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Assessment of Heavy Metal Contamination in the Weija Dam, Ghana

Raphael Kwaku Klake* Vincent Kodzo Nartey DavidEdem Dinku
School of Physical and Mathematical Sciences, Chemistry Department, University of Ghana, P.O. Box LG 56, Legon, Accra, Ghana

Abstract
This study was conducted to assess heavy metal contamination (Fe, Pb, Cd and Mn) in water and sediments from the Weija dam. It was carried out in March 2014, representing the dry season and August 2014, representing the wet season at ten (10) sampling Sites. Water and sediment samples were taken from ten different Sites within the Weija dam in March, 2014 (dry season) and August, 2014 (wet season). Heavy metal concentrations were determined using atomic absorption spectrophotometer (AAS). In the dry season, mean concentration of heavy metals in the water were 0.03 mg/L(Fe), 0.02 mg/L (Cd), 0.03 mg/L (Mn) and 0.02 mg/L (Pb) while in the wet season, the mean concentrations were 0.28 mg/L (Fe), 0.00 mg/L (Pb), 0.02 mg/L (Cd) and 0.03 mg/L (Mn). Levels of all heavy metals were below the WHO guideline values for drinking water. All the metal concentrations in the sediment were higher than that of the water samples in both dry and wet seasons. The concentrations of all the metals studied were below USEPA guideline values. Results of Pollution Indices computed namely, Concentration factors (C_f), Geo-Accumulation Index (I-Geo)Pollution load Index showed no pollution. The results from this study therefore showed that the water in the Weija dam is relatively clean with regard to the measured heavy metals.
Keywords: Weija dam, water, sediment, heavy metals, seasonal variation Concentration factors, Geo-Accumulation Index, Pollution load Index.

1. Introduction

Pollution of aquatic environment by heavy metals has since been identified as a serious contamination problem (Larsson et al., 1985; Mance, 1987; Langston, 1990;not only because of the threat it poses to water supplies and to the public, but also the possibility of causing damage to aquatic life (Corbett, 1977; Mance, 1987; Leland et al., 1978, Canli 1998; Nasreenet al., 1995; Jan et al., 2002). This situation makes the water unsafe for human consumption (Karadedeet al.2004; Mendil and Uluozlu, 2007). Heavy metals in large amounts are usually present in fresh waters due to the weathering of rocks and soils (Muwanga, 1997; Anderson, 2003; Babel and Opiso, 2007; Samarghandiet al., 2007; Igweetal., 2008; Al-Juboury, 2009). However, these metals could also be present as a result of human activities.

The main sources of heavy metal pollution in aquatic ecosystem are natural sources and anthropogenic activities. These heavy metals are continuously added into aquatic systems, causing serious threat to aquatic lives due to their toxic nature (Dutton *et al* 1988, Bowlbyet al.,1988, Bhuvaneshwariet al.,2012). Moreover, they do not only affect the ecosystems, but also human life through bioaccumulation in the food chain as well as their non-biodegradable nature in ecosystems making them persistent (Sastry 1982; Puelet al., 1987, Eisler, 1988; USEPA, 1991; Yousafzai and Shakoori, 2008). Heavy metals are deposited, assimilated or incorporated in water, sediments and in aquatic organisms since they cannot be degraded (Abdel-Bakiet al., 2011).Sediments can also act as a sink for pollutants such as metals whichare transported by rivers and by atmospheric precipitation to the sediments where they are accumulated (Sigg, 1985).The dam has been subjected to various forms of degradation due to pollution arising from stone quarrying, dumping of domestic wastes, industrial effluents and agricultural run offs (Asante et al., 2005). Among these pollutants, metals are of particular concern because of their potential toxic effect and ability to bioaccumulate in aquatic ecosystems (Miller et al., 1993; Censiet al., 2006). Hence, it isof public interest (Gibbs, 1972; Niemiet al., 1990) to have knowledge of the levels of these metals in the sediments since aquatic organisms in the sediments can also be exposed to them. The use of fertilizers in farming within a dam's catchment isa potential source of heavy metal discharge into water bodies. As a result of the rate and extent of anthropogenic activities impacting on the quality of water in the dam, it is therefore imperative to assess the waterquality and sediments from the dam in order to ascertain the level of pollution.

There have been some studies on the quality of the Weija dam (Anim et al., 2011). However, there has not been any known study on the levels of heavy metals and their seasonality inwater and sediments in recent times. The objective of the study is to provide a quantitative record of the seasonal changes as well as the concentrations of heavy metals in the water and sediments as well as computing the degree of sediment contaminations using various indices namely contamination factors (C_f), Geo-accumulation index (I-geo) and pollution load index (PLI) from the Weija dam.

2. Materials and Methods

2.1 Study Area Description

The Weija dam is situated in Accra, the capital of the Greater Accra region of Ghana. The Weija dam is 14 km long, 2.2 km wide and has a total surface area of 38 km^2 (sq.) with mean depth of 5m (Vanden, 1990). The dam is located between 0^o 20' W 0^o 25' W and 5^o 30' N 5^o 45' N about 17 km west of Accra andclose to the mouth of the 116 km long river Densu which lies between latitude 5^o 30^1N and 6^o 20^1N and between longitudes 0^o10^1 and 0^o 35^1W (Anim et al 2011). The dam was created in 1977 as a replacement for an earlier one, which was washed away in 1968 by Ghana Water Company Limited through the damming of River Densu mainly to satisfy the demand for potable water supply (Asante, 2005). The current reservoir provides water to the western parts of Accra, supports irrigation projects as well as fisheries. The normal surface elevation is estimated at 14.37 km with a maximum of 15.24 km (Nukunya and Boateng, 1979).

The catchment of the dam lies in the coastal savanna zone where rainfall is seasonal, with two rainfall peaks between June and September, while dry periods span between December and March. Major crops grown in the catchment area include maize, cassava, sugarcane and vegetables.

2.2 Sampling

Water and sediment samples were collected in March 2014, which represents the dry season and in August 2014, the wet season from ten sampling Sites as shown in Figure 1. One hundred surface water samples were collected from the Lake into acid pre-cleaned Teflon-bottles using ultra-clean free metal sampling protocol (Gill and Fitzgerald, 1985, 1987). The water samples for analyses were collected from the surface using 1 L polyethylene bottles. At each sampling Site, the polyethylene sampling bottles were rinsed three times before sampling. Sediment samples were collected from the bottom of the Lake at each sampling point with pre-cleaned polyethylene bags sealed and labelled. Water and sediment samples collected were all kept in an ice chest at a temperature of about 4°C and transported to the Chemistry Laboratory of the Ghana Atomic Energy Commission (GAEC) for analyses.

2.3 Preparation and determination of heavy metals

In the laboratory, the dissolved heavy metal concentrations in the water samples were determined for Fe, Cu, Pb, Cd and Mn by using direct flame Atomic Absorption Spectrometry (AAS). A 6ml of 65% HNO_3, 3ml of 35% HCl, and 0.25ml of H_2O_2were added to 100 cm^3 of water and 1.5 g of the sediment samples into a Teflon beaker.The resulting solutions were placed in an Ethos 900 Microwave for 30 minutes at 250 Watts power for digestion. The digested solutions were topped to 20ml by adding de-ionized distilled water. The solutions were thoroughly mixed and aspirated into the spectrometer (Varian AA240 Fast Sequential Atomic Absorption Spectrometer) following specifications outlined for each element in the cook book of AAS.

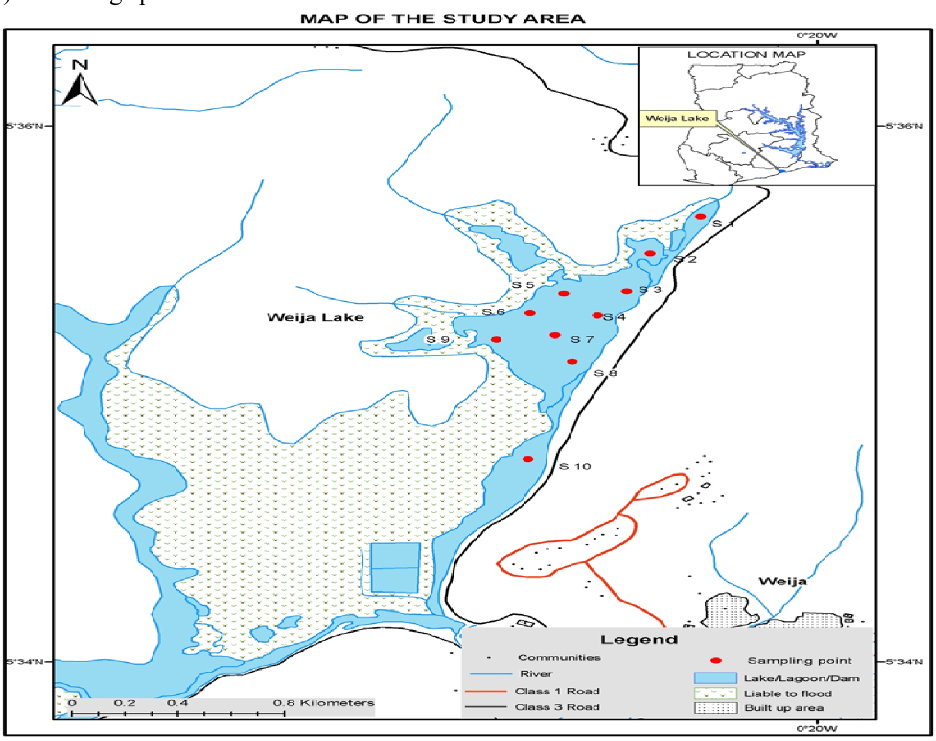

Figure 1: Map of the study area indicating the sampling Sites.

The contamination factor (C_f), Geoaccumulation Index and Pollution Load Index are indices used to determine the contamination status of sediment in the Weija dam.

2.3 Contamination Factor (C_f)

The level of heavy metal contamination of sediments from the Weija Dam is expressed in terms of a contamination factor (C_f).
The contamination factor is expressed byequation 1

C_f=C_mSample/ C_m Background Equation 1

WhereC_mSamplerepresents the concentration of the given metal in the sediment and C_m Background is the value of the metal represents mean shale concentration given by Martin and Meybeck (1979).
Contamination factor values for describing the ascribed levels of contamination are indicated in**Table 1**

Table 1:Contamination Factor and Level of Contamination (Hakanson 1980)

Contamination Factor (Cf)	Level of Contamination
Cf < 1	Low contamination
1≤ Cf <3	Moderate contamination
3≤ Cf <6	Considerable contamination
Cf > 6	Very high contamination

2.4 Geo-accumulation Index (I_{geo})

The Geo -accumulation Index (I_{geo}) was calculated to determine the contamination of heavy metals in sediments from the Weija Dam. The Geo-accumulation Index was proposed by Muller (1979) and later classified by Muller (1981) It evaluates pollution in terms of seven classes based on the increasing numerical values of the index. The seven contamination classes are indicated in Table 2

Table 2: Muller's Classification for the Geo-AccumulationIndex

I-Geo	Value Class	Sediment Quality
≤ 0	0	Unpolluted
0-1	1	From Unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	From moderately to strongly polluted
3-4	4	Strongly polluted
4-5	5	From strongly to extremely polluted
> 6	6	Extremely polluted

The geo-accumulation Index is expressed by the following equation 2

: $I_{geo}=Log_2(C_n/(1.5*B_n)$ Equation 2

Where Cn is the measured concentration of the sediments for metal (n), Bn is the geochemical background value for metal (n). 1.5 representsrock average given by Martin and Meybeck (1979)]. The factor 1.5 is incorporated in the relationship to account for possible variation in background data due to terrigenouseffects.

3. Results and Discussion

Mean, standard deviation and range for heavy metal concentrations in water from the Weija dam areshown in **Table 3** and **Table 4** for the dry and wet season respectively. Mean, standard deviation and range for heavy metal concentrations in sediments from theWeija dam areshown in **Table 5** and **Table 6** for the dry and wet season respectively. .**Table 7 andTable 8** show Geo-accumulation Index, Contamination factor and Pollution Load Index for heavy metal concentrations in sediments from theWeija dam in the dry and wet season respectively.

3.1 Iron

Though iron is one of the essential elements in human nutrition, its presence at elevated concentration in aquatic ecosystems can pose serious pollution and health problems (Akan 2012)

The overall mean concentration of Fe at the ten sampling sites was 0 .031 mg/L and ranged between 0.02 mg/L (Site 3,7) and0.04 mg/L (Site 2,3 and 10) in the dry season. However, Fe mean concentrations in the ten sampling Sites in the wet season was 0.067 mg/L and ranged between 0.01 (Site 10) and 0.00174 mg/L. (Site2) The Fe levels observed in all the sampling stations were lower than the recommended limit of 0.01mg L-1 in drinking water (WHO, 2011). Thisimpliesa no pollutionof reservoir waterby Fe

The mean Iron (Fe) concentration in the sediments in the dry season was 26.22mg/kg and ranged from 20.45 mg/kg (Site 4) to 29.47 mg/kg (Site 1). The mean concentration during the wet season was 30.54 mg/kg and ranged from 12.09 mg/kg (Site 7) to 45.35 mg/kg (Site 3 and 5). The mean Fe value for the dry and wet seasons was below theUSEPA (1991) sediment quality guideline of 30 mg/L

The mean Contamination factor of Fe was 5.58 and ranged from 4.35 (Site 4) to 6.27 (Site 1) during the dry season and the mean during the wet season was 6.56withranges between 2.57 (Site 7) and 9.65 (Site 3). All the C_f values were more than one suggesting moderate contamination by Fe.

The Geo-accumulation Index values (I-Geo) during the dry season, had a mean value of 1.88 and ranged from 1.54 to 2.06 (Site 1). In the wet season, the mean was 2.00 and ranged from 0.78 (Site 7) to 2.69 (Site4). This, from the Muller's classification, falls into category 2indicating moderate pollution by Iron (Fe).

3.2 Lead

The overall mean concentration of Pb at the ten sampling sites was 0 .019 mg/L and ranged between 0.004 mg/L (Site9) andto 0.06 mg/L (Site 4) in the dry season. However, in the wet season. Pb concentrations in the ten sampling Sites ranged between 0.000 (Site 5) and 0.002 mg/L. (Site 6).The Pb levels observed in all the sampling stations were lower than the recommended limit of 0.01mg L-1 in drinking water (WHO, 2011). This means that the water in reservoir is not polluted by Pb.

The mean Lead (Pb) concentration in the sediments was 1.48 mg/kg in the dry season and ranged between 0.84 mg/kg at Site8 and 2.37 mg/kg at Site 3. The mean concentration was 1.70 mg/kg in the wet season and ranged between 1.46 at Site9 and 1.92 (Site 1 and 2). The mean Pb concentrations in the sediments observed in this study were lower than the recommended limit of 40 mg/kg for Pb in sediment (WHO, 20011).

The mean Contamination factor (C_f) for Pb in the sediments was 0.07 and ranged from 0.04 (Site 8) to 0.1 (Site 9) in the dry season and a mean of 0.9ranging from07 (Site8 and 9) to 0.1 (Site 1 and 2) in the wet season. All the C_f values were less than one suggesting low contamination by Pb.

The Geo-accumulation Index values (I-Geo) for Pb ranged from -3.66 (Site 3) to -4.74 (Site7) in the dry season with a mean of -4.15 and ranging from -3.97 (Site 1) to -4.38 in the wet season. The Geo-accumulation values for all the sampling Sites were negative.This from the Muller classificationfalls into category 0indicating no pollution by Lead.

3.3 Cadmium

The overall average concentration of Cdat the ten sampling sites was of 0 .023 mg/L ranging between 0.013 mg/L (Site 6) andto0.039 mg/L (Site 4) in the dry season. However, in the wet season Cd mean concentrations in the ten sampling Sites was 0.018 mg/L and ranged between 0.01 (Sites 4,6,7,8) and 0.004 mg/L. (Site4).Cadmium concentrations in the water samples in the dry season were relatively higher than that of the wet season. This could be due to factors such as runoff from agricultural soils where phosphate fertilizers are used (Stoeppler, 1991), leaching from Nickel-Cadmium based batteries and other metals from waste (Gampson, 2013; Akan, 2012).The Cd levels observed in all the sampling stations were lower than the recommended limit of 0.01mg L-1 in drinking water (WHO, 2011). This means that the water in reservoir is not polluted by Cd.

The mean Cadmium (Cd) concentration in the sediments in the dry season was 0.11mg/kg and ranged from 0.03mg/kg (Site 8) to 0.16 mg/kg (Site4 and 5) while the mean cadmium (Cd) concentration in the wet season was 0.06 mg/kg and ranged from 0.03mg/kg (Site 6) to 0.14 mg/kg (Site 4). The mean Cd value was below the USEPA sediment quality guideline of 0.6 mg/Kg.

The mean Contamination factor (Cf) was 0.22 and ranged from 0.10 (Site 6) to 0.47 (Site 4) during the dry season. The mean for the wet season was 0.35 and ranged from 0.10 (Site 8) to 0.53 (Site 3,4 & 5). All the Cf values were less than one suggesting low contamination by Cd.

The Geo-accumulation Index values (I-Geo) in the wet season had a mean of -2.94 and ranged between -3.49 (Site 6 & 10) to -1.68 (Site 4). During the dry season, the mean of -2.27 was recorded and ranges from -3.91 (Site 8) to -1.49 (Site 3,4 & 5). The Geo-accumulation values for all the sampling Sites were negative. . From the Muller classificationthis falls into category 0indicating no pollution byCd.

3.4 Manganese

Manganese is a common problem element in natural waters. In drinking waters, this element may cause unsightly stains and problems that can be associated with neurological damage (Kondakis et al., 1989).

The overall mean concentration of Mn at the ten sampling sites was 0 .034 mg/L and ranged between 0.010 mg/L (Site5) to 0.088 mg/L (Site4) in the dry season. However, the wet season meanMn concentrations in the ten sampling Sites was 0.028 mg/L ranging between 0.000 (Site 7) and 0.065 mg/L.(Site6) The Mn levels observed in all the sampling stations were lower than the recommended limit of 0.01mg L-1 in drinking water (WHO, 2011). This means that the water in the reservoir is not polluted by Mn.

The mean Manganese (Mn) concentration in the dry season was found to be 20.83mg/kg and ranged from 18.02 mg/kg (Site 4) to 21.92 mg/kg (Site 1)in the wet season the mean concentration was 19.99 mg/kg and ranged from 17.86mg/kg (Site 8) to 21.88mg/kg (Site 5). The mean Mn value was below the USEPA sediment quality guideline of 30 mg/Kg.

The mean Contamination factor (C_f)was 0.02 which remains constant throughout all the Sites during the dry season and the mean during the wet season is 0.02 and ranges from 0.02 (Site1,2,3,4,6,7,8,9,10) to 0.03 (Site5).C_f values below 1 indicates no pollution. This means the dam is not polluted with respect to Mn.

The Geo-accumulation Index value (I-Geo)) during the dry season was -6.02 and ranged between -6.23 (Site 4) and -5.87 (Site 5) The mean I-Geo value in the wet season was -6.08 and ranged from -6.24 (Site 8) to -5.95 (Site 5. . From the Muller classification this falls into category 0indicating no pollution by Manganese.

2.5 Pollution Load Index (PLI)

The Pollution Load Index (PLI) is used to determine the contamination status of the sediments found in the Weija Dam. The PLI for the Weija Dam was evaluated based on the following equation 3:

$$PLI=(C_F1*C_F2*C_F3*C_F4)^{1/n} \quad \text{Equation 3}$$

where n represents the number of metals.

The PLI value> 1 is an indication of pollution whereas PLI value < 1 indicates nopollution (Seshan et al., 2010). The results of the Pollution Load Index (PLI) are shown in Table 7 and 8.Thke values for all the sites for both the dry and wet seasons are less than 1 which indicates that the dam is not polluted with respect to the heavy metals measured.

Table3: Mean, Standard deviation and Range for heavy metal concentrations in water of Weija dam in the dry season (mg/L

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Mean of 10 Sites
Fe	0.03	0.04	0.02	0.03	0.03	0.03	0.02	0.03	0.04	0.04	0.0310
St. Dev.	±0.03	±0.03	±0.03	±0.01	±0.01	±0.02	±0.02	±0.03	±0.02	±0.03	-
Range	0.01-0.07	0.01-0.07	0.00-0.02	0.01-0.04	0.02-0.05	0.01-0.07	0.01-0.05	0.00-0.06	0.01-0.06	0.00-0.07	-
Cd	0.024	0.029	0.027	0.039	0.014	0.013	0.015	0.025	0.028	0.019	0.0233
St. Dev.	±0.017	±0.014	±0.017	±0.025	±0.01	±0.01	±0.001	±0.01	±0.018	±0.01	-
Range	0.01-0.05	0.01-0.04	0.01-0.05	0.00-0.07	0.01-0.02	0.00-0.03	0.01-0.02	0.01-0.03	0.01-0.05	0.01-0.03	-
Pb	0.015	0.004	0.021	0.06	0.028	0.024	0.014	0.007	0.004	0.008	0.0185
St. Dev.	±0.008	±0.004	±0.002	±0.02	±0.003	±0.009	±0.007	±0.007	±0.003	±0.005	-
Range	0.00-0.02	0.00-0.01	0.01-0.02	0.04-0.08	0.02-0.03	0.01-0.03	0.00-0.02	0.00-0.02	0.00-0.01	0.00-0.01	-
Mn	0.033	0.064	0.035	0.025	0.029	0.065	0.024	0.018	0.025	0.019	0.0337
St. Dev.	±0.026	±0.011	±0.02	±0.01	±0.012	±0.076	±0.011	±0.018	±0.007	±0.005	-
Range	0.01-0.07	0.05-0.07	0.02-0.07	0.01-0.04	0.02-0.05	0.01-0.20	0.01-0.04	0.00-0.04	0.01-0.03	0.00-0.04	-

Table 4: Mean, Standard deviation and Range for heavy metal concentrations in water of Weija dam in the wet season (mg/L)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Mean of 10 Sites
Fe	0.14	0.11	0.17	0.02	0.02	0.02	0.02	0.14	0.02	0.01	0.0670
St. Dev.	±0.08	±0.01	±0.10	±0.01	±0.02	±0.01	±0.02	±0.05	±0.01	±0.01	-
Range	0.00-0.20	0.09-0.13	0.00-0.25	0.00-0.04	0.00-0.04	0.00-0.03	0.00-0.04	0.05-0.20	0.00-0.03	0.00-0.03	-
Cd	0.03	0.03	0.02	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.0180
St. Dev.	±0.004	±0.001	±0.003	±0.001	±0.011	±0.004	±0.000	±0.003	±0.002	±0.006	-
Range	0.03-0.03	0.03-0.03	0.02-0.03	0.01-0.01	0.02-0.04	0.01-0.02	0.01-0.01	0.01-0.02	0.01-0.01	0.00-0.01	-
Pb	0.001	0.001	0	0.001	0	0.002	0.001	0.001	0.001	0.001	0.0009
St. Dev.	±0.001	±0.002	±0.001	±0.001	±0.000	±0.002	±0.001	±0.001	±0.001	±0.001	-
Range	0.000-0.003	0.000-0.004	0.000-0.001	0.000-0.004	0.000-0.001	0.000-0.005	0.000-0.003	0.000-0.003	0.00-0.002	0.000-0.003	-
Mn	0.018	0.058	0.022	0.02	0.01	0.038	0.088	0.016	0.004	0.004	0.0278
St. Dev.	±0.01	±0.02	±0.01	±0.01	±0.00	±0.02	±0.02	±0.01	±0.00	±0.001	-
Range	0.01-0.03	0.04-0.08	0.01-0.03	0.01-0.03	0.00-0.01	0.02-0.07	0.07-0.11	0.01-0.04	0.00-0.01	0.00-0.01	-

Table 5: Mean ±Standard deviation and Range for heavy metal concentrations in sediments of Weija dam in the dry season (mg/kg)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Fe	29.47	29.21	25.87	20.45	24.29	28.48	27.94	22.29	25	29.2
St. Dev.	±1.40	±0.60	±1.49	±1.69	±2.05	±1.99	±1.84	±3.33	±6.12	±1.67
Range	27.07-30.65	28.38-30.04	23.86-27.32	18.93-23.33	21.03-26.07	26.78-30.68	24.72-29.12	19.67-28.09	17.00-29.94	0.00-0.00
Cd	0.14	0.09	0.16	0.16	0.16	0.1	0.06	0.03	0.09	0.06
St. Dev.	±0.22	±0.01	±0.12	±0.07	±0.01	±0.05	±0.04	±0.01	±0.03	±0.03
Range	0.04-0.53	0.08-0.11	0.07-0.30	0.05-0.20	0.15-0.17	0.02-0.15	0.01-0.09	0.02-0.05	0.05-0.13	0.00-0.08
Pb	1.77	1.64	2.37	1.25	1.11	1.25	1.12	0.84	2.01	1.48
St. Dev.	±0.74	±0.46	±0.99	±0.30	±0.36	±0.39	±0.18	±0.27	±0.36	±0.72
Range	0.99-2.76	1.03-2.31	1.63-4.08	0.99-1.75	0.84-1.69	0.99-1.92	0.99-1.40	0.56-1.20	1.65-2.60	0.87-2.55
Mn	21.92	20.79	20.95	18.02	23.03	19.7	21.79	21.28	20.94	19.89
St. Dev.	±1.25	±0.60	±0.63	±1.63	±4.17	±1.46	±2.17	±1.57	±0.52	±1.02
Range	21.03-24.11	20.03-21.44	20.02-21.45	16.25-19.94	16.57-26.46	17.24-21.03	19.66-24.17	18.97-22.96	20.32-21.46	18.63-20.96

Table 6: Mean ±Standard deviation and Range for heavy metal concentrations in sediments of Weija dam in the wet season (mg/kg)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Fe	22.52	18.97	45.35	43.82	21.29	27.16	12.09	36.99	34	43.17
St. Dev.	±3.90	±2.55	±2.66	±4.52	±6.36	±5.07	±1.90	±6.17	±8.46	±2.27
Range	17.45-28.02	14.80-21.20	41.70-48.20	39.22-49.53	11.94-28.12	20.10-31.63	9.86-14.23	30.22-45.88	28.60-49.01	40.20-45.26
Cd	0.1	0.06	0.08	0.14	0.04	0.03	0.05	0.04	0.1	0.03
St. Dev.	±0.02	±0.04	±0.02	±0.04	±0.02	±0.01	±0.01	±0.01	±0.02	±0.01
Range	0.08-0.13	0.04-0.12	0.05-0.11	0.11-0.20	0.02-0.06	0.03-0.04	0.04-0.06	0.03-0.05	0.08-0.12	0.03-0.04
Pb	1.92	1.92	1.75	1.65	1.49	1.81	1.74	1.44	1.46	1.85
St. Dev.	±0.26	±0.24	±0.46	±0.43	±0.32	±0.32	±0.48	±0.52	±0.67	±0.90
Range	1.58-2.25	1.65-2.21	1.00-2.23	1.21-2.35	1.20-1.99	1.26-2.01	1.37-2.56	0.96-2.23	1.00-2.65	1.21-3.19
Mn	21.05	21.58	19.02	20.18	21.88	20.11	19.97	17.86	19.38	18.84
St. Dev.	±1.84	±1.65	±2.32	±4.13	±1..66	±3.95	±1.89	±4.78	±5.10	±5.21
Range	18.99-23.66	19.87-24.02	16.00-22.10	15.67-24.33	19.35-23.23	13.59-24.02	17.83-22.22	10.23-22.37	11.24-24.21	12.32-25.32

Table 7: Geo-accumulation Index, Contamination factor and Pollution Load Index for heavy metal concentrations in sediments of Weija dam in the dry season

Parameter	Overall Concentration (mg/kg)				Geoaccumulation Index (Geo-I)				Concentration factor (Cf)				Pollution Load Index (PLI)
	Fe	Cd	Pb	Mn	Fe	Cd	Pb	Mn	Fe	Cd	Pb	Mn	
Site 1	29.47	0.14	1.77	21.92	2.06	-1.68	-4.08	-5.94	6.27	0.47	0.11	0.03	2.09E-03
Site 2	29.21	0.09	1.64	20.79	2.05	-2.32	-4.19	-6.02	6.21	0.30	0.10	0.02	1.17E-03
Site 3	25.87	0.16	2.37	20.95	1.88	-1.49	-3.66	-6.01	5.50	0.53	0.15	0.02	2.68E-03
Site 4	20.45	0.16	1.25	18.02	1.54	-1.49	-4.58	-6.23	4.35	0.53	0.08	0.02	9.61E-04
Site 5	24.29	0.16	1.11	23.03	1.78	-1.49	-4.76	-5.87	5.17	0.53	0.07	0.03	1.30E-03
Site 6	28.48	0.10	1.25	19.70	2.01	-2.17	-4.58	-6.10	6.06	0.33	0.08	0.02	9.14E-04
Site 7	27.94	0.06	1.12	21.79	1.99	-2.91	-4.74	-5.95	5.94	0.20	0.07	0.03	5.33E-04
Site 8	22.29	0.03	0.84	21.28	1.66	-3.91	-5.16	-5.99	4.74	0.10	0.05	0.03	1.56E-04
Site 9	25.00	0.09	2.01	20.94	1.83	-2.32	-3.90	-6.01	5.32	0.30	0.13	0.02	1.23E-03
Site 10	29.20	0.06	1.48	19.89	2.05	-2.91	-4.34	-6.08	6.21	0.20	0.09	0.02	6.72E-04
Mean	26.22	0.11	1.48	20.83	1.88	(2.27)	(4.40)	(6.02)	5.58	0.35	0.09	0.02	1.11E-03

Table 8: Geo-accumulation Index, Contamination factor and Pollution Load Index for heavy metal concentrations in sediments of Weija dam in the wet season

Parameter	Overall Concentration (mg/kg)				Geoaccumulation Index (I-Geo)				Concentration factor (Cf)				Pollution Load Index (PLI)
	Fe	Cd	Pb	Mn	Fe	Cd	Pb	Mn	Fe	Cd	Pb	Mn	
Site 1	22.52	0.10	1.92	21.05	1.68	-2.17	-3.97	-6.00	4.79	0.33	0.10	0.02	6.42E-02
Site 2	18.97	0.06	1.92	21.58	1.43	-2.91	-3.97	-5.97	4.04	0.20	0.10	0.02	2.77E-02
Site 3	45.35	0.08	1.75	19.02	2.69	-2.49	-4.10	-6.15	9.65	0.27	0.09	0.02	1.51E-01
Site 4	43.82	0.14	1.65	20.18	2.64	-1.68	-4.18	-6.06	9.32	0.47	0.08	0.02	2.37E-01
Site 5	21.29	0.04	1.49	21.88	1.59	-3.49	-4.33	-5.95	4.53	0.13	0.07	0.02	1.79E-02
Site 6	27.16	0.03	1.81	20.11	1.95	-3.91	-4.05	-6.07	5.78	0.10	0.09	0.02	2.54E-02
Site 7	12.09	0.05	1.74	19.97	0.78	-3.17	-4.11	-6.08	2.57	0.17	0.09	0.02	7.26E-03
Site 8	36.99	0.04	1.44	17.86	2.39	-3.49	-4.38	-6.24	7.87	0.13	0.07	0.02	4.52E-02
Site 9	34.00	0.10	1.46	19.38	2.27	-2.17	-4.36	-6.12	7.23	0.33	0.07	0.02	9.99E-02
Site 10	43.17	0.03	1.85	18.84	2.61	-3.91	-4.02	-6.16	9.19	0.10	0.09	0.02	5.55E-02
Mean	30.54	0.07	1.70	19.99	2.00	-2.94	-4.15	-6.08	6.50	0.22	0.09	0.02	6.18E-02

4. Conclusion

The results of this study showthe presence of heavy metals in the water and sediments from the Weija dam. These levels were not high enough to pose danger to consumers. All the heavy metal levels in the water were below the WHO maximum permissible limits. The levels of the heavy metals were generally higher in the dry season compared to the wet season with a few exceptions. Heavy metal levels in the sediment were higher in the dry season than in the wet season except for iron, which was higher in the wet season than in the dry season. The contamination factors and **:** Geo-accumulation Index for all the elements indicate that there is no contamination of the Weija dam.The Pollution Load Index (PLI), all sampling sites in the Dam suggest no overall pollution of the Dam. Though the levels of these metals are not exceedingly high, it will be beneficial to establish long-term monitoring stations in the catchment area to regulate anthropogenic activities that lead to the contamination of the water and sediments.

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