Seasonal Variation in Water Quality of the Weija Dam, Ghana

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Abstract

The water quality examination of the Weija dam was conducted by determining the physicochemical parameters at ten (10) sampling sites in March 2014, representing the dry season and August 2014, representing the wet season. Physicochemical parameters such as temperature, pH, conductivity, hardness and nutrients were measured. Values of the parameters were all within the acceptable limits of WHO with the exception of phosphate concentrations which were above the threshold limit in the wet season. The results of this study also indicated that there were significant differences in concentrations of the physicochemical parameters between the two seasons. The physiochemical parameters ranged from 6.62 to 8.00 (pH unit), 94.95 to 285.61.00 µS/cm (electrical conductivity), 28.59 to 73.45 mg/L (total dissolved solids), 49.18 to 94.54 mg/L (total hardness), 86.21 to 105.68 mg/L (alkalinity) and dissolved oxygen levels of 2.70 to 5.84 mg/L in both seasons. The mean concentration of nitrates in the dry season was 0.32 mg/L and 0.31 mg/L in the wet season. Chloride, fluoride and phosphate concentrations ranged from 43.54 to 67.13 mg/L, 0.03 to 0.09 mg/L and 0.03 to 0.40 mg/L respectively.

Keywords: Weija dam, Water quality, physicochemical analyses, seasonal variation

1. Introduction

Water is vital to the existence of life. Today, people are concerned about the quality of drinking water. This is because the quality of this valued resource is increasingly being compromised as a result of the growth of human populations and increased demand for water for domestic purposes and economic activities (UNEP, 2000).

Polluted water tends to serve as a vessel for the spread of diseases. In developing countries, 1.8 million people, mostly children, die every year as a result of water related diseases (WHO, 2004).

Ghana's water resources have been under increasing threat of pollution in recent years. This threat is due to rapid establishment of new human settlements which lack the appropriate sanitary infrastructure and other human activities such as farming very near to water bodies. Many of such settlements can be found in the Accra Metropolis (Ghana Statistical Service, 2002). Inhabitants of such settlements more often utilize the contaminated surface water for, drinking, recreation and irrigation thus resulting in serious health effects (Verma,1990).

Weija Lake is an important drinking water source for the Accra metropolis and its surrounding communities. However, the lake is being polluted by indiscriminate disposal of sewage and industrial waste. These activities result in changes in physicochemical characteristics and microbiological quality of the water (Koshy, 1999).

Pollution of the lake is a serious and growing problem. For example, increasing amounts of domestic waste, contributes to oxygen demand and nutrient loading which leads to the destabilization of the aquatic ecosystem (DWAF and WRC, 1995; WRC, 2000). Industrial and agricultural waste discharged into the lake also has deleterious effects on aquatic organisms. In addition, this can be detrimental to human and animal health and safety (Adekunle and Eniola, 2008). Disposal of sewage wastes into a large volume of water like the Weija Lake could also increase the biological oxygen demand to such a high level that all the available oxygen may be removed, thus causing the death of organisms like fish (Maduka, 2004). Due to the rate and extent of anthropogenic activities impacting on the water quality of the dam, it is necessary to determine the physicochemical properties of the water from the Weija Lake in order to record any alteration in the water quality, which could lead to serious health effects. There has been some studies on the quality of the Weija dam (Anim et al 2011). However, there has not been any new study on the characteristics and seasonality of water quality in recent times. The objective of the study is to provide a quantitative record of the seasonal changes as well as the levels of the various physicochemical parameters.

2. Materials and Methods

2.1 Study Area Description

The Weija dam is situated in Accra, the capital town of Ghana. The Weija dam is 14 km long, 2.2 km wide and has a total surface area of 38 km^2 with mean depth of 5 m (Vanden, 1990). The dam, located between 0^o 20' W, 0^o 25' W and 5^o 30' N, 5^o 45' N is about 17 km west of Accra and almost at 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 by Ghana Water Company Limited as a replacement for an earlier one which was washed away in 1968 through the damming of River Densu. This dam was 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 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.

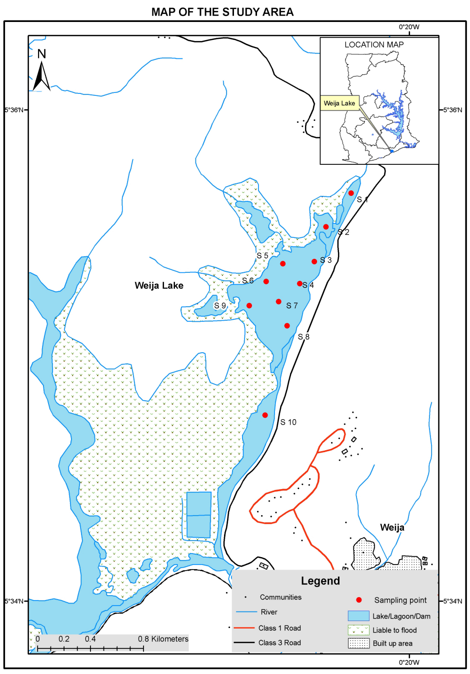

Figure 1: Map of the study area indicating the sampling sites.

2.2 Sampling

Water samples were collected in March, 2014 representing the dry season and in August, 2014 representing 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 and 300 ml bottles for the determination of dissolved oxygen. Azide modification of the Winkler method was used to fix oxygen on site (APHA, 1998). At each sampling site, the polyethylene sampling bottles were rinsed three times before sampling was done. The water samples were kept in an ice chest at a temperature of about 4 ^oC and transported to the Chemistry Laboratory of the Ghana Atomic Energy Commission (GAEC) for analyses. Temperature, pH, electrical conductivity (EC), total dissolved solids (TDS) were measured at the sampling site.

2.3 Physicochemical Analyses

The pH, temperature, electrical conductivity (EC) and total dissolved solids (TDS) were determined using Hanna instruments: pH Meter Model HI 98103 and Hach Model 44600 Conductivity/TDS Meters respectively. Alkalinity, was determined by titration (WII, 2008). Total hardness (TH) was determined by complexometric titration with standard EDTA solution using Eriochrome Black T as indicator. Chloride concentration was determined using argentometric titration, while Nitrate (NO_3^-) and phosphate (PO_4^{3-}) were determined by UV spectrophotometric method (APHA, 1998). Fluoride was also determined by SPANDS method.

3. Results and Discussion

The results of the physicochemical characteristics of water samples from the Weija dam for dry and wet seasons are presented in Tables 1 and 2 respectively. The results were compared with World Health Organization (WHO, 2004) guideline values to assess the potability of the water.

The mean pH values ranged from 6.62 (site 9) to 7.16 (site 8) in the dry season and ranged from 6.75 (site 6) to 8.02 (site 3) in the wet season with their seasonal mean values of 6.93 and 7.36 for the dry and wet seasons respectively. All the pH values were within the (WHO, 2006) guideline range of 6.50 – 8.50 for drinking water. The lower pH values in the dry season could be attributed to surface evaporation.

The measured temperature values ranged from 26.52 ℃ at site 5 to 28.19 ℃ at site 4 in the dry season with the mean value of 27.34 ℃ (Table 1) and from 25.67 ℃ at site 9 to 27.01 ℃ at site 10 with the mean value of 26.26 ℃ (Table 2) in the wet season. The higher temperature of the water samples in the dry season than in the wet season could be as a result of the high temperature during the dry season. High temperature reduces the amount of dissolved oxygen in water thereby affecting aquatic lives (Akan *et al*., 2012). High temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and odor and elevates metabolic activity of organisms.

The results of conductivity measurements varied from 164.57 µS/cm (site 4) to 285.61 µS/cm (site 7) in the dry season and ranged from 94.95 µS/cm (site 8) in the wet season to 190.58 µS/cm (site 10). The mean values of 215.41 µS/cm (dry) (Table 1) and 156.08 µS/cm (wet) (Table 2) were obtained. The high conductivity mean values in the dry season may be due to a reduction in the lake volume as a result of evaporation at the water surface resulting in concentration of ions and dissolved organic matter (Coke, 2001) which gets into the dam through runoffs. However, the lower conductivity in the wet season' might be due to high rainfall which reduces the level of dissolved solids by dilution of water in the lake through runoff which increases the volume of water (FAO, 1993). Electrical conductivity (EC) values measured for both seasons were far below the WHO maximum permissible limit.

The dry season recorded the highest TDS of 47.52 mg/L (Table 1) and ranged from 28.60 mg/L at site 6 to 73.45 mg/L at site 2 while the wet season recorded the lowest mean value of 41.50 mg/L (Table 2) and ranged from 30.00 mg/L at site 6 to 52.00 mg/L at site 9. Decrease in the volume of water due to the evaporation on the surface of the water might be the reason for the high TDS values in the dry season. However, the TDS levels recorded in the entire sample points were below the WHO maximum permissible limit of 1000 mg/L for the protection of fisheries and aquatic life and for domestic water supply.

The major factors controlling dissolved oxygen concentration are photosynthesis producing oxygen while respiration and nitrification consume oxygen (Best *et al.,* 2007. The wet season recorded mean DO values varying from 4.56 mg/L to 5.84 mg/L at sites 6 and site 1 respectively and from 2.70 mg/L at site 7 to 4.10 mg/L at site 4 in the dry season. The relatively higher DO levels in the waters of Weija dam in the wet season could be attributed to mixing and aeration due to wind action (Straskaba and Tundisi, 1999), as well as photosynthetic activity. High DO levels may also be due to the inflow of cool oxygenated flood waters from the catchment area. The inflow is an annual event that normally occurs from May to August, a phenomenon which was also reported by Ameka *et al*. (2000). In general, DO levels less than 3 mg/L are stressful to most aquatic organisms. Most fish die at 1.00 – 2.00 mg/L. However, fish can move away from low DO areas. The oxygen levels in the Weija dam were slightly above the 5.00 mg/L threshold needed to support fish life (Hynes, 1970; USEPA, 1999 and WHO, 2002) especially in the wet season.

The levels of alkalinity measured was between 90.43 mg/L (site 2) and 105.68 mg/L (site 8) in the dry season and from 86.21 (site 9) to 102.00 mg/L (site 2) in the wet season. The mean alkalinity for the respective seasons was 98.18 mg/L (Table 1) for the dry season and 94.68 mg/L (Table 2) for the wet season. The reduction in the water volume due to evaporation might increase the constituents of alkalinity. The activities of vegetables farmers within the catchment of the dam may have resulted in the relatively high values in the dry season. The alkalinity values recorded were all below WHO (2003).

Chloride concentrations varied from 44.18 mg/L (site 8) to 68.98 mg/L (site 4) in the dry season while the concentration varied from 39.53 mg/L (site 9) to 67.13 mg/L (site 4) in the wet season. There was a difference in chloride concentrations for both seasons, with the dry season showing a relatively higher chloride level (53.33

mg/L) than the wet season (50.04 mg/L). This is probably due to evapotranspiration (Asante *et al.,* 2005). Results obtained in both seasons were below the WHO maximum permissible limit of 250.00 mg/L for drinking water.

The fluoride concentrations measured ranged from 0.09 mg/L (site 2) to 0.05 mg/L (site 9) in the dry season, and from 0.03 mg/L (site 8) to 0.07 mg/L (site 6) in the wet season with mean a value of 0.07 mg/L (dry) which was slightly higher than 0.06 mg/L (wet) season. Presence of fluoride may be due to the weathering of rocks within the catchment area. WHO (2003), report showed that low levels of fluoride are medically good for healthy teeth but high levels can result in a disease called fluorosis. Fluoride levels within the dam in both seasons were generally below WHO recommended levels for drinking water of 1.50 mg/L.

The phosphate concentrations determined ranged from 0.15 mg/L (site 9) to 0.82 mg/L (site 5) in the dry season with the mean value of 0.27 mg/L (Table 1) while the wet season levels ranged from 0.03 mg/L (site 7) to 0.13 mg/L (site 5) with the mean value of 0.06 mg/L (Table 2). The huge agricultural activities together with the use of fertilizer, other agrochemicals as well as other human activities within the study area might have been responsible for the levels of phosphate in the water samples (Asante *et al.,* 2005). The concentrations of phosphate in almost the entire water sampling sites were below the WHO maximum permissible limit of 0.30 mg/L

Concentrations of nitrates measured ranged from 0.18 mg/L (site 6) to 0.47 mg/L (site 10) with a mean 0.32 mg/L (Table 1) in the dry season. The wet season level varied from 0.41 mg/L (site 10) to 0.21 mg/L (site 6) with the mean value of 0.31 mg/L (Table 2). This might be as a result of runoff from fertilized farm lands and domestic wastes (Asante *et al.,* 2005). Many nitrogenous fertilizers are converted into mobile nitrates by natural processes which contaminate nearby water bodies (Freeze and Cherry, 1979, Walter *et. al.*, 1975). These nitrate levels were below the WHO limit of 10.00 mg/L therefore does not constitute a health hazard.

Table 1: Statistical summary of physico-chemical parameters in the dry season (Mean ± SD)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Total	WHO
pH	6.92 ±0.21	7.03 ±0.13	7.01 ±0.09	7.02 ±0.23	6.94 ±0.20	7.03 ±0.28	7.16 ±0.21	6.62 ±0.39	6.84 ±0.12	6.77 ±0.07	6.93 ±0.24	6.5-8.5
Temp.	27.06 ±0.05	26.57 ±0.57	26.99 ±0.14	28.19 ±0.19	26.52 ±0.07	27.72 ±0.12	27.44 ±0.08	28.10 ±0.04	27.63 ±0.26	27.20 ±0.01	27.34 ±0.59	25
EC	207.60 ±45.80	178.60 ±44.72	222.50 ±42.03	164.57 ±41.57	231.53 ±53.23	246.46 ±47.43	285.61 ±41.29	188.78 ±84.70	229.73 ±48.09	198.72 ±69.55	215.41 ±59.22	1000
DO	3.70 ±0.31	2.90 ±0.27	3.90 ±0.31	4.10 ±0.29	3.10 ±0.22	3.60 ±0.48	2.70 ±0.46	4.00 ±0.24	3.20 ±0.25	4.00 ±0.70	3.52 ±0.56	5
TDS	55.09 ±3.97	73.45 ±5.83	44.66 ±1.38	30.73 ±6.39	48.73 ±3.68	28.59 ±6.35	46.26 ±4.15	51.62 ±3.31	44.86 ±8.30	51.16 ±3.20	47.52 ±12.86	1000
Alkalinity	93.55 ±2.14	105.68 ±1.23	92.22 ±0.90	99.61 ±7.91	101.76 ±2.33	94.36 ±2.62	101.60 ±2.57	90.43 ±4.66	99.63 ±2.41	103.00 ±5.84	98.18 ±6.06	400
T. Hardness	75.86 ±8.00	68.94 ±1.64	83.47 ±4.99	71.15 ±2.27	91.07 ±0.53	94.54 ±4.50	79.94 ±3.88	90.73 ±3.70	89.94 ±0.88	80.28 ±0.46	82.59 ±9.19	500
Chloride	51.66 ±3.25	46.12 ±10.03	53.50 ±5.22	68.98 ±2.02	57.18 ±6.47	51.94 ±6.36	55.80 ±3.19	44.18 ±1.51	48.74 ±1.62	55.22 ±1.49	53.33 ±7.98	250
Fluoride	0.08 ±0.01	0.09 ±0.01	0.07 ±0.02	0.09 ±0.01	0.07 ±0.02	0.08 ±0.01	0.07 ±0.02	0.06 ±0.02	0.05 ±0.02	0.07 ±0.03	0.07 ±0.02	1.5
Phosphate	0.38 ±0.06	0.29 ±0.04	0.24 ±0.02	0.30 ±0.02	0.28 ±0.03	0.22 ±0.03	0.19 ±0.02	0.22 ±0.02	0.15 ±0.05	0.40 ±0.06	0.26 ±0.09	0.3
Nitrate	0.38 ±0.06	0.29 ±0.04	0.24 ±0.02	0.30 ±0.02	0.28 ±0.03	0.18 ±0.05	0.29 ±0.04	0.36 ±0.05	0.39 ±0.07	0.47 ±0.04	0.32 ±0.09	10

All parameters are in mg/L except for conductivity (µS/cm), temperature (^{o}C) and pH (no unit). WHO – World Health Organisation

Table 2: Statistical summary of physico-chemical parameters in the wet season (Mean ± SD)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Total	WHO
pH	7.40 ±0.30	7.38 ±0.33	7802 ±0.16	7.20 ±0.07	8.00 ±0.17	6.75 ±0.12	7.20 ±0.09	6.94 ±0.09	7.30 ±0.06	7.38 ±0.38	7.36 ±0.43	6.5-8.5
Temp.	26.41 ±0.51	26.38 ±0.45	25.81 ±0.43	26.10 ±0.07	26.72 ±0.41	25.95 ±0.32	25.82 ±0.28	26.69 ±0.51	25.67 ±0.46	27.01 ±0.53	26.26 ±0.58	25
EC	110.26 ±25.21	114.00 ±18.34	203.43 ±37.44	165.48 ±59.57	100.05 ±1.18	189.78 ±7.23	187.12 ±12.38	94.95 ±1.32	205.19 ±21.54	190.58 ±10.03	156.08 ±49.63	1000
DO	5.84 ±0.17	5.28 ±0.35	5.40 ±0.38	5.40 ±0.51	5.12 ±0.11	4.56 ±0.46	5.14 ±0.15	5.00 ±0.21	5.56 ±0.30	4.94 ±0.09	5.22 ±0.44	5
TDS	39.00 ±1.41	36.00 ±1.87	58.00 ±2.24	36.00 ±2.92	40.00 ±0.00	30.00 ±1.58	51.00 ±2.24	34.00 ±3.08	52.00 ±2.45	39.00 ±2.45	41.50 ±18.89	1000
Alkalinity	98.90 ±1.68	102.00 ±2.05	86.82 ±3.46	97.24 ±1.11	100.05 ±1.19	91.84 ±2.27	99.52 ±1.95	90..42 ±2.27	86.21 ±4.95	93.77 ±3.34	94.68 ±5.96	400
T. Hardness	64.67 ±1.93	49.18 ±2.65	55.25 ±3.52	62.22 ±1.10	71.51 ±2.16	65.75 ±2.65	58.20 ±2.06	54.27 ±30.26	58.60 ±2.02	62.60 ±3.24	60.23 ±10.84	500
Chloride	48.11 ±2.29	50.65 ±4.88	50.64 ±1.78	67.13 ±3.41	47.64 ±3.55	49.24 ±2.21	43.56 ±5.18	43.54 ±2.94	39.53 ±1.48	60.34 ±3.19	50.04 ±8.40	250
Fluoride	0.07 ±0.01	0.06 ±0.01	0.07 ±0.01	0.64 ±0.01	0.07 ±0.01	0.06 ±0.01	0.03 ±0.02	0.04 ±0.01	0.06 ±0.01	0.07 ±0.01	0.06 ±0.02	1.5
Phosphate	0.06 ±0.01	0.05 ±0.01	0.06 ±0.00	0.05 ±0.01	0.13 ±0.01	0.07 ±0.00	0.03 ±0.00	0.06 ±0.00	0.05 ±0.00	0.05 ±0.00	0.06 ±0.02	0.3
Nitrate	0.36 ±0.02	0.29 ±0.01	0.23 ±0.02	0.29 ±0.01	0.28 ±0.01	0.21 ±0.10	0.29 ±0.02	0.34 ±0.02	0.38 ±0.02	0.41 ±0.02	0.31 ±0.07	10

All parameters are in mg/L except for conductivity (µS/cm), temperature (^oC) and pH (no unit). WHO – World Health Organisation

4. Conclusion

This study has shown that pH, electrical conductivity (EC), total dissolved solutes (TDS), total hardness (TH), alkalinity, dissolved oxygen (DO), chloride, fluoride and nitrate content of the river water were found to be within the limits set by the WHO (2004) standards for drinking water and domestic use. However, exceptions were observed in the dissolved oxygen (DO) where for the dry season all the sites recorded values which were below WHO maximum permissible limit of 5.00 mg/L whereas for the wet season, all the sites were above the WHO permissible limit. In the case of phosphate, concentrations in the wet season were all below the WHO maximum permissible limit of 0.30 mg/L However, for the dry season with the exception of site 1 and 10 all others were below the WHO maximum permissible limit. Hence it is recommended that people using water from the dam for domestic and agricultural activities without treatment should be cautioned of the possible adverse health effect.

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