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PHYSICO-CHEMICAL CHARACTERISTICS OF THE BUI DAM AREA OF THE BLACK VOLTA RIVER, GHANA

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ABSTRACT

Pre- and post-impoundment studies of physical and chemical parameters of water in the Bui dam area of the Black Volta were carried out from March 2011–December 2012. The physico-chemical parameters monitored fell within the ranges suitable for the sustenance of aquatic life in freshwater bodies with the exception of dissolved oxygen, nitrates, sulphates and phosphates. The physico-chemical characteristics showed wide seasonal variations, while between sampling stations the differences were insignificant ($p>0.05$). Electrical conductivity, total dissolved solids, colour, dissolved oxygen, nitrates and sulphates differed significantly ($p<0.05$) in the pre-impoundment (March–May 2011), immediate post-impoundment (June–December 2011) and late post-impoundment (January–December 2012) periods. Hence, reflecting the alterations in the river continuum due to impoundment. Nitrates, sulphates and phosphates were outside recommended ranges suitable for aquatic life. The reasons for these high nutrient levels were not clear in this study and therefore require further research. In the interim however, agricultural activities, especially the use of inorganic fertilizers within the catchment area, should be monitored and controlled by the Bole District Assembly, the Bamboi and Bui Traditional Councils, the Ministry of Fisheries and Aquaculture Development and the Bui Power Authority.

Key Words: Water quality, parameters, impoundment, Black Volta River

INTRODUCTION

Building a dam across a river, and impounding water behind it, may cause profound changes in the limnological regime of the water body (Egborge, 1979; Reynolds, 1997; Ogbeibu and Oribhabor, 2002). The ecological impacts of impounding a river have been dramatic and extensive. Dams can affect the geomorphology of streams that have a large sediment load, as the reservoir traps sediments and release clear water. The resulting downstream geomorphic effects of clear water releases from dams include channel instability and alteration of habitat (Collier *et al*., 1996).

Flow variability controls physico-chemical and hydro-biological phenomena in a river. Impoundments, particularly those of storage-release nature, reduce the natural variability of flow, although hydro-power impoundments may increase diel variability. Some hydro-power dams have underground power stations, resulting in the desiccation of a section of the river downstream of the dam. Resident fishes experiencing flow alterations may be affected for great distances downstream. Flow modifications affect water quality, water depth and velocity, substrate composition, food production and transport, stimuli for migration and spawning, survival of eggs, and eventually fish species composition (Petts, 1984). Reductions in sediment load caused by impoundments prompt the river downstream to recapture its load by eroding the downstream channel and banks. Release patterns also affect downstream biota in several ways (Welcomme, 1985). Large flow variations may adversely affect downstream productivity by impacting spawning and disrupting benthic populations. Lower nutrient concentrations in releases can result in lower primary production in the tail water. Conversely, nutrient-rich releases stimulate increases and lavish development of algae and macrophytes. The benthic community may shift towards grazers and collectors and experience loss of diversity as organisms depending on thermal cues for spawning, hatching and emergence will dwindle (FAO, 2001).

The Black Volta has so far received little limnological studies. The physico-chemical factors measured by Petr (1970) from April 1965 to April 1967 in the Black Volta were temperature, pH and dissolved oxygen. Also, Welcomme (1972) recorded conductivity and pH values in the Black Volta. The Snowy Mountains Engineering Corporation feasibility study conducted in the 1970s made an assessment of water quality in the Black Volta based on spot measurements taken in May 1976 at Bui, and reached the conclusion that the river was a suitable source that can be treated for drinking and other purposes and that slightly acidic to slightly alkaline conditions exist in the Black Volta with sampled values ranging from 6.6 to 7.2 (Environmental Resources Management, ERM, 2007).

Water quality parameters in the Black Volta including surface water temperature, pH, turbidity, nutrient levels, and dissolved oxygen also fulfilled the biological requirements of aquatic flora and fauna (Gordon *et al*., 2003). The waters were generally turbid, with high levels of total suspended solids; however, such levels were not so high as to adversely affect the presence or abundance of aquatic flora and fauna. It is anticipated that there will be changes in the water quality of the Black Volta soon after the creation of the Bui dam. The objectives of this study were therefore, firstly to analyze the seasonal variations in the physico-chemical parameters, and secondly, to give a comparative account of the same parameters in the pre- and post-impoundment periods of the Black Volta River, with a view of identifying significant changes attributable to the river impoundment. The current study will therefore generate information on the water quality in both periods of impoundment.

MATERIALS AND METHODS

Study area

The study was conducted in the Bui dam section of the Black Volta River. The study area stretched from the Bui reservoir (upstream) to Bamboi (downstream) within latitudes 8º 09´ - 8º 16´ N and longitudes 2º 01´ - 2º 15´ W covering a distance of about 37.5 km. Two sampling stations were chosen: the upstream station at Bui (08° 16' 829" N and 02° 15' 470" W) and the downstream station at Bamboi (08° 09' 249" N and 02° 01' 940" W) (Fig. 1). This formed part of the Black Volta basin primarily located in north-western Ghana approximately 150 km upstream of Lake Volta. The basin covers parts of the Upper, Northern and Brong Ahafo Regions of Ghana. The basin embraces the total catchment area of 142,056 km^2 including areas outside Ghana. The part of the Black Volta in Ghana is estimated to be 650 km in length with a catchment area of 35,105 km^2 (Vanden Bossche and Bernacsek, 1990).

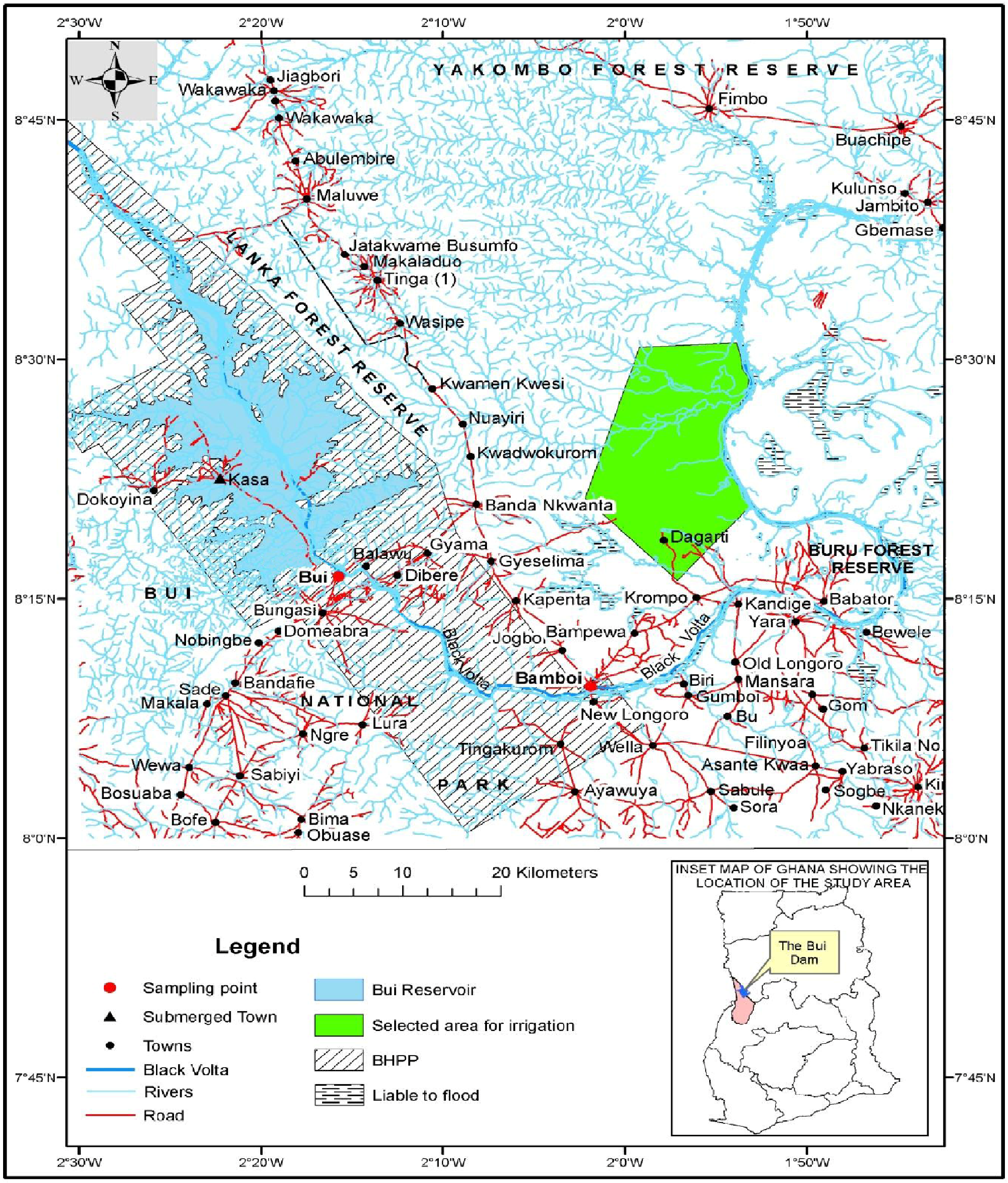

Fig. 1: Map of study area showing sampling stations (after Ofori-Danson *et al.*, 2012)

Study design

In order to provide an all-year picture of the water quality of the study area, a three-level stratified sampling approach was adopted. The first stratum, which was defined by the four designated hydrological seasons in the study area, was referred to as follows: dry season (January to March); pre-wet season (April to June); wet season (July to September); and post-wet season (October to December) (Abban *et al.*, 2000). The second stratum, which was defined by the three impoundment periods in the study area, included: pre-impoundment (March to May 2011); immediate post-impoundment (June to December 2011); and late post-impoundment (January to December 2012). The third stratum, on the other hand, which was defined to improve sampling for accuracy included: upstream of the dam site or reservoir area with sampling station at Bui (old town currently submerged); and downstream of the dam site area with sampling station at Bamboi (a distance of about 37.5 km).

Measurement of physico-chemical parameters

Monthly readings of temperature, pH, dissolved oxygen, conductivity, colour and TDS were taken in the field using the multi-purpose Water Quality Checker or probe (HI 9829 Hanna Multi-parameter). The probe was immersed in the water at each of the two sampling stations and the mode for each of the above parameters pressed and when the figure registered on the screen became stable, it was recorded. Three readings, about 30.0 cm below the water surface were taken at each sampling station for each of the above parameters and the average value found was recorded. Water samples were also taken from the same depth at each station with a 2.0-litre Hydro-Bios Kiel TP® water sampler to the laboratory for nutrient content analysis.

Nutrient content analysis

The nutrients analysed were phosphates, nitrates and sulphates using a Hach DR2010® direct-reading spectrophotometer and pre-package reagents within 24 hours after sampling. For phosphates analysis, about 25 ml of the water taken to the laboratory was measured into a reaction bottle and Phos Ver 3 reagent added and swirled. The sample was then allowed to stand for 2 minutes. Blue colour indicated the presence of phosphates in the sample. The concentration of phosphate was recorded in mgL^{-1}on a spectrophotometer at 890 nm to two decimal places following the methods described in APHA (1998). For nitrates analysis, another 25 ml of water was measured into a reaction bottle and Nitra Ver 5 reagent added and shaken for 1 minute. The sample was then allowed to stand for 5 minutes. Brown colour indicated the presence of nitrates in the sample. The concentration of nitrates was recorded in mgL^{-1} to two decimal places on the spectrophotometer at 400 nm following the methods described in APHA (1998).

For sulphates analysis, about 10 ml of water sample was measured into a 25 ml erlenmeyer flask. Exactly 0.5 ml conditioning reagent was added and mixed by stirring uniformly. A table spoonful of barium chloride crystals was then added while still stirring and timing immediately for 60 seconds at a constant speed. After stirring, the absorbance rate was measured at 420 nm on the spectrophotometer within 5 minutes. The concentration of sulphate was read directly from the calibration curve and the results expressed in mgL^{-1} to two decimal places.

Statistical analysis

Descriptive statistics, Analysis of Variance (ANOVA), correlation and student's *t*-tests were used for data analysis. One way analysis of variance (ANOVA) of SPSS v. 16 was used. Fixed effect ANOVAs were performed using dates as replicates. Where there were significant differences ($p<0.05$) among means, the Duncan multiple range (DMR) test was used to compare the treatment means. The Pearson's rank correlation was used to examine correlation between parameters. All tests were two-tailed, a probability value of $p<0.05$ was considered statistically significant.

RESULTS

There were spatial and seasonal variations recorded in physico-chemical parameters in the Bui dam area of the

Black Volta during the study period, as shown in Tables 1, 2, 3 and 4. For instance, the mean seasonal physico-chemical characteristic for the 2012 sampling year indicated that, EC values decreased from 122.53 µS/cm in the wet season to 82.3 µS/cm in post-wet season with significant difference (p<0.05) between pre-wet season and post-wet season (Table 2). TDS on the other hand decreased from 85.47 mgL^{-1} during the pre-impoundment period to 48.08 mgL^{-1} during the immediate post-impoundment period. There were significant differences (p<0.05) between the pre-impoundment, immediate post-impoundment and late post-impoundment periods (Table 3).

Correlation matrix

Correlation analyses showed that there were significant differences in quality of water measured in 2011 and 2012. In 2011, significant differences suggested strongly positive relationship between parameters such as TDS and conductivity (r=0.997**,** p< 0.05), nitrates and sulphates (r=0.8199, p< 0.05) (Table 5). In 2012, temperature strongly correlated with pH (r=0.9932**,** p<0.05) and DO also correlated with sulphates (r= 0.9943, p< 0.05) (Table 6).

DISCUSSION

Temperature is important because of its effect on chemical and biological reactions in aquatic organisms (Trivedy and Goel, 1986). It is the most important physical parameter and has a pronounced effect on biochemical reactions in fish. The Black Volta near the Bui dam showed narrow differences in temperature during the four hydrological seasons. This could be due to the fact that river water showed little thermal stratification because of the turbulent flow which ensures that any heat received is evenly distributed. Aquatic organisms have their own tolerance limits to temperature and this affects their distribution and migration. The temperature range of 27.2±0.15–30.2±0.62 ºC recorded in this study was favourable and could support fisheries and aquatic life and similar to earlier findings (29.8 ºC–31.7 ºC) by Petr (1970) in the Black Volta. According to Alabaster and Lloyd (1980), the temperature of natural inland waters in the tropics generally varies between 25 and 35 ºC. Similar observations were made on the Volta Lake by Ofori-Danson and Ntow (2005). There was no significant difference (p>0.05) in temperature measured between the pre- and post-impoundment periods. Hence, temperature did not change following the impoundment of the Black Volta by the Bui dam.

The pH of a water body is very important for the determination of water quality since it affects other chemical reactions such as solubility and metal toxicity (Fakayode, 2005). Freshwaters with little change in pH are generally more conducive to aquatic life. The pH levels encountered in this study (6.9–8.3) were considered suitable for fish growth since the best pH values for the survival of fish in freshwaters have been reported to range from 5–9 (Jobling, 1995). Petr (1970) made similar observations for pH values of 7.7–8.6 in the Black Volta. Abowei (2010) however noted that, pH higher than 7 but lower than 8.5 is ideal for biological productivity, while pH lower than 4 is detrimental to life in freshwaters (Chapman and Kimstach, 1996). There was no significant difference (p>0.05) in pH measured between the pre- and post-impoundment periods. Hence, pH did not change following the impoundment of the Black Volta by the Bui dam.

Table 1: Seasonal variation in physico-chemical parameters in 2011 (mean ± standard error)

Parameter	Dry season	Pre-wet season	wet season	Post-wet season
Conductivity (µS/cm)	141.83[a] ± 0.65	129.97[a] ± 12.94	84.83[b] ± 7.92	75.07[b] ± 2.06
Total Dissolved Solids (mgl^{-1})	85.03[a] ± 0.31	78.09[a] ± 7.98	50.80[b] ± 4.71	40.50[b] ± 3.50
pH (pH unit)	7.16[a] ± 0.22	7.61[a] ± 0.08	7.17[a] ± 0.17	7.78[a] ± 0.43
Temperature (ºC)	29.50[a] ± 0.12	27.90[a] ± 1.41	27.37[a] ± 1.53	29.63[a] ± 0.13
Colour (Hz)	28.33[b] ± 1.67	165.00[ab] ± 10.54	291.67[a] ± 20.83	191.67[ab] ± 12.02
Nitrates (mgL^{-1})	0.25[b] ± 0.35	2.32[a] ± 0.96	2.96[a] ± 0.12	1.83[ab] ± 0.39
Sulphates (mgL^{-1})	3.85[c] ± 1.16	14.34[bc] ± 9.04	36.28[a] ± 1.78	21.73[ab] ± 0.43
Phosphates (mgL^{-1})	0.04[a] ± 0.18	0.02[a] ± 0.02	0.01[a] ± 0.01	0.29[a] ± 0.18
Dissolved Oxygen (mgL^{-1})	2.47[a] ± 0.58	2.51[a] ± 0.47	2.73[a] ± 0.12	1.77[b] ± 0.15
Water level (m)	0.85[a] ± 0.10	1.39[a] ± 0.36	5.73[a] ± 1.69	3.97[a] ± 2.27

Figures on the same row with different superscript letters are significantly different ($p < 0.05$)

Table 2: Seasonal variation in physico-chemical parameters in 2012 (mean ± standard error)

Parameter	Dry season	Pre-wet season	wet season	Post-wet season
Conductivity (µS/cm)	104.07[ab] ±2.95	98.63[ab] ± 4.81	122.53[a] ± 15.31	82.30[b] ± 2.03
Total Dissolved Solids (mgl^{-1})	62.50[b] ± 1.85	59.57[b] ± 2.66	76.67[a] ± 7.05	65.60[ab] ± 2.27
pH (pH unit)	7.16[a] ± 0.22	7.61[a] ± 0.08	7.17[a] ± 0.17	7.78[a] ± 0.43
Temperature (ºC)	30.20[a] ± 0.62	29.57[a] ± 1.84	27.20[a] ± 0.15	28.80[a] ± 0.15
Colour (Hz)	29.17[a] ± 16.73	32.50[a] ± 1.51	139.43[a] ± 61.68	67.53[a] ± 1.57
Nitrates (mgL^{-1})	1.12[a] ± 0.19	2.13[a] ± 0.91	2.25[a] ± 0.14	1.53[a] ± 0.38
Sulphates (mgL^{-1})	3.85[c] ± 1.89	7.67[bc] ± 4.66	21.13[a] ± 4.73	16.30[ab] ± 2.28
Phosphates (mgL^{-1})	-	-	0.11[a] ± 0.00	0.11[a] ± 0.02
Dissolved Oxygen (mgL^{-1})	3.30[b] ± 1.10	3.97[ab] ± 0.89	6.00[a] ± 0.06	5.87[a] ± 0.03
Water level (m)	0.89[a] ± 0.02	1.70[a] ± 0.70	1.34[a] ± 0.34	1.53[a] ± 0.49

Figures on the same row with different superscript letters are significantly different ($p < 0.05$)

Table 3: **Variations in physico-chemical parameters during the pre- and post-impoundment periods (mean ± standard error)**

Parameter	Pre-impoundment (Mar - May 2011)	Immediate post-impoundment (June - Dec 2011)	Late post-impoundment (Jan - Dec 2012)	*P* value
Conductivity (µS/cm)	$142.13^{a} \pm 0.93$	$83.40^{b} \pm 4.99$	$101.88^{b} \pm 5.57$	0.00^{*}
TDS (mg/l)	$85.47^{a} \pm 0.35$	$48.08^{b} \pm 3.83$	$66.07^{c} \pm 2.59$	0.00^{*}
pH	$7.49^{a} \pm 0.19$	$7.47^{a} \pm 0.21$	$7.57^{a} \pm 0.08$	0.14
Temperature (ºC)	$29.27^{a} \pm 0.20$	$28.01^{a} \pm 0.87$	$28.94^{a} \pm 0.54$	0.52
Colour (Hz)	$50.00^{a} \pm 13.23$	$260.71^{b} \pm 28.33$	$67.16^{a} \pm 19.36$	0.00^{*}
Dissolved oxygen (mgL^{-1})	$2.56^{a} \pm 0.07$	$2.27^{a} \pm 0.19$	$4.78^{b} \pm 0.46$	0.00^{*}
Nitrates (mgL^{-1})	$1.07^{a} \pm 0.61$	$2.62^{b} \pm 0.35$	$1.76^{ab} \pm 0.26$	0.05^{*}
Phosphates (mgL^{-1})	$0.02^{a} \pm 0.02$	$0.13^{a} \pm 0.09$	$0.05^{a} \pm 0.02$	0.39
Sulphates (mgL^{-1})	$5.00^{a} \pm 2.23$	$29.42^{b} \pm 2.86$	$13.7^{a} \pm 2.27$	0.00^{*}
Water level (m)	$0.98^{a} \pm 0.10$	$4.45^{b} \pm 1.19$	$1.36^{a} \pm 0.22$	0.01^{*}

*on the P value indicates significant differences ($p<0.05$); figures on the same row with different superscript letters are also significantly different ($p<0.05$)

Table 4: Spatial variation in physico-chemical parameters in 2011 and 2012 (mean ± standard error)

Parameter	2011		2012	
	Bamboi	Bui	Bamboi	Bui
Conductivity (µS/cm)	$101.00^{a} \pm 9.59$	$101.05^{a} \pm 12.88$	$101.88^{a} \pm 5.57$	$101.04^{a} \pm 7.82$
Total Dissolved Solids (mgl^{-1})	$59.29^{a} \pm 6.28$	$58.99^{a} \pm 8.14$	$66.08^{a} \pm 2.59$	$59.11^{a} \pm 5.00$
Temperature (ºC)	$28.40^{a} \pm 0.63$	$28.68^{a} \pm 0.79$	$28.94^{a} \pm 0.54$	$28.54^{a} \pm 0.49$
Colour (Hz)	$197.50^{a} \pm 37.71$	$114.80^{a} \pm 24.12$	$67.16^{a} \pm 19.36$	$156.10^{a} \pm 23.76$
Nitrates (mgL^{-1})	$2.16^{a} \pm 0.37$	$1.86^{a} \pm 0.40$	$1.76^{a} \pm 0.26$	$2.01^{a} \pm 0.27$
Sulphates (mgL-1)	$22.09^{a} \pm 4.25$	$19.82^{a} \pm 4.03$	$12.24^{a} \pm 2.58$	$20.96^{a} \pm 2.86$
Phosphates (mgL^{-1})	$0.10^{a} \pm 0.06$	$0.21^{a} \pm 0.19$	$0.06^{a} \pm 0.02$	$0.16^{a} \pm 0.99$
Dissolved Oxygen (mgL^{-1})	$2.35^{a} \pm 0.14$	$2.39^{a} \pm 0.11$	$4.78^{a} \pm 0.46$	$2.37^{a} \pm 0.09$

Figures on the same row with same superscript letters within the same year are homogenous ($p < 0.05$)

Table 5: Correlation analyses showing physico-chemical factors measured in 2011

	Cond.	TDS	pH	Temp.	Nitrates	Sulphate	Phos.	DO
Cond.	1							
TDS	0.997*	1						
pH	-0.2488	-0.2991	1					
Temp.	-0.0353	-0.1049	0.2994	1				
Nitrates	-0.5002	-0.4519	0.1629	-0.795	1			
Sulphate	-0.807	-0.7596	-0.1098	-0.5405	0.8199*	1		
Phos.	-0.634	-0.6919	0.6713	0.7181*	-0.1488	0.0624	1	
DO	0.4612	0.5282	-0.7431	-0.7879	0.2671	0.1361	-0.9771	1

*Correlation is significant at 0.05 Level

Table 6: Correlation analyses showing physico-chemical factors measured in 2012

	Cond.	TDS	pH	Temp.	Nitrates	Sulphate	Phos.	DO
Cond.	1							
TDS	0.9129*	1						
pH	-0.8833	-0.9843	1					
Temp.	-0.8499	-0.9572	0.9932*	1				
Colour	0.8926*	0.989*	-0.9996	-0.9895				
Nitrates	0.4889	0.497	-0.6347	-0.7153	1			
Sulphate	0.7908	0.9438*	-0.984	-0.9933	0.6968	1		
Phos.	0.7538	0.9534*	-0.9659	-0.9569	0.5328	0.9767*	1	
DO	0.7237	0.9162*	-0.9622	-0.9755	0.6823	0.9943*	0.9805*	1

*Correlation is significant at 0.05 Level

Oxygen is essential to all forms of aquatic life as it affects the growth, survival, distribution and physiology of aquatic organisms. It is also an important limnological parameter indicating the level of water quality and organic pollution in a water body (Wetzel and Likens, 2006). Oxygen concentration in water is controlled by four factors: photosynthesis, respiration, exchanges at the air-water interface, and supply of water to the water body (Erez *et al*., 1990). The mean dissolved oxygen levels of 3.37 mgL^{-1} in 2011 and 4.78 mgL^{-1} in 2012 were below the 5 mgL^{-1} threshold needed to support fish life in freshwaters (Hynes, 1970; Chapman and Kimstach, 1996). This could be due to the continuous input and decomposition of allochthonous detritus which tends to decrease the oxygen concentration even in periods of autotrophy (Carvalho *et al*., 2001). There was a negative correlation ($r=-0.79$) between dissolved oxygen and temperature. According to Wetzel (2001), there is a direct effect of temperature on the solubility of gases, in particular dissolved oxygen. In addition, there is a direct temperature effect on decomposition rates due to microbial activity. Hence an increase in temperature can cause a two-fold to three-fold increase in bacterial activity, and consequently decreased dissolved oxygen concentrations (Rocha *et al*., 2009). The negative effect of temperature on oxygen concentration as reflected in this study corroborates other studies that showed that high temperatures found in tropical aquatic ecosystems are responsible for rapid detritus breakdown (Carvalho *et al*., 2005). The low level of dissolved oxygen (2.27 mgL^{-1}) recorded during the immediate post-impoundment period indicated deteriorating water quality which probably resulted from the death and decay of aquatic macrophytes, increased active organic decomposition in the bottom sediment and the absence of flow induced turbulence which normally enhance oxygen dissolution in water (Ogbeibu and Oribhabor, 2002). There was significant difference ($p<0.001$) in Dissolved Oxygen concentration measured between the pre- and post-impoundment periods. Hence, Dissolved Oxygen concentration changed following the impoundment of the Black Volta by the Bui dam.

The conductivity of water is dependent on its ionic concentrations and temperature. It provides a good indication of the changes in water composition particularly its mineral concentration. There was a significant difference ($p < 0.001$) in the conductivity measured between the pre- and post-impoundment periods. Hence, conductivity of the water changed following the impoundment of the Black Volta by the Bui dam. The conductivity values of 75.07–142.13 µS/cm recorded in this study in the water of the Black Volta confirms its freshness (Chapman and Kimstach, 1996). There is also a relationship between conductivity and total dissolved solids in water. As more dissolved solids are added, the water conductivity increases (Bhatt *et al*., 1999; Abowei *et al*., 2010). This scenario of direct relationship between conductivity and TDS ($r=0.997$) was observed throughout the four hydrological seasons in this study. TDS levels have been used to evaluate water purity since many of these solutes could be pollutants in the aquatic environment. There was a significant difference ($p<0.001$) in the TDS levels measured between the pre- and post-impoundment periods. Hence, TDS of the water changed following the impoundment of the Black Volta by the Bui dam.

There were high nutrient levels in the Black Volta near the Bui dam. Nitrate levels exceeded optimum considering the global average of 0.1mgL^{-1} in freshwater (Meybeck and Helmer, 1989). The positive correlation ($r=0.68$) in 2012 between nitrates and dissolved oxygen in this study could be explained by the dependence of the nitrification process on oxygen supply (Wetzel, 2001). There was a significant difference ($p<0.05$) in the nitrate levels measured between the pre- and post-impoundment periods. Hence, nitrate concentration of the water changed following the impoundment of the Black Volta by the Bui dam. The concentrations of sulphates also exceeded the average of 4.8 mgL^{-1} for freshwaters (Meybeck and Helmer, 1989). Mean seasonal sulphate concentrations measured in this study was 19.05 $mgL^{-1}$and 12.24 mgL^{-1} in 2011 and 2012 respectively. It may thus be inferred that sulphate was abundant in the Bui dam area of the Black Volta. There was a significant difference ($p<0.001$) in the sulphate levels measured between the pre- and post-impoundment periods. Hence, sulphate concentration of the water changed following the impoundment of the Black Volta by the Bui dam. Though the optimum ranges of phosphate in freshwater is 0.005–0.05 mgL^{-1} (Dunne and Leopold, 1978), mean seasonal phosphate levels recorded in this study were 0.09 mgL^{-1} in 2011 and 0.06 mgL^{-1} in 2012. The concentration of phosphates in uncontaminated waters is reported to be about 0.01 mgL^{-1} (McNeely *et al*., 1979). There was no significant difference ($p> 0.05$) in phosphate levels measured between the pre- and post-impoundment periods. Hence, phosphate concentration did not change following the impoundment of the Black Volta by the Bui dam. The reasons for these high nutrient levels in the Bui dam area of the Black Volta was not clearly known in this study. It could however, be due to the breakdown of submerged dead plant materials as a result of the impoundment of the Black Volta. These high nutrient levels could however, be comparatively short-lived, and therefore requires further investigation by researchers. There was also a significant difference ($p<0.05$) in the water level measured between the pre- and post-impoundment periods. Hence, the depth of water changed following the impoundment of the Black Volta by the Bui dam.

CONCLUSION

The physico-chemical parameters measured during the study differed significantly ($p<0.05$) between the pre- and post-impoundment periods except for pH, temperature and phosphates, hence reflecting the alterations in the river continuum due to impoundment by the Bui dam.

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