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Physicochemical Characteristics and Heavy Metals Contamination Assessment in Water and Sediment in a Tropical Hydroelectric Dam of Sassandra River, Côte d'Ivoire

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Abstract Buyo hydroelectric dam is one of the highest concrete rock-filled dams in Côte d'Ivoire. This paper presents results of physicochemical parameters in water supply, heavy metals concentrations, and ecological risks in sediment from Buyo hydroelectric dam. In-situ measurement of physicochemical parameters of water and sediment samples were collected in 3 stations along the reservoir from April 2018 to March 2019. The sediment samples have been acidic digested and metal concentrations were analyzed using an atomic absorption spectrophotometer and mercury analyzer. Results indicated that conductivity, oxygen content, temperature, nitrite, and chloride were within the limits established by WHO for potable water, while pH was acidic. The Pearson correlation indicated a strong positive correlation and significant linear relation between various pairs physicochemical parameters. In comparison with upper continental crust concentrations, all heavy metals in sediments showed high concentrations in the upstream than the downstream and pristine stations, with exception of Cu. The geo-accumulation (Igeo) and enrichment factor (EF) indices used indicate that sediments were classified as uncontaminated according to Zn and Mn concentrations and they have a lithogenic source. Whereas, Igeo and EF values of Hg and Cu showed that the sediments lie in the range of moderate to heavily contaminated, suggesting anthropogenic inputs on these metal levels. Except for Hg, which had high ecological risks, Cu, Zn, and Mn pose a low ecological risk. This study provides an insight into water qualities and risk assessment of environmental pollution and important outputs for decision-makers to set policy for resources management.

Keywords: *heavy metals, water, sediments, hydroelectric dam, ecological risk*

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1. Introduction

Dam construction lead to huge economic benefits for human development (e.g hydropower generation, seasonal flood control, irrigation and drinking water supplies, recreation, and navigation). Most of the reservoirs in the world, are built by intercepting of rivers but only 2.2 % are intended to energy production [1]. Although, dams provide many economic benefits, they have considerable negative impacts on the ecosystem [2,3]. Impoundment disturbed the global watershed by changing the hydrologic, basin connectivity, and the sediment regime but also the chemical, biological, and physical characteristic [4,5]. Heavy metals are one of the most common concerns affecting water and sediments quality in reservoir. They are introduced in aquatic system through natural phenomena such as the rock weathering, the volcanic eruption, soil erosion, or from various human activities. Once in aquatic media, heavy metals are accumulate in sediments and they could be release into overlying water following to physicochemical parameters changing [6]. For example, heavy metals precipitate and were absorbed onto sediment surfaces or they are released into water at higher and lower pH, respectively [7]. Also, when the concentration of dissolved oxygen is low (less than 7 mg L^{-1}), metals bound to organic matter sediments are released into overlying water [8,9]. Hence, microorganisms, aquatic flora, fauna, and fish may be contaminated, which, in turn, threaten human health through food chain. The sediments and physicochemical condition characterization can provide substantial information in predicting the extent of heavy metals pollution of reservoir and dam water.

The Buyo hydropower dam is located in Nawa region, in southwest of Côte d'Ivoire. This region covered an area about 9,193 km^2, and the population of 2014 was 1,053,084 [10]. This agricultural region is known for its exportation products cultivation such as cocoa, coffee oil palm, rubber, and banana plantain (Kamelan, 2014). Buyo dam construction was completed in 1980 and it's one of the largest dams in Nawa area. The Buyo dam provide surface drinking water and annual fishing is estimated to 3,900 tons [11]. The sediments of Buyo hydropower dam are an important repository for toxic metals from rivers and surrounding environment. Although, numerous studies have been conducted on heavy metals occurrence in different media of the country such as mining area [12,13], lagoons [14,15], rivers [16,17], landfills [18,19], researchers have paid little attention to the spatial distribution and contamination level assessment of metals in water and sediments.

The objectives of this study was to assess physicochemical parameters variation and quantify the metallic pollutants in the Buyo dam, in order to understand heavy metals contamination status, sources, and ecological risks. To reach this, seven physicochemical parameters were measured in water and Cu, Hg, Zn, and Mn concentrations in surface sediments collected from three stations were determined.

2. Material and Methods

2.1. Study Area Description

Buyo Hydropelectric Dam, is located in Taï area of southwestern Côte d'Ivoire, in Nawa region (Figure 1). This area lies within longitude 06° 54' - 07° 31' W and latitude 06° 14'-07° 03' N. It built since 1981, for power generation, the dam is situated on the Sassandra River [20]. The climate is equatorial with average temperature between about 25°C and 30°C and precipitation reaching up to 1700 mm with two rainfall seasons occurred in June and September. Vegetation is forest type which favours the development of plantations for export products such as rubber, cocoa, coffee, oil palm and, other food crops as maize, cassava and, plantains. As regard geology aspect, Buyo dam is constructed by using embankment and rockfill materials.

Three sampling stations were chosen in study area: Guessabo, Buyo-ville, and PK 15. The Guessabo station is located around Zoukougbeu department, at the upstream from the dam site. It subject to many agricultural activities. The Buyo-ville and PK 15 stations are located at the downstream from dam in the town of Buyo and near a fishermen camp, respectively. The station PK 15 is chosen due its typical position. It situated not far to national park of Taï, which is a pristine area. The GPS coordinates of the sampling stations are summarized in Table 1.

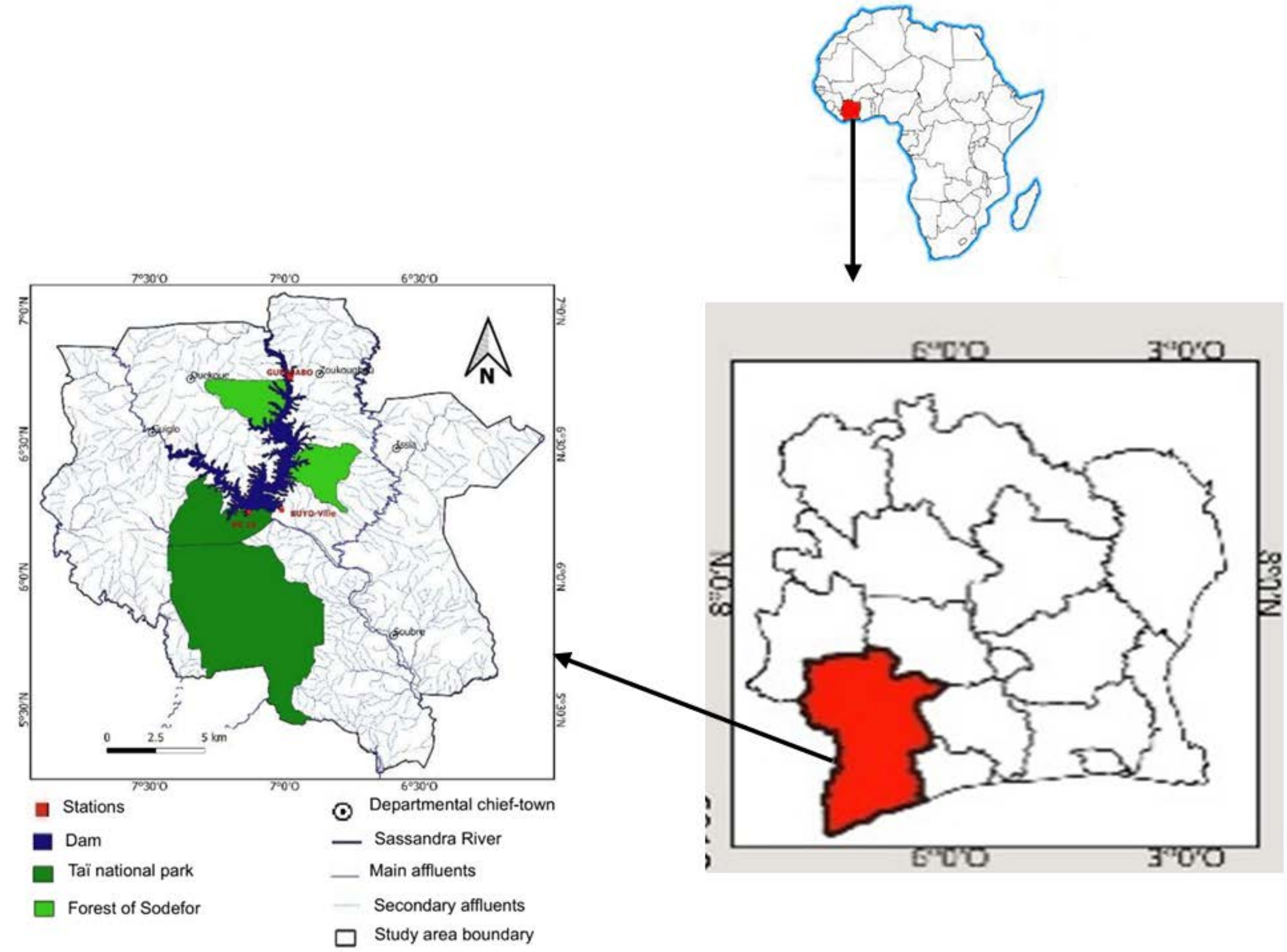

Figure 1. Map of the study area and sampling sites location

Table 1. Sampling stations coordinates

Sampling stations	GPS coordinates
Guessabo	06 ° 45'141. N - 06 ° 58'793. W
Buyo-ville	06 ° 15'109. N - 07 ° 00'577. W
PK15	06 ° 14'599. N - 07 ° 07'954. W

2.2. Sampling and Analytical Methods

To investigate the water quality and trace metal contents in the Buyo dam, water and sediment samples were collected from April 2018 to March 2019. A total of 9 physicochemical parameters were analyzed. Water temperature, pH, dissolved oxygen, conductivity, Total Dissolved Solid, nitrite, total phosphate, total chlorine, transparency were measured during sampling in the field. A multi-parameter (Lovibond, Senso Direct) was used to determine the water temperature, pH, conductivity, total dissolved solid, and dissolved oxygen, while the nitrite, phosphorus, and total chlorine were measured with a photometers (HANNA mini-photometers). The secchi disc deph was measured using a secchi disc in the field, while the dam width was determined visually.

At each station, 6 sediment samples were collected from Buyo dam. All sediment samples were stored in an acid-rinsed plastic bag, placed in an icebox and transported to the laboratory. The sediment samples were air dried at room temperature. The air-dried sediment samples were ground until all particles passed through a 100-mesh nylon sieve after the coarse debris was removed. The dried sediment samples were digested into a closed Teflon vessel with aqua regal (4/1 v/v concentrated hydrochloric acid to concentrated nitric acid) according to Mc Grath and Cunlife (1985). All heavy metals total concentrations in water and sediment samples were determined by flame atomic absorption spectrophotometer (VARIAN SpectrAA 110 type or AAS). All measure of above parameters were done in triplicate and average of the three independent measures was reported. The detection limits for AAS were 0.0010 $mg.L^{-1}$ for Cu, 0.0004 $mg.L^{-1}$ for Zn, 0.0012 $mg.L^{-1}$ for Mn, 0.0013 mg L^{-1} for Fe and 0.1 $\mu g.L^{-1}$ for Hg in water, while in the sediment samples, the detection limits for AAS were 0.019, 0.018, 0.035, 0.013, and 0.051 $mg.kg^{-1}$, for Cu, Zn, Mn, Fe, and Hg, respectively.

2.3. Assessment of Degree and Source Contamination

Geo-accumulation (I_{geo}) and enrichment factor (EF) were indexes currently used to determine the heavy metals contamination level and source in sediment. The I_{geo} index was calculated as indicated by Eq. (1) [21]

$$I_{geo} = \log_2\left(\frac{C_s}{1.5C_{ref}}\right) \quad (1)$$

Where Cs, represents the total concentration measured for a given heavy metal in this study, and C_{ref}, is its geochemical background of the trace metals in the study area while 1.5 is the constant value which multiplied the background concentration of the element in to take account the lithogenic variation. Due to the lack of trace metals background values for the study area, the geochemical background concentrations in the upper continental crust determined by Wedepohl [22] were used. The contamination level may be classified in a seven class (Table 2).

Table 2. Classification of geoaccumulation index (*Igeo*)

Class	*Igeo* values	Sediment contamination levels
0	$Igeo \leq 0$	Uncontaminated
1	$0 < Igeo < 1$	Uncontaminated to moderately contaminated
2	$1 < Igeo < 2$	Moderately contaminated
3	$2 < Igeo < 3$	Moderately to strongly contaminated
4	$3 < Igeo < 4$	Strongly contaminated
t	$4 < Igeo < 5$	Strong to extremely contaminated
6	$Igeo \geq 5$	Extremely contaminated

For estimate natural or anthropogenic origin of the trace metals in sediment, enrichment factor is the most used index [12,23]. According to this technique, metal concentration in sediments was normalized to metal concentrations of average shale [24]. Fe and Al are widely used as normalizer. In this study, Fe is used as normalizer element. The EF index for a metal is defined as follows (Eq. 2):

$$EF = \frac{\left(\frac{C_s}{Fe_s}\right)}{\left(\frac{C_{ref}}{Fe_{ref}}\right)} \quad (2)$$

Where C_s and Fs represent total concentration of a given metal in sediment found in this study and C_{ref} and Fe_{ref} are background concentration in the UCC. According to EF values, trace metal enrichment was divided into 7 classes (Table 3).

Table 3. Enrichment factor classes

Enrichment factor	Categories of contamination
EF < 1	No enrichment
1 < EF < 3	Minor enrichment
3 < EF < 5	Moderate enrichment
5 < EF < 10	Moderately to severe enrichment
10 < EF < 25	Severe enrichment
25 < EF < 50	Very severe enrichment
EF > 50	Extremely enrichment

2.4. Ecological Risk Assessment

The ecological risk index $\left(E_r^i\right)$ was calculated as described in Eq. (3). It used to estimate the ecological risk of an individual metal [23], while the potential ecological risk index (RI) (Eq. 4) was evaluate harmful effects of all the measured trace metals in the examined environment.

$$E_r^i = T_r^i \times \left(\frac{C_i}{C_0}\right) \quad (3)$$

The risk index (RI) of sampling sites was calculated as following:

$$\mathrm{RI} = \sum_{i=1}^{n}\left(\mathrm{T_r^i} \times \left(\frac{\mathrm{C_i}}{\mathrm{C_0}}\right)\right) \quad (4)$$

C_i is the concentration of metal i in the sediment, C_0 is the background concentration of metal (i) in the UCC, given by Wedepohl [22], T_r^i is the biological toxicity factor of an individual element, referring to Hakanson [23], with T_r^i values for Cu = 5, Zn = 1, and Hg = 40; RI is defined as the sum of E_r^i for all trace metals. The Table 4 describe the risk factor E_r^i and RI as suggested by Hakanson [23].

Table 4. Risk factors E_r^i and RI.

E_r^i	Potential ecological risk for single regulator	RI	Ecological risk for all factors
$E_r^i < 40$	Low	RI < 95	Low
$40 \le E_r^i < 80$	Moderate	95 ≤RI < 190	Moderate
$80 \le E_r^i < 160$	Considerable	190 ≤ RI < 380	Considerable
$160 \le E_r^i < 320$	High	RI ≥ 380	Very high
$E_r^i \ge 320$	Very high		

2.5. Statistical Analysis

One-way analysis of variance (ANOVA) was performed on data to compare trace metals concentrations between the sampling sites. The difference was considered significant when the probability p was less than 0.05. The average and standards deviations were calculate using Sigmaplot 12.0 software.

3. Results and Discussion

3.1. Physicochemical Parameters

The physicochemical parameters determined in the three studied stations, and their average and range have been presented in Table 5.

The pH values in water samples were ranged from 4.91 to 5.75 along the dam course. The average values were 5.39±0.20 for Buyo-ville, 5.53±0.19 for Guessabo, and 5.46±0.14 for PK 15. This indicate that acidic are important in Buyo dam. The pH values fall out to the limit (6.5 - 8.5) established by WHO for potability [25], the one-way ANOVA comparison of the water pH values revealed no significant difference between the pH values recorded in the three stations. Average pH value found in this study was less than those (7.60± 0.05) reported by Asare et al. [26] in Bontanga Reservoir in Ghana.

The conductivity values varied from 45.5 to 91.9 µS cm^{-1} for all stations. As compared to Buyo-ville and PK 15, Guessabo station recorded a relatively higher value of conductivity. The highest average conductivity value (81.1±6.92 µS cm^{-1}) was found in dry season at Guessabo, whereas the levels of conductivity were not significantly difference in the three stations.

Low dissolved oxygen level was found in water sample from Buyo dam with values ranged from 1.00 to 7.95 mg L^{-1}. This result indicate that the stations having high organic pollution load. Similarly, Jindal et al. (2011) reported low dissolved oxygen level (2.81 - 4.81 mg L^{-1}) in water samples from Sutlej reservoir in India.

Total dissolved solids (TDS) values ranged from 30.3 to 65.3 mg L^{-1}. The highest and lowest TDS values were recorded at PK 15 station. The average value (of TDS found at Guessabo station was high than those registered at PK 15 and Buyo-ville stations, whereas no significance difference ($p < 0.05$) was observed in their concentrations among station and season.

The temperature is one of the most important parameters that influence almost all the physical, chemical and biological properties of water and it chemistry. The temperature recorded in water samples were ranged between 27.4 and 31.9°C. The highest temperature was registered at PK 15 whereas no statistical difference ($p<0.05$) was not noticed in the temperature values among the stations.

Secchi disc transparency was ranged from 57.5 to 188 cm. The highest average value of transparency (158 ± 29.4 cm) was found at PK 15. No significant difference ($p < 0.05$) was detected among the sampling sites. Consistently with our results, Zhang et al. [27] reported that the Three Gorges reservoirs showed similar transparency values found along the three stations.

Chloride content in water could be monitored water body pollution. In this study, chloride values in water samples varied between < 0.01 to 0.41 mg L^{-1}. The maximum chloride value was found at PK 15 stations whereas no significant difference ($p < 0.05$) was found between the chloride contents. In overall, the chloride values obtained were less than the limit (250 mg. L^{-1}) value indicated by WHO for drinking water in all stations. Low chloride values found in the three stations suggest no degradation of water quality.

Table 5. Physicochemical parameters variation in water from Buyo hydroelectric dam

Stations		pH	Conductivity (µS cm^{-1})	Temperature (°C)	TDS (mg L^{-1})	Dissolved oxygen (mg L^{-1})	Transparency (cm)	Nitrite (mg L^{-1})	Phosphate (mg L^{-1})	Chloride (mg L^{-1})
Buyo-ville	Range	4.91-5.62	54.1-65.8	28.1-31.9	37.3-44.5	1.20-6.80	57.5-132	< 0.01	0.08-0.20	0.01-0.12
	Mean±SD	5.39±0.20	58.8±3.90	30.4 ± 1.17	39.6±2.06	4.31±1.55	106	-	0.18±0.03	0.04±0.04
Guessabo	Range	5.10-5.75	63.0-92.0	27.90-31.8	44.7-61.7	1.00-7.95	58.0-154	<0.01	0.07 -0.20	<0.01 - 0.21
	Mean±SD	5.53±0.19	77.4±8.57	30.5±1.22	51.9±5.15	5.70±2.05	96.5±29.0	-	0.19±0.03	0.07±0.06
PK 15	Range	5.25-5.63	45.5 - 63.9	27.4-31.9	30.4-65.4	4.00-7.00	77.0 - 188	<0.01	0.06-0.20	<0.01 - 0.41
	Mean±SD	5.46±0.14	54.9±5.55	29.92±1.26	38.4±8.70	5.58±0.80	142±33.4	-	0.17±0.04	0.08±0.11
WHO (2011)		**6.5 - 8.5**	**1000**	**16 - 32**	**1000**	**4 - 6**	**-**	**1.00**	**2.50**	**250**

-: not determined.

The nitrites and phosphates values registered in water samples varied from < 0.01 to 0.02 mg L^{-1} and from 0.06 to 0.20 mg L^{-1}, respectively. But no significant difference ($p < 0.05$) was observed in comparison of these parameter values. The nitrites and phosphates values in water samples were below WHO limits values in drinking water, which are 1 mg L^{-1} for nitrite and 2.5 mg L^{-1} for phosphate. Similarly to the chloride content, no pollution was observed for nitrite and phosphate contents found in the Buyo dam.

3.2. Trace Metals Concentrations in Water

Trace metal concentrations in water samples were consigned in Table 6. The concentrations of Zn, Mn and Fe in all stations varied from 0.05 to 0.57 mg L^{-1}, from 0.27 to 0.84 mg L^{-1}, and from 0.50 to 1.66 mg L^{-1}, respectively. The highest average concentrations were recorded at Guessabo for Zn (0.40 ± 0.25 mg L^{-1}) and Fe (1.21±0.21 mg L^{-1}, and at Buyo-ville for Mn (0.59±0.35 mg L^{-1}). The concentrations of Mn and Zn were below, while Fe concentrations exceeded the permissible limit of concentration established by WHO [28]. This result indicate that there is no health risk lie to Buyo dam water consumption. In addition, ANOVA test showed that there is no significant variation ($p < 0.05$) was observed between the concentrations of these elements in the three studied stations. Zinc, Fe and Mn are essential elements for humans and animals. Although there have been epidemiological report adverse neurological effects following extended exposure to very high levels in drinking water but number of these studies have failed to observe effects following exposure through drinking water [28].

The toxic metals Cu and Hg are responsible for many acute and chronic diseases, such as skin and mucous membrane irritation, sensitization, corrosion, dermatitis, and chronic ulceration [28,29]. The concentrations of Cu and Hg in the three stations water samples were ranged from 0.03 to 2.07 mg L^{-1} and from < 0.001 to 0.007 mg L^{-1}, respectively. The highest average concentrations of Cu (1.05 ± 1.44 mg L^{-1}) and Hg (0.004 ± 0.005 mg L^{-1}) were recorded at Guessabo and Buyo-ville stations, respectively. No significant difference ($p < 0.05$) was observed between them concentrations in all stations. Mercury and Cu concentrations were below the admissible limits recommended by WHO, suggested no pollution in Buyo dam water, according to trace metals concentrations. In comparison with our results, Anim-Gyampo et al. [30] reported low concentration values of Zn, Mn and Fe in water samples collected from Tono dam, in Ghana. Similarly, Zn, Mn and Fe concentrations obtained in this study were higher than those observed by Dong et al. [31] in Xiaolangdi reservoir water, China.

3.3. Trace Metals Concentrations in Sediments

Figure 2 summarizes the results of trace metal concentrations in sediment from study area.

The average concentrations of the trace metals in sediments decreased in the following order: Fe > Cu > Mn > Zn > Hg for Buyo-ville, Fe > Mn > Zn > Cu > Hg for Guessabo, and Fe > Mn > Cu > Zn > Hg for PK 15. The studied heavy metal average concentrations showed high variability in the three stations. With the exception of Cu, the highest average concentrations were recorded at Guessabo in the upstream area of the reservoir dam. It indicate that the sediment concentrations in upstream and natural reserve were higher than those observed in downstream area, implying that impacts from anthropogenic activities were most intense in Guessabo station. In addition, compared to the upper continental crust (UCC) values determined by Wedepohl [22], showed that the toxic metals such as Hg and Cu at PK 15 were 8 to 26 folds higher than UCC. It suggested Hg and Cu pollution in studied area including PK 15 which is assumed to be a pristine area.

3.4. Physicochemical Parameters Correlation

Using one-way ANOVA, no significant variation ($p < 0.05$) were noted between the physicochemical parameter values at the three stations. The Pearson correlation matrix for the selected parameters in water are presented in Table 7. Positive correlations were noted for pairs such as pH-O_2, pH-NO_2^-, EC-TDS at Guessabo, TDS-EC, PO_4^- - O_2, Cl^- - PO_4^- at Buyo-ville, and TDS-EC, Cl^- - EC at PK 15. The strong correlation between these pairs indicate single source for the physicochemical parameters.

3.5. Contamination Sources Identification

The resulting Igeo values of trace metals were shown in Figure 3. According to Igeo index values for Cu, Zn, and Mn could be considered as uncontaminated for Zn and Mn (Igeo < 0) and moderately contaminated for Cu (Igeo < 2) in the surface sediments of Buyo dam. The Igeo values of Hg (approximately 3) suggest that moderate to heavily Hg contaminated occurred in all sediments. This result implies also that Hg and Cu were enriched significantly by anthropogenic inputs.

The resulting EF values of trace metals are shown in Figure 4. Mn and Zn are low enrichment with the EFs values less than 1. Cu shows enrichment classified as no enrichment to moderately enrichment with EF values ranged from 1 to 4. Hg shows severe enrichment at PK 15 station (EF = 11.2) and moderately severe enrichment at Guessabo and Buyo-ville stations (5 < EF < 10). This trend indicates that Hg at all sites suffers from anthropogenic source while Cu, Zn, and Mn show moderate to minor enrichment. On the whole, EF and Igeo values indicating that anthropogenic enrichment of Hg occurred in the Buyo dam.

3.6. Potential Ecological Risk Assessment

The ecological factor E_r^i and potential ecological risk (RI) index values are given in Table 8. The ecological risk factor for Cu and Zn were lower than 40 in all stations, which belong to low ecological risk. The ecological risk factors of Hg are 304, 231, and 332 for Guessabo, Buyo-ville, and PK 15 stations, respectively, which reached the high risk level ($160 \leq E_r^i < 320$) for the three studied stations. In overall, the considerable risk status was found in all stations according to the RI mean value was 304, with the highest value recorded at PK 15 station. In all trace metals, Hg presented the highest ecological risk because the highest toxicity factor although the Hg concentrations were lower than other metals.

Table 6. Trace metals concentrations (mg L^{-1}) in water from Buyo hydroelectrique dam

Stations		Cu	Zn	Mn	Hg	Fe
Buyo-ville	Range	0.03-1.71	0.05-0.52	0.34-0.84	<0.001-0.007	0.50-1.66
	Mean±SD	0.87±1.19	0.29±0.33	0.59±0.35	0.004±0.005	1.08±0.82
Guessabo	Range	0.03 - 2.07	0.22-0.57	0.35-0.43	<0.001-0.005	1.07-1.36
	Mean±SD	1.05±1.44	0.40±0.25	0.39±0.06	0.002±0.003	1.21±0.21
PK 15	Range	0.08-1.96	0.21-0.52	0.27-0.30	<0.001-0.005	0.94-1.06
	Mean±SD	1.22±1.33	0.36±0.21	0.29±0.02	0.003±0.003	1.00±0.09
WHO (2003)		**2.00**	**5.00**	**0.50**	**0.006**	**0.3**

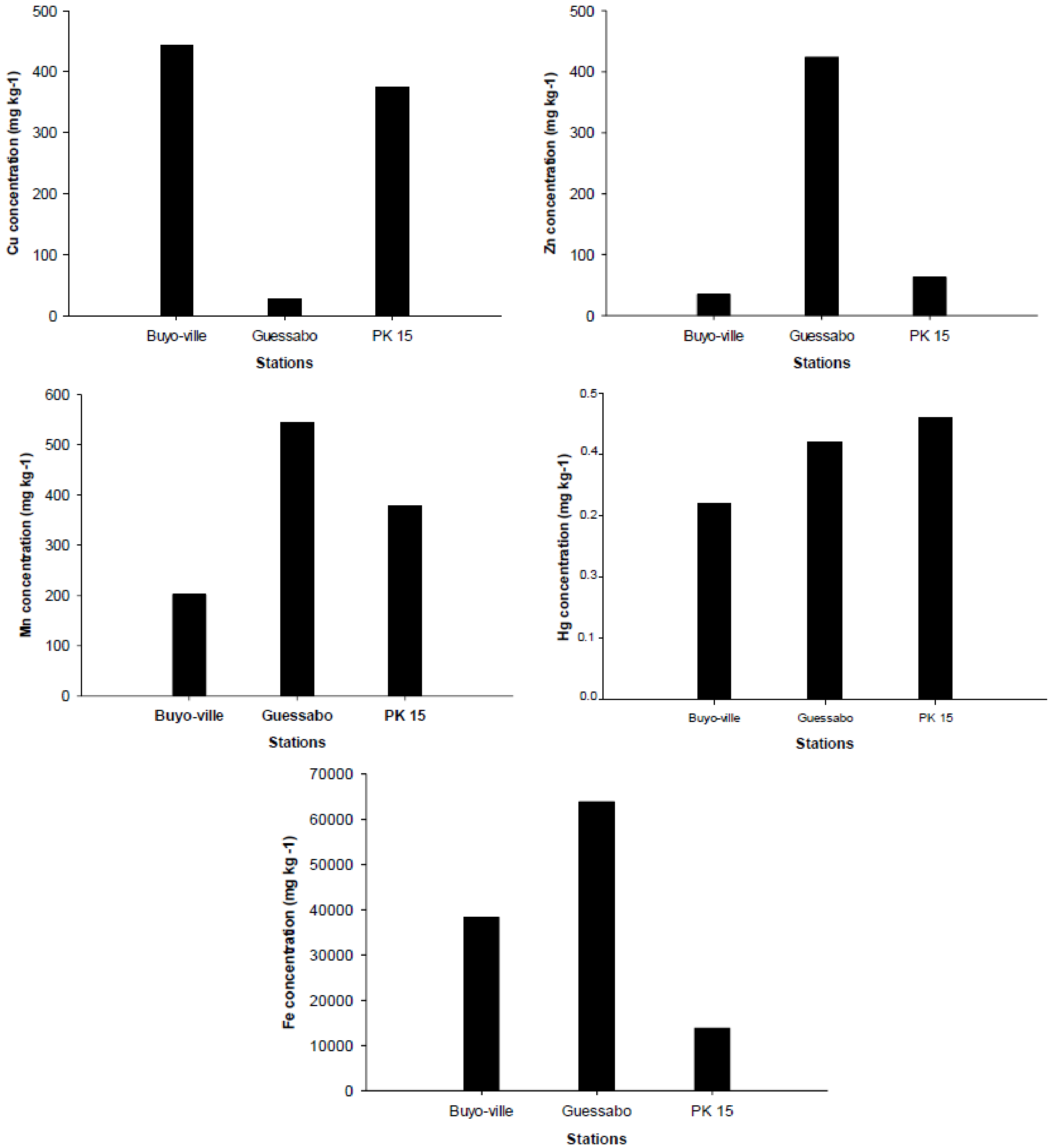

Figure 2. Summary of trace metal concentrations from Buyo hydroelectric dam

Table 7. Correlation matrix for physicochemical parameters in water from the studied stations

Guessabo station							
Parameters	pH	EC	TDS	O_2	NO_2^-	PO_4^-	Cl^-
pH	1						
EC	0.49	1					
TDS	0.34	**0.95**	1				
O_2	**0.59**	0.01	-0.12	1			
NO_2^-	**0.61**	0.24	0.18	0.55	1		
PO_4^-	0.26	-0.39	-0.32	**0.69**	0.29	1	
Cl^-	-0.49	-0.37	-0.24	-0.54	0.05	-0.15	1
Buyo-ville station							
pH	1						
EC	-0.01	1					
TDS	0.01	**0.84**	1				
O_2	-0.01	**-0.67**	-0.38	1			
NO_2^-	0.44	-0.09	-0.19	0.30	1		
PO_4^-	0.44	-0.50	-0.17	**0.67**	0.31	1	
Cl^-	-0.44	0.51	0.26	**-0.59**	-0.33	**-0.62**	1
PK 15 station							
pH	1						
EC	0.30	1					
TDS	0.39	**0.73**	1				
O_2	0.17	0.07	0.28	1			
NO_2^-	0.48	0.54	0.33	0.14	1		
PO_4^-	-0.15	-0.13	0.01	-0.41	-0.01	1	
Cl^-	-0.15	**0.58**	0.12	-0.19	0.46	0.06	1

In bold significant correlation at the 0.05 level.

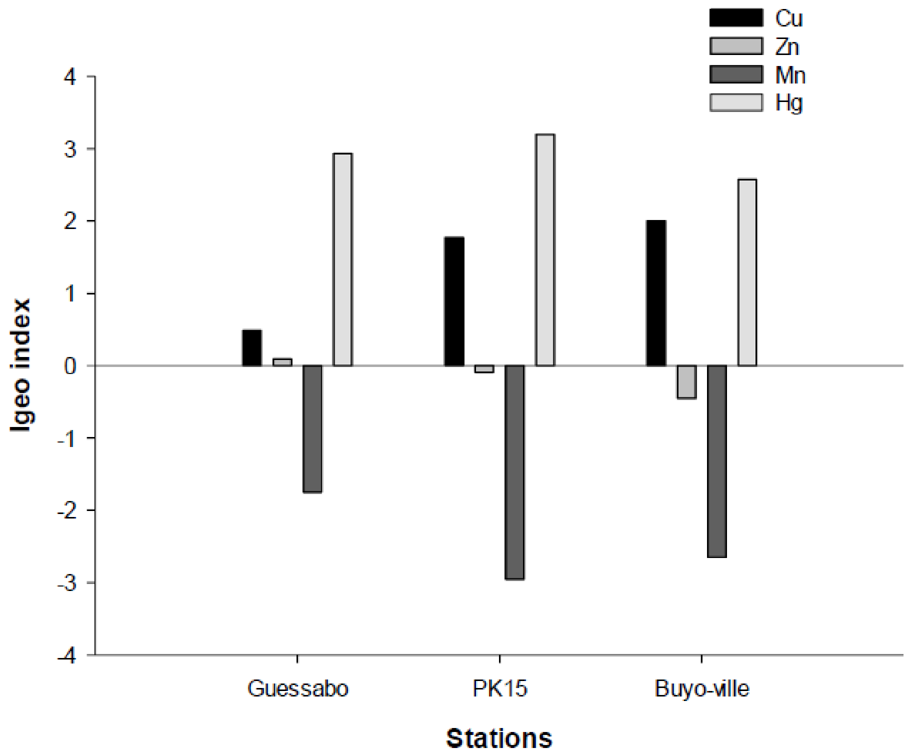

Figure 3. The geoaccumulation index for trace metals in surface sediments from Buyo hydroelectric dam

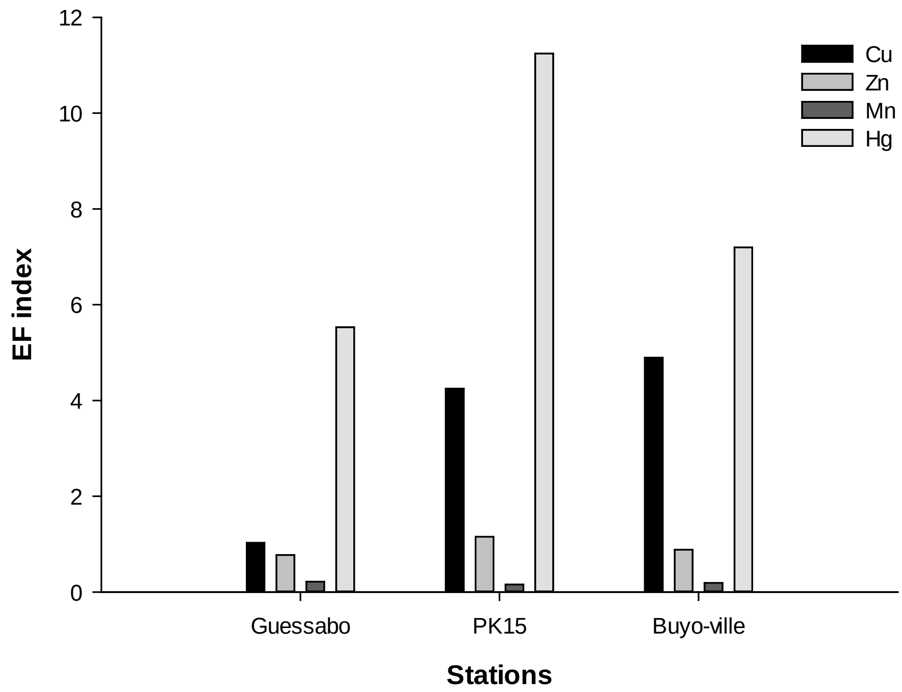

Figure 4. The enrichment factor values for trace metals in surface sediments

Table 8. Ecological risk factor (E_r^i) and the potential ecological risk index (RI) of trace metals in surface sediments of Buyo dam.

Stations	E_r^i			RI
	Cu	Zn	Hg	
Guessabo	9.63	0.96	304	314
PK 15	14.1	1.21	332	347
Buyo-ville	18.5	0.67	231	250
Mean	**14.1**	**0.945**	**289**	**304**

Based on the ecological risk factors and the ecological potential risk index, Hg must be put in high attention as ecological hazard and be considered as priority pollutant. Therefore, the monitoring and improvement for Buyo dam should be strengthened to prevent pollution aggravation in drinking water source.

3.7. Limitations of the Study

This study assessed spatial, seasonal distribution of trace metals in water and sediments from Buyo hydroelectric dam and ecological risk. The sample size was small. Further studies should be include a statistically appropriate number of water and sediment samples. On the other hand, local background value must be used as reference in further research for a better metal enrichment understanding.

4. Conclusion

This study examined the distribution of heavy metal concentrations and ecological risk in water and sediments from Buyo hydroelectric dam. The physicochemical parameter values indicated that the water samples from Buyo dam was safe for consumption. The pH for all water samples were below the limit (6.4 - 8.5) established by WHO for drinking water. The heavy metal concentrations in water were within the prescribed limits whereas, sediments collected at PK 15 station were contaminated by Hg and Cu. It was supported by the result of the Igeo and EF, which indicate that this site is moderately to heavily contaminate and moderately to severely enriched with Cu and Hg. The analysis of ecological risk (E^i_r) for a single element in sediment showed that Cu and Zn presented low ecological risk, and Hg pose a very high risk. The ecological risk index for all studied metals showed a risk level belonged in the category of considerable risk. The appropriation and updating of these data are necessary for implementation of water quality continuous monitoring and the establishment of local water and sediment guidelines.

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Statement of Competing Interests

The authors declare that they have no conflict of interest.

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