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Research Article

Dam-induced Pollution in Ghana: Assessment of the Activities of Resettled Communities in the Vicinity of Bui Power Project on Freshwater Bodies

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Abstract

Dam-induced pollution of freshwater bodies in sub-Saharan Africa has increased with its attendant resettlement challenges. The damming of the Black Volta in Ghana led to the resettlement of some inhabitants who lived close to the Black Volta. The study aims to investigate the impact of the Bui Power Project on the surface water quality of its resettlement communities, 5 years after the operation of the dam. The study employed standard operating protocols to assess selected physicochemical indicators of pollution in selected freshwater bodies in the study area over a 12 month period. Parameters analysed included pH, conductivity, total dissolved solids, alkalinity, calcium, magnesium, BOD, COD, $SO_4{}^{2-}$, DO and total hardness. Membrane filtration technique was employed to enumerate total coliform, feacal coliform and E. coli using Chromocult Coliform Agar. The result showed that pH levels did not differ significantly among the analysed freshwater bodies. The Black Volta showed a large deviation from its baseline pH value (7.0). Agbelekame South and Bongaase Nsuano freshwater bodies recorded significantly high electrical conductivity (78.97 ± 2.758) and alkalinity (33.38 mg/L), respectively. TDS of the Black Volta was also significantly high (96.5 mg/L), however, it had a much lower value than its baseline (166.3 mg/L). Magnesium level in the Agblekame South was high (31.83 mg/L) followed by Gyama Nsuano (23.23 mg/L). The Black Volta also had an elevated BOD (26.75 mg/L) and COD (71 mg/L) values. Faecal coliform from Agbelekame North and Agbelekame South (4.4×10^4 and 4.0×10^4 cfu/100mL, respectively) exceeded the GEPA/WHO acceptable guidelines for drinking water. Bongaase Nsuano and Gyama Nsuano recorded high total coliform count (9.1 cfu/100 mL and 15 cfu/100 mL, respectively) with values exceeding the recommended guidelines. Our study has provided evidence to show that adjoining surface waterbodies around the Bui power project were microbiologically polluted due to resettlement of communities around the Bui Dam environs.

Keywords
Dam-induced Pollution, Water Pollution, Analytical Assessment, Drinking water quality, Impact of Dams, Ghana

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Contents

1. Introduction

In recent times, dam-induced pollution of freshwater bodies in sub-Saharan Africa has increased due to a rise in the creation of more impoundments with its accompanying resettlement challenges [1]. These challenges are not merely limited to the unavailability of water to downstream inhabitants but also the impact of the relocated population on their new ecological habitat [2]. When a large freshwater body is dammed, communities near the dam are displaced due to the expansion of the impoundment as a result of the dam. In their new environment, resettled inhabitants will have to find shelter, food and potable drinking water for survival [3]. In the absence of potable drinking water, relocated inhabitants often depend on available freshwater sources with unknown quality. In addition, poor sanitary conditions and the discharge of untreated excreta from relocated (lack of properly designed toilet facilities), can further contaminate available freshwater bodies [4].

Dams have often been criticized by ecologists and bio-geochemists for fragmenting habitats [5], disrupting floodplain hydrologic cycles and causing large-scale methane emissions [6]. Such trends contradict the concept of carbon-neutral energy (green energy) delivery [7]. Additionally, the building of dams break up river systems, cause multilevel transformations in the ecosystem [8][9] and entrap sedimentary nutrients [10] leading to possible pollution. Furthermore, they alter weather variables in the local environment and adversely undermine aquatic ecosystems [11] Damming of large rivers change in ecosystem services resulting in the release of anthropogenic pollutants. Damming change shifts in biogeochemical cycling activities of riverine/lacustrine microorganisms [12]. Damming of large surface water bodies could also lead to some resettlement related problems. In some developing countries commonly in Africa, a plethora of challenges faced include access to proper toilet facilities and a good source of water for newly resettled communities. This could lead to open defecation with its attendant water pollution issues [13]. In spite of the above-mentioned challenges, dams continue to provide a lot of benefits to many developing countries

In many sub-Saharan countries such as Ghana, dams have been used as a driver of economic growth and social advancement through the regulation of water supply, flood control and irrigation apart from their primary importance in electricity generation [14]. Could these activity in relation to resettlement of new communities around the dam vicinity lead to a possible pollution of water bodies around these impoundments? It is therefore important to investigate and document the potential downstream effects of the Bui Power Project on the quality of water of selected freshwater bodies among resettlement communities.

The Bui hydroelectric dam is a 400-megawatt (540,000 hp) project situated on the Black Volta. It is one of the largest energy-generating plants in Ghana, second to Akosombo dam. Its first operation activity was commissioned in May 2013 and this required the resettlement of a large number of inhabitants living close to the Black Volta [15]. An earlier study conducted and published by Gyasi et al., [16] showed that, inhabitants living in the environs of the dam perceived the emergence of the dam had impacted negatively on their livelihoods as well as a possible pollution of surrounding water bodies but policy makers had always attributed this to mere perception.

Five years after damming the Black Volta, there has been no published data detailing the environmental effect on freshwater bodies within the adjoining settlements apart from the baseline studies. These developments have raised questions about the real impact of the dam on the surrounding freshwater bodies in resettlement communities. To unravel this will require a post construction analytical assessment of these freshwater bodies. The study aimed to investigate the dam-induced pollution of selected freshwater bodies by the Bui power Project, 5 years after the operation of the dam in Ghana. Specifically, the study investigated some physicochemical and microbiological indicators of pollution of adjoining water bodies around the Bui dam, 5 years after its operation.

2. Materials and Methods

2.1 Study Design

A longitudinal approach was adopted for this study where samples of water was collected from selected freshwater bodies from 5 different resettlement communities around the Bui dam and analysed monthly over a period of 12 months starting from January to December 2017.

2.2 Study Area and Community Selection

This study communities were purposely selected from 2 districts in 2 adjoining regions of Ghana. These were Savannah and Bono East regions of the 16 regions of Ghana. Surface waterbodies included Gyama Nsuano (GN), Bongase Nsuano (BN), Agbelekame South (AS) and Agbelekame North (AN). A fifth sampling point, that is the Black Volta, (BV), the freshwater body used for the impoundment also selected. With the exception of GN which flowed into the dam (control), all the other 3 i.e., BN, AS and AN freshwater bodies took their sources from the BV as shown in Fig 1 below [16].

2.3 Study Approach

In each of the 5 sampling locations, freshwater bodies where community members collected water daily for domestic chores, agriculture and livestock were marked with a Global Positioning System (GPS) GERIM (Etrex10). From a depth of about 50cm in the BV, water was agitated gently for about 10 seconds after which 500 mLs were taken at 3 different depths (i.e., 10 cm, 20 cm and 30 cm from the surface) between 8-11 am on each sampling day. These samples were then pooled together in a clean plastic bucket after which 1L clean plastic container was filled with portions of the pooled samples, appropriately labelled and kept in a cool ice box. This method for collecting samples was repeated for all the 4 other freshwater bodies (BS, AN, AS and GN). Another set of samples were collected in similar fashion but with sterilized sample bottles for microbiological analysis.

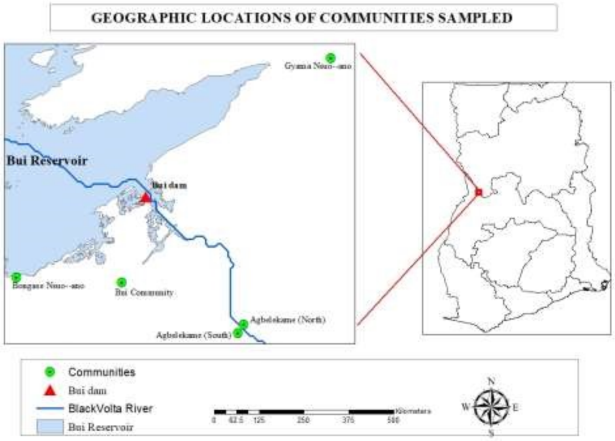

Figure 1. The Location of Freshwater Bodies in the Sampling Sites (Gyasi et al., 2018)

2.4 In-situ Analysis

The dissolved oxygen, pHandconductivity were measured in-situ (Mettler Toledo pH meter, United Kingdom 2012) and noted in a field notebook. The sampling bottles were tightly capped and hurriedly transported to the laboratory in a cool ice chest with ice packs for immediate analysis.

2.5 Laboratory Analysis

Physicochemical Analysis: Physicochemical analyses were carried out according previously published protocol with slight modification (ALPHA/AWWA, 2005), 2005, . Parameters analysed included total dissolved solids, alkalinity, calcium, magnesium, biochemical oxygen demand, (BOD), chemical oxygen demand (COD), sulphate ($SO_4{}^{2-}$) and total hardness. The 5-day BOD test (Winkler Azine Modification) was used to determine the BOD of the samples. Special-air tight BOD bottles were filled with water samples to 500 ml. The initial Dissolved Oxygen (DO) was determined and recorded as DO1 with a DO meter (Mettler Toledo DO meter, United Kingdom 2012). The samples were then incubated at the required temperature ($20^{o}C$) for five (5) days after which the DO was again determined and recorded as DO5. The BOD was computed from the difference between the DO1 and DO5 (APHA, 1998).

Mathematically the BOD was deduced as;

$BOD5 = DO1 - DO5$:

Where;

BOD5 was the biological oxygen demand after day five,

DO1 was the initial dissolved oxygen (measured in-situ) and

DO5 was the dissolved oxygen after 5 days period of incubation.

2.6 Determination of Total Hardness by Complexometric Titration using EDTA

About 50 ml of the water samples were measured followed by the addition of 1ml buffer solution and . 1) g Eriochrome Black T indicator solution. A red to blue colour change was observed upon titrating the resultant solution with 0.01N EDTA..

Total Hardness (mg/L of $CaCO_3$) $= \frac{A \times B \times 100}{sample\, volume}$

Where: A = titre value for sample

B = ml $CaCO_3$ equivalent of EDTA

2.7 Estimation of Magnesium Calcium by EDTA Titration

The analytical method involved chelation of the cations with ethylene diaminetetra-acetic acid (EDTA). Magnesium and calcium were collectively determined by poring an aliquot of 20 ml of the field sample solution in a 250 ml conical flask. The resulting solution was then diluted to 150 ml using laboratory prepared distilled water. Fifteen (15) milliliters of buffered solution and a ml each of potassium ferro-cyanide, potassium cyanide, hydroxyl-amine-hydrochloride, , triethanolamine (TEA) were added followed 5 drops of erichrome black T.. The resulting solution was then titrated against 0.005 M EDTA.

Determination of calcium was carried out by pipetting 10 ml of the field sample into a 250 ml conical flask. This was then diluted with distilled water (150ml) . One (1) ml each of potassium ferro-cyanide, potassium cyanide andhydroxyl-amine-hydrochloride were added followed by the addition of ETDA. Five drops of Calcon indicator were then added after which the resulting solution was titrated with 0.005 M ethylene diaminetetra-acetic acid. The calcium hardness was calculated using the equation;

Calcium hardness (mg/L) $= \frac{Ve \times M \times 50 \times 1000}{Volume\, of\, sample}$

Where;

Volume of EDTA = Ve

Molarity of EDTA = M

Volume of sample / Titre value = Vs

Equivalent weight of $CaCO_3$ = 50

2.8 Total Dissolve Solids (TDS)

The total dissolve solids concentration was also determined directly in the field by using COM-80 Hydrotester for EC/TDS/Temperature. The instrument was first calibrated to ensure maximum accuracy. The probes were then inserted into the samples. The values that appeared on the screen for total dissolve solid were recorded.

2.9 Total Alkalinity by titration

About 50 ml of the field sample was added to 2 drops of phenolphthalein indicator in a clean Erlenmeyer flask. . A pink colour change upon addition of 0.02N H2SO4 whiles swirling the sample gentlysignalled an end point:

Phenolphthalein Alkalinity (mg/L) $CaCO_3$= $\frac{Tv \times 100}{Sample\, volume}$

After phenolphthalein alkalinity, two (2) drops of methyl orange indicator was added to the colourless sample. The sample was titrated with 0.02N H_2SO_4 whiles swirling gently until the colour changed from yellow to orange. The titre value (Tv) was recorded and this was the endpoint of the total alkalinity titration.

Total Alkalinity as mg 1. $CaCO_3 = \frac{A \times t \times 100}{Sample\, volume}$

Where:

A= mls of standard acid used

t = titre value of standard acid inmg $CaCO_3$/ml.

2.10 Determination of Sulphate by Gravimetric Method

Hundred (100) ml of the field sample was filtered into a 250 mls glass beaker, after which 2ml HCL was added. The sample was then placed on an a hot plate until the initial volume was halved. The residue was precipitated with 5 ml $BaCl_2$ on water bath. Using an ashless filter, the precipitate was filtered and washed with hot distilled water and subjected to silver r nitrate test.. Dry filter paper was then heated to at 800^OC for 1 hour,. placed in a in a desiccator for 30 min and weighed for net weight determination.

Calculation;

$$CuSO_4 + BaCl_2 = BaSO_4 + CaCl_2$$

mg $SO_4{}^{2-}$/L $= \frac{A \times 411.6}{sample\, volume}$

Where: A = mg $BaSO_4$

2.11 Determination of Chemical Oxygen Demand by Titration Method

Ten (10) ml of the field sample was heated into a round bottom reflex flask containing. glass beads.. 15 ml silver Sulphate acid was slowly added to the final mixture containing 1 ml mercury sulphate mixed with 5 ml of K2Cr2O7 to the solution and digested in a reflex condenser for 2 hours. Upon cooling the content of the flask was solubilized in 25 ml distilled water. The contents of the flask was and titrated with 0.025 M ferrous ammonium sulphate in the presence of 2–4 drops of ferroin indicator. A control sample was prepared using distilled water. The chemical oxygen demand was calculated using the formula below

COD $= \frac{8 \times 1000 \times DF \times M \times (Vb - Vs)}{volume\, of\, sample\, in\, ml}$

Where;

DF- Dilution factor

M – The molarity standardized Ferrous Ammonium Sulphate solution

Vb – The volume of samples consumed in reaction with blank preparation

Vs – The volume of samples consumed in reation with sample preparation

2.12 Microbiological Analysis

Microbial indicators of pollution analysed included total coliform, faecal coliforms and Escherichia coli. Membrane filtration techniques was used with ultra-filtration method to serially dilute the samples prior to culture. A 0.45 micrometer Millipore filter paper was used to filter 100 mL of the water samples. Then after, sterile forceps were used aseptically to transfer the filtered papers onto an already-prepared Chromocult Coliform Agar (CCA) in pre-labeled petri dishes. Fisher Scientific Thermo incubator (USA, 2016) was then utilised to culture filtered paper using CCA at 37^oC for 24 hours according to the manufacturer's manual with slight modification (17). Chromocult Coliform Agar was used due to its cost effectiveness and speed in microbial detection processes. The use of CCA media permitted the detection, the enumeration and the final confirmation of coliforms and E. coli (24 hours). After incubation, coliform bacteria and E. coli were enumerated using visual examination with the use of manual colony counter (Interscience Scan 100, USA, 2016). The presence of salmon to red coloured colonies were presumptive for the presence coliforms bacteria, while the absence of dark-blue to violet confirmed the absence of E. coli.

2.13 Data Analysis

Data entry and preliminary data analysis were done in Microsoft Excel. Variables with Non-Gaussian distribution were transformed for further analysis. Water quality indicators of pollution from the control community (GN) were compared with the rest of the surface waterbodies. Results obtained from all these communities were also compared with the Environmental Protection Agency, Ghana and WHO)guidelines. (Table 1). In addition, the current results from the BV were compared with baseline data from an earlier assessment prior to the construction of the dam. Chi-square testing was used to test for significant differences among categorical variables using Graph Pad Prism 7, San Diego, California.

3. Results

3.1 Baseline Studies

Prior to the construction of the dam, a baseline study was conducted on the Black Volta (which was dammed) under the auspices of the Bui Power Project to assess its initial water quality indices. The results of the baseline studies are presented in Table 1. The baseline study focused on 10 selected physicochemical indicators of pollution. Microbiota was however not estimated during the earlier baseline studies. The results showed that, the Black Volta was not polluted as all the values fell below the GEPA and WHO (Table 1).

Table 1. Baseline Study Results of Selected Physicochemical Parameters of the Black Volta within the Bole Banda Ahenkro District of Ghana

Parameter	mean	Minimum	Maximum	GEPA/WHO
pH	7	6.5	8	6 - 9
Conductivity (mg/L)	111.3	105	115	1000
TDS (mg/L)	166.3	37.2	379.6	500
Alkalinity	51.7	27	69	Nil
Calcium (mg/L)	11.16	3.47	40.72	75
Magnesium (mg/L)	6.51	0.78	21.88	50
BOD (mg/L)	3.8	Nil	Nil	50
SO42-	5.17	1.96	15.8	-
DO (mg/L)	11.2	-	-	-
Total Hardness (mg/L)	57.9	22.8	109.6	500

Analysis of the results with respect to pH showed that, pH levels did not differ significantly among all the freshwater samples (BN: 6.703 ±0.1057; AN: 6.845 ±0.0597; AS: 6.863 ± 0.057). However, the BV had a lower pH (6.413 ± 0.222) compared to the GN, the control (6.860 ± 0.057) (Table 2). The pH of the BV showed the largest deviation from the baseline pH value (7.0) recorded prior to the construction of the dam ($p < 0.05$).

Abgalakeme south (AS) freshwater body had the highest electrical conductivity (78.97 ± 2.758 mg/L) compared to the control, GN (60.10+13.83 mg/L) (Table 2). The BN however recorded the lowest (conductivity) value (59.15 ± 7.757 mg/L) but the difference was not significant (Table 2). The study showed significantly elevated levels of dissolved solids in GN and the baseline data. AS was the most laden with particulate matter (113 mg/L) (Table 2). The difference was significant ($p<0.005$) compared to the control (80.5 mg/L) as shown in Table 2. The study also showed that, TDS of the BV was also significantly high (96.5 mg/L) ($p<0.001$) (Table 1). However, it had a much lower TDS than its baseline value (166.3 mg/L) before the construction of the dam ($p< 0.05$)(Table 1). TDS of all the freshwater bodies under investigation had values that were within acceptable limits mandated by both GEPA and WHO (500 mg/L) (Table 1 and 2).

Alkalinity assessment of the freshwater bodies showed that, the BN had the highest significant level (33.38 mg/L) ($p<0.001$). Abgalakeme North (AN) however had the lowest alkalinity (25.45 mg/L) ($p>0.05$) (Table 1). Our study also showed that, the alkalinity of the BV had dropped from (51.7mg/L) to (24.45 mg/L), 5 years after the constructing of the dam (Table 1 and 2). Calcium and magnesium content of the freshwater bodies in the study area were also assessed. The results showed no significant differences in their content as shown in Table 2 below. Additionally, calcium level in the BV had declined from its initial value before the dam construction, i.e., from 11.16mg/L to 8.425 mg/L (Table 2). At baseline, the concentration of magnesium in the BV was 6.51 mg/L. However, 5 years after constructing the dam, the level of magnesium had increased to 22.2 mg/L (Table 1 and 3).

Magnesium level in the Agblekame South was high (31.83 mg/L) followed by Gyama Nsuano (23.23 mg/L)(Table 2). Bongaase Nsuano and Agblekame North recorded the least magnesium level (18.23 mg/L). The magnesium level in the Black Volta has increased from 6.51 mg/L to 22.2o mg/L as shown in Tables 1 and 2.

The study investigated theBOD and COD of freshwater bodies in the vicinity where the Bui power project was built. The BV had a significantly elevated BOD (26.75 mg/L) and COD values (71 mg/L) ($p>0.05$) (Table 3). Prior to the construction of the dam, the mean baseline values of the BOD of the BV was 3.8 mg/L (Table 1). However, 5 years down the line, this had risen to 26.75 mg/L. The chemical oxygen demand (COD) for BN (24.5 mg/L), AN (33.5 mg/L), and AS (34.5 mg/L) was significantly elevated compared to the control, GN (Table 3).

The concentration of sulphates in the BV had increased, 5 years after damming the Black Volta. Prior to the construction of the dam, DO for the BV was 11.22 mg/L and the level rose to 23 mg/L (Table 1 and 3) 5 years after. The BV recorded the highest estimated value for total hardness (46.0 mg/L) and alkalinity value (46.0 mg/L) compared to the rest. Agbalekame South (AS) recorded, the highest concentration (12.25 mg/L) of sulphates and the highest level of dissolved oxygen (24.2 mg/L). (Table 3).

A summary of microbiological assessment for pollution is shown in Fig 2. Agblekame North (AN) had the highest total coliform numbers (1.8×10^4 cfu/100 mL), followed by the AS (1.4×10^4 cfu/100 mL). Both freshwater bodies exceeded the GEPA/WHO acceptable guidelines for drinking water. Faecal coliforms for BN recorded the highest microbial level of 4.9×10^5 cfu/100 mL as shown in Fig 2. This was followed by AN 2.3×10^5 cfu/100 mL and both had their mean values exceeding the GEPA/WHO permissible guidelines for drinking water (Fig 2). Meanwhile the BV recorded the least levels of both total coliforms (1.0×10^5 cfu/100 mL) and faecal coliforms (3.0×10^5 cfu/100 mL), respectively. Escherichia coli was however absent in all the freshwater bodies.

Table 2. Some Physicochemical Parameters of Selected Streams Based on Location.

	Gyama Nsuano (Control)(GN)	Bongaase Nsuoano (BN)	Black Volta (BV)	Agblekame North (AN)	Agblekame South (AS)
	Mean (SEM)	**Mean (SEM)**	**Mean (SEM)**	**Mean (SEM)**	**Mean (SEM)**
Parameters					
pH	6.860 ± 0.057	6.703 ±0.105ns	6.413 ± 0.222ns	6.845 ±0.059ns	6.863 ± 0.057ns
Conductivity (mg/L)	60.10+13.83	59.15+7.750ns	69.70+11.170ns	71.65+12.470ns	78.97+2.750ns
TDS (mg/L)	80.50+5.437	**110.3+5.170****	**96.50+0.957***	**112.0+5.017****	**113.0+11.530***
Alkalinity(mg/L)	32.45 ± 2.420	33.38 ± 1.839ns	30.65 ± 0.759ns	**25.45 ± 2.435***	31.40 ±1.742ns
Calcium (mg/L)	8.300 ± 1.515	10.13 ± 1.429ns	8.425 ± 1.898ns	12.35 ± 4.916ns	7.600 ± 1.608ns
Magnesium (mg/L)	23.23 ± 2.150	18.28 ± 6.546ns	22.20 ± 1.821ns	18.28 ± 6.546ns	31.83 ± 4.361ns

Footnote: SD-Standard Deviation (N = 12), SEM-Standard Error of Mean, Level of significance were determined using students unpaired t-test. ns implies $p>0.05$ (*) implies $p \leq 0.05$, (**) implies $p \leq 0.005$.

Table 3. Some Physicochemical Parameters of Selected Streams Based on Location

Parameter	Gyama Nsuano (GN)(Control)	Bongase Nsuano (BN)	Black Volta (BV)	Agblekame North (AN)	Agblekame South (AS)
	Mean (SEM)	**Mean (SEM)**	**Mean (SEM)**	**Mean (SEM)**	**Mean (SEM)**
BOD (mg/L)	5.50 ± 1.708	8.000 ± 0.816ns	**26.75 ± 2.689*****	10.00 ± 2.610 ns	10.00 ± 2.160 ns
COD (mg/L)	17.00 ± 1.291	**24.50 ± 0.957****	**71.00 ± 3.109*****	**33.50 ± 0.957****	**34.50 ± 1.500*****
SO42- (mg/L)	7.025 ± 0.344	6.075 ± 0.423	7.200 ± 0.456ns	9.800 ± 0.509	**12.25 ± 0.625*****
DO (mg/L)	12.18 ± 1.046	23.53 ± 4.686 ns	**23.00 ± 1.472*****	**20.06 ± 2.189 ***	**24.20 ± 0.840*****
Total Hardness	36.00 ±1.459	36.00 ± 1.460ns	46.00 ± 0.674ns	40.00 ± 2.266ns	40.00 ± 3.854ns

Footnote: Gyama Nsuano (Control Community), SD-Standard Deviation (N = 12), SEM: Standard Error of Mean, WHO-World Health Organization (WHO, 2013), Level of significance were determined using students unpaired t-test. ns implies $p>0.05$ (*) implies $p \leq 0.05$, (**) implies $p \leq 0.005$.

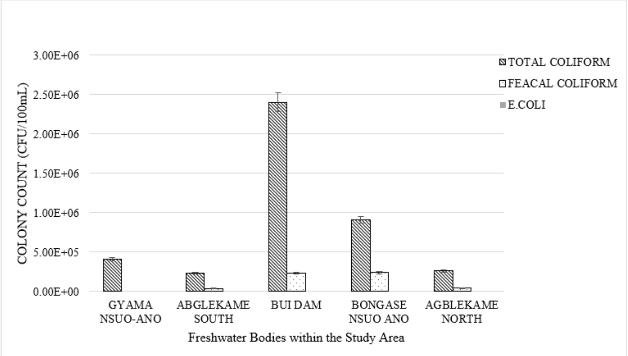

Figure 2. Total coliform, Feacal coliform and E. coli numbers in freshwater bodies in the Study Area

4. Discussion

This is the first time a study is being conducted to document and present findings on the impact of the medium-term assessment of the Bui Power Project on the quality of surface waterbodies at 5 different sites around the dam by an independent group of researchers. Five (5) years after the construction of the Bui dam, pH of the Black Volta on which the dam is located had become more acidic but with no significant difference between the adjoining surface water bodies. The pH values for all the other water sources were considered safe. This level posed no immediate safety threat to humans for consumption according to the WHO. Similar reports from studies involving the Weija dam in Ghana found no significant change in water pH after construction [18]. If the pH was low, say less than 3, (acidic pH), cationic metals in water will usually be known to express better solublility characteristics, by dissipating metallic ions aqueous solution [19]. Metals toxicity hinges on the solubility of ions and on the category of anions present [20]. This could illicit some health concerns ifthe levels of ions exceed recommended limits for inhabitants using water for domestic purposes. [21].

With the exception of AN, all the other freshwater bodies had comparable alkalinity. Alkalinity is a quantitative property reflecting the hydroxyl ion concentration of a water source and its capacity to counteract or resist wastewater pollution from acidic rainfall [22]. Differences in alkalinity may result from local anthropogenic practices by near-by inhabitants. However, a drop in the alkalinity of the BV, 5 years after the constructing of the dam was observed. Long-term changes in the alkalinity in freshwater bodies may result from human activities. The conductivity for the BV in the present study was far below its baseline value prior to the building of the dam. However, the conductivity for all samples were within the national and international standards of drinking water. Both conductivity and TDS did not exceed the GEPA/WHO guideline levels. Similar findings were made by Anim et al., [18] elsewhere in a separate study conducted in Ghana on a different dam and published in 2011. The presently low conductivity index as well as TDS value for the BV may be indicative of the relative purity and freshness of the water sources [23][24]. Water sources with threshold electrical conductivity below 325 μS·cm-1 are generally regarded as wholesome [25]. For aesthetic threshold, 500 mg/L of TDS qualifies the water as preferrable [26]. Generally, conductivity is a useful parameter in water analysis and this reflects the capacity to carry and conduct flow of electrons [27].

Moreover, it can be used as a convenient proxy for estimating concentrations of dissolved ions or salts (TDS) in water [27]. For any water sample, this electrical capacity is imparted as a function of ionic strength (from dissolved salts) and is directly proportional to temperature [28][29]. By comparison, a high content of TDS was disclosed in other reports from an embankment site in Nigeria, highlighting the impact of seasonal variation on surface water turbidity and conductivity [30]. Our study established that the calcium level of BV has reduced 5 years after construction and all the other freshwater bodies met the mandated guidelines of the regulatory bodies. Discordant results were reported elsewhere by Anim et al.,[18]. In that report, the levels of Mg and Ca were higher compared with the WHO limits. It is unclear what accounted for the high levels of calcium relative to magnesium. High calcium levels are generally undesirable from a domestic consumption perspective.

The BV had a significantly elevated BOD. An increase in the biochemical oxygen demand of the BV, after generating hydroelectric power over 5 years was also observed. BOD signifies the biological strength of water in terms of its ability to support biological life by way of flora and fauna. It also shows the volume of available dissolved oxygen present in a given water body. A high BOD index for waterbodies may be an indicator of decomposing biodegradable matter. This could be influenced by natural decomposition of dead plants or decomposing waste influx when the BV was dammed, turning its riverine properties to that of an impoundment. This meant that, at the time of the study, there was less decomposed matter present in the dam which could be good for aquatic life. This was confirmed by none of the samples having values exceeding the GEPA/WHO recommended levels of BOD. A similar study conducted earlier reiterated that, although there were no direct health effects for the presence of low BOD, it is an important indicator of overall water quality [31]. On the other hand, high BOD levels may be deleterious to the aquatic ecosystem by a mechanism resulting in oxygen depletion in water [31]. Polluted streams are composed of a variety of inorganic and organic substances. Oxidation of these organic compounds could result in microorganisms using the organic matter as food source to reduce pollution [32].

The presence of coliform bacteria in the surface water samples showed high bacteria loads which flouted national and international standards for domestic water [6]. When a large surface water body is dammed, inhabitants near-by are displaced who will have to find a good source of potable water for drinking and good toilet facilities. In the absence of this, open defecation becomes the only option with its pollution related challenges. The contamination of waterbodies by organic micropollutants (micro-organisms) is a great public health concern. At the beginning of gastrointestinal diseases outbreaks, the contamination by a microbiological is rarely [32]. Very few studies have have demonstrated significant and consistent association between disturbance to a water body and the outbreaks of waterborne disease [33]. Human activities, such as the construction of dams play a dominant role in water pollution compared to any other natural processes and this can affect the functioning of a given aquatic ecosystem [34][35]. Stresses on waterbodies cancause an interrelated complex outputs that include the intended impacts on the quality of the water systems [36]. In 2015, the World Water Development (WWD), , declared “water is at the core of sustainable development” [37]. This is directly linked with the availability and/or access to sufficient amount of water at a particular time. This must also be in sync with the quality of water for the preservation of a healthy aquatic system. This according to the report is critical for socio-economic and human development. In this situation,the hreat to health of end-users may constitute a public health concern is paramount and this calls for urgent attention.

The more than tolerable level of both total coliform recorded for both AN and AS is a matter that must be addressed immediately. High levels of total and faecal coliform numbers suggests the pollution of these surface waterbodies with faecal matter and this presents a danger to household consumption. The presence of disease-causing microorganisms (pathogens) can annex host tissue and propagate or elucidate toxic compounds which can interfere with normal body processes. Pathogens present in these microbiologically contaminated polluted freshwater sources can enter the human body through ingestion [37].

It is unlikely the microbiological pollution was initiated directly by the construction of the Bui dam because even though the surrounding freshwater bodies were microbiologically polluted, the BV itself was not polluted at the time of sampling. It was realized during data collection that, most of the inhabitants were predominantly peasant farmers, fishermen, fish processors and petty traders. It was also observed that some people in all the 4 resettled communities practiced open defecation. These poor behavioral hygienic practices in addition to poor fish-waste management practices may have impacted negatively on their freshwater bodies and not the building of the dam per se. This may be explained by describing the pollution of the surface waters as indirectly caused by poorly managed resettlement strategies of adjoining communities as a result of the Power project.

5. Conclusions

Our study has provided evidence to show that adjoining surface waterbodies around the Bui power project were generally not polluted in terms of selected physicochemical parameters. However, they were microbiologically compromised due to resettlement of communities around the Bui Dam environs. As stated earlier, the creation of the impoundment displaced a large population of people who were quickly resettled. The operational activities of these new settlers may have microbiologically compromised the quality of their freshwater sources. It is therefore that, more education ought to be carried out on community hygienic practices among the resettled population in the study communities who depend on freshwater bodies.

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