi AY & Walter C 2015. Application of pollution indices for the assessment of heavy metal pollution in flood impacted soil. *Int. Res. J. Pure and Appl. Chem*., 8(3): 2231-3443.

Iwegbue CMA, Nwajei EG & Arimoro FO 2007. Assessment of contamination by heavy metals in the sediment of Ase River, Niger Delta, Nigeria. *Res. J. Envt. Sci*., 1(5): 220-228.

Jarup L 2003. Hazards of heavy metals. *British Medical Bulletin*, London, 68(1): 167-182.

Jeje JO & Oladepo KT 2014. Assessment of heavy metal of boreholes and hand dug well of Ife North local government area of Osun State, Nigeria. *Int. J. Sci. and Techn.,* 3(4): 209-214.

Jones LHP & Jarvis SC 1981. The fate of heavy metals in the chemistry of soil processes with DJ Green & MBH Hayes, Eds, *John Wiley and Sons,* New York, USA, pp. 6, 593.

Kaasalainen M & Yli-Halla M 2003. Use of sequential extraction to assess metal partitioning in soils. *Environmental Pollution,* 126(2): 225-233.

Kealey D & Haines PJ 2005. Instant notes, analytical chemistry. *BIOS Scientific Publishers Limited, Oxford, United Kingdom,* 3: 1-353.

Khan S, Cao Q, Zheng YZ, Huang YZ & Zhu YG 2008. Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. *Environmental Pollution,* 152(3): 686-692.

Khatoon N, Khan AH, Rehman M & Pathak V 2013. Correlation study for the assessment of water quality and its parameters of Ganga River, Kanpur, Uttar Pradesh, India. *IOSR J. Appl. Chem.*, 5(3): 80-90.

Kirpichtchikova TA, Manceau A, Spadini L, Panfili F, Marcus MA & Jacquet T 2006. Speciation and solubility of heavy metals in contaminated soil using X-ray microfluorescense, EXAFS Spectroscopy, chemical extraction and thermodynamic modeling. *Geochemical etCosmochimicaActa,* 70(9): 2163- 2190.

Klake KK, Nartey VK & Dinku DE 2016. Assessment of heavy metal combination in Weija Dam, Ghana. *J. Natural Sci. Res.,* 6(2): 18-26.

Lasat MM 2000. Phytoextraction of metals from contaminated soil: a review of plant/ soil/ metal interaction and assessment of pertinent agronomic issues. *J. Hazardous Substances Res.,* 2: 1-5.

Latifah AM & Met L 2014. An ecological evaluation approach for dam project development in Malaysia. *Life Science Journal,* 11(7): 225-237.

Lokeshewari H & Chandrappa GT 2006. Heavy metal contents in water hyacinth and sediment of Lalbagh Tanks, Bangalore. *Indian J. Envtal. Sci. Engr.,* 48: 183-188.

Maslin P & Maier RM 2000. Rhamnolipid – enchanced mineralization of phenantherene in organic metal co-contaminated soils. *Bioremediation Journal,* 4(4): 295-308.

McConell JR & Edward R 2008. Coal burning leaves toxic heavy metal legacy in the Arctic. *Proc. National Acad. Sci.,* USA, 105(34): 12140-12144.

Monge G, Jimenez-Espejo FJ, Garcia-Allix A, Martinez-Ruiz F, Mattielli N, Finlayson C, Ohkouchi N, Sanchez MC, Bermudez de Castro JM, Blasco R, Jordi R, Jose C, Rodriguez-vidal J & Finlayson G 2015. Assessment of Heavy metal in Northern Mexico River. *Journal of Environment,* 12: 63–69.

Narayanaswamy SY & Ramachandra MM 2014. Seasonal influence on physicochemical parameters of Yelahanka Lake Water of Bangalore. *World J. Pharmacy and Pharmac. Sci.,* 3(11): 453-464.

Nevoh GO, Akhionbare SMO & Uzoma HC 2015. Water quality aspects of River Okpoka in relation to watershed activities. *J. Resou. and Envt.,* 5(4): 124-133.

Nicholson FA, Smith SR, Alloway BJ & Carlton-Smith C & Chambers BJ 2003. The inventory of heavy metal inputs to agricultural soils in England and Wales. *Science of the Total Environment.*311(1-3): 205-219

Nicklow JW 2003. 'Dams' water science and issues. The gale group incorporated Encyclopaedia.com, 7(3): 1-15.

Nocete F, Saez R, Bayona MR, Peramo A, Inacio N & Abril D 2011. Direct chronometry (^{14}C AMS) of the earliest copper metallurgy in the Guadalquivir Basin (Spain). *Natural Environment,* 12(3): 23–29.

Ntakirutimana GD, Guo JS, Gao X & Huang L 2013. Pollution and potential ecological risk assessment of heavy metals in lake. *Poll. Envtal Stud.,* 22(4): 1129-1134.

Odoemalam SA, Okorie DO & Oko IO 2014. Physico-chemical parameters and Heavy metal contents of water, fish and sediments from Cross River at Afikpo North local government area of Ebonyi state, Nigeria. *Biores. Bull. Open Access J.,* 3(1): 10-24.

Ogbeibu AE, Omoigberale MO, Ezenwa IM, Eziza JO & Igwe JO 2014. Using pollution load index and Geo-accumulation index for the assessment of heavy metal pollution and sediment quality of the Benin River, Nigeria. *Natural Environment,* 2(1): 1-9.

Okafor EC & Opuene K 2007. Preliminary assessment of tracemetals and polycyclic aromatic hydrocarbons in the sediments. *Int. J. Envtal. Sci. and Techn*., 4(2): 233-240.

Ololade I 2014. An assessment of heavy metal contamination in soils within auto-mechanic workshops using enrichment factors with geo-accumulation indices. *J. Envtal. Protec.,* 5(11): 970-982.

Olomukoro JO & Azubuike CN 2009. Heavy Metals and Macroinvertebrate communities in bottom sediment of Ekpan Creek, Warri, Nigeria. *Jordan J. Biol. Sci.,* 2(1): 1-8.

Patil PN, Sewant DV & Deschmukh RN 2012. Physico-chemical parameters for testing of water – A review. *Int. J. Envtal. Sci.,* 3(3): 1104-1207.

Prater BE 1975. The metal content and characteristics of Steelwork effluents discharging to the tees estuary. *Water Pollution Control,* 74: 63-78.

Premlata VK 2009. Multivariant Analysis of drinking water quality parameters of Lake of Pichhola in Udaipur, India. *Biological Forum – An International Journal,* 1(2): 97-102.

Priju CP & Narayana AC 2006. Spatial and temporal variability of trace element concentrations in a tropical Lagoon, Southwest Coast of India: Environmental Implications. *J. Coastal Res.,* 39: 1053–1057.

Puyate YT, Rim-Rukeh A & Awatefe JK 2007. Metal pollution assessment and particle size distribution of bottom sediment of Orogodo River, Agbor, Delta State, Nigeria. *J. Appl. Sci. Res.,* 3(12): 2056-2061.

Radojevic M & Bashkin VN 1999. Practical Environmental Analysis. Royal School of Chemistry, Thomas Graham House, Science Park Cambridge, UK, pp. 4, 645.

Rahmanian N, Siti-Hajar BA, Homayoonfard AHJ, Rehan M, Sadef Y & Nizami AS 2015. Analysis of physicochemical parameters to evaluate the drinking water quality in the state of Perak, Malaysia. *Journal of Chemistry,* 1115: 1-10.

Rasheed KA, Sabri AW, Al-Lami AA Kassim TI & Shawkat SF 2001. Distribution of some heavy metals in water, suspended solids, sediments, fish and aquatic plants of the river Tigris, Iraq. *Sci. J. Iraqi Atomic Energy Commission*, 3(1): 198-208.

Reimann C & De Caricat P 2005. Distinguishing between natural and Anthropogenic sources for elements in the environment: Regional geochemical surveys versus enrichment factor. *Science of Total Environment*, 337: 91-107.

Richaud R., Herod AA., and Kandiyoti R 2004.Comparisons of trace element contents in low temperature ash from coal and biomass. *Fuel Bulletin*, 83: 14-15.

Rodbell DT, Delman EM, Abbot MB, Besonen MT & Tapia PM 2014. The heavy metal contamination of Lake Junin National reserve, Peru: An unintentional consequence of the juxtaposition of hydroelectricity and Mining. *GSA Today*, 24(8): 4-10.

Sado A, Gani AM & Ibrahim AQ 2013. Pollution status of heavy metals in water and bottom sediment of River Delimi in Jos, Nigeria. *Am. J. Envtal. Protec.*, 1(3): 47-53.

Saeed MD & Mahmoud AM 2014. Determination of some physico-chemical parameters and some heavy metals in boreholes from Fagge LGA of Kano Metropolis, Kano State, Nigeria. *World J. Analyt. Chemi.*, 2(2): 43-46.

Salah EAM, Zaidan TA & Al-Rawi AS 2012. Assessment of heavy metal pollution in the sediments of Euphrates River, Iraq. *J. Water Resou. and Protec.*, 22(4): 77–86.

Saleh T, Sayed S, Saeedi S, Gholamali AB, Atena D & Mohammed S 2010. Heavy metals (Zn, Pb, Cd, Cr) in fish, water and sediment sample from Southern Capsian Sea, Iran. *Toxicology and Industrial Health*, 26(10): 649-656.

Scragg A. 2006. Environmental biotechnology. *Oxford University Press, Oxford, UK.*2nd Edition, pp. 7, 22-24.

Siong FS, Teck YL, Lee N, Norliza G, Yiew EW & Liang PK 2016. Assessment of heavy metals in water, sediments and fishes of a large tropical hydroelectric dam in Sarawak, Malaysia. *Journal of Chemistry*, 2016: 1-10.

Siti-Farizwana MR, Mazrura S, Zurahanim FA & Ahmad RG 2010. Determination of aluminium and physico-chemical parameters in the palm of estates water supply at Johor, Malaysia. *J. Envtal. and Public Health*, 2(1): 61-76.

Summer ME 2000. Beneficial use of effluents, wastes and biosolids. *Communications in Soil Sci. and Plant Anal.*, 31(14): 1701-1715.

Tam NFY & Wong WS 2000. Spatial variation of Heavy Metals in Surface sediments of Hongkong Mangrove Swamp. *Environmental Pollution*, 110: 195-205.

Tchounwou PB, Yedjou CG, Patil AK & Sutton DJ 2012. Heavy metal toxicity and its environmental hazards. *Journal of Life Science*, 223(9): 1-5.

Tripathi A & Misra DR 2012. A study of physico-chemical properties and heavy metals in contaminated soils of municipal waste dumpsites at Allahabad, India. *Int. J. Envtal. Sci.*, 2(4): 2024 –2033.

Trivedy PK & Goel PK 1986. Chemical and Biological studies for water pollution studies. *Environmental Publication*, Karad, Maharashtra, 23(8): 1-7.

Turnland JR 1988. Copper nutrition, bioavailability and influence of dietary factors. *J. Am. Dietetic Assoc.*, 1: 303-308.

Uzairu A, Uba S, Sallahu MS, Abba H & Okunola OJ 2013. Seasonal chemical fractionation of Metals in some dumpsites soils in Zaria Metropolis, Nigeria. *J. Envt. and Earth and Sci.*, 3(2): 1-12.

Varol M 2011. Assessment of heavy metal contamination in sediment of Tigris River (Turkey) using pollution indices and multivariate statistical techniques. *Journal of Hazardous Materials*, 195: 355-364.

Webster 2010. New World College Dictionary. *Wiley Publishing Incorporated*, Cleveland, Ohio. 211, 1-2.

WHO 2001. Arsenic and Arsenic compounds. *Environmental Health Criteria*, Geneve. 224, 33-39.

WHO 2006. Guidelines for Drinking Water Quality Criteria and Other Supporting Information. *Environmental Health Criteria*, Geneve, 2: 5-7

Wuana RA & Okieimen FE 2011. Heavy metals in contaminated soils: A review of sources, chemistry, risk and best available strategies for remediation. *Int. Scholarly Res. Notices*, 11: 1-20.

Yujun Y, Zhifeng Y & Shanghong Z 2011. Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze River Basin. *J. Envtal. Poll.*, 159(10): 2575-2585.

Zarei I, Pourkhabbaz1 A & Babaei H 2013. Evaluation of some physiochemical parameters and heavy metal contamination in Hara Biosphere Reserve, Iran, using a new pollution index approach. *Iranian J. Toxicol.*, 7: 21.

Zhang MK, Liu ZY & Wang H 2010. Use of single extraction method methods to predict bioavalaibility of heavy metals in polluted soils to rice. *Communications in Soil Sci. and Plant Anal.*, 41(7): 820-831.