

## Assessment of the Nutrient Load and Selected Heavy Metals in the Owabi Reservoir and its Feeder Waters

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### ABSTRACT

The effects of anthropogenic activities on the water quality of the Owabi reservoir, a dam which provides drinking water to most parts of the Ashanti region of Ghana was assessed by monitoring physicochemical parameters, trace metals and nutrient levels of five feeder water sources. Trace metal levels (mg/L) were in the range of 0.67-3.20, 0.001-0.1, 0.001-0.06, 0.02-0.2, 0.05-0.15 and 0.002-0.019 for Iron, Zinc, Copper, Aluminum, Chromium, and Manganese respectively. Chromium and Iron exceeded USEPA maximum acceptable levels for drinking water. The nutrients content (mg/L) ranged from 5.00-28.00, 0.08-0.53, 0.82-4.20 and 0.03-0.53 for Sulphate, Nitrate, Phosphate and Ammonia respectively.

**Key words:** Heavy metals. Owabi, Pollution, Nutrients, Water quality.

### INTRODUCTION

Water pollution is the introduction of substances by man directly or indirectly, that can cause harm to living resources, hazard to human health, hindrance to aquatic activities and impairment of water quality with respect to its use in agriculture, industrial and other economic activities (Varol and Sen, 2012).

The importance of water as a resource to improve the social well being of a people and for national development cannot be over emphasized. Fast urbanization and industrial development during the last few years have provoked some serious concerns for the environment. Excessive fertilization (eutrophication) is one of the most significant causes of water quality deterioration in lakes and reservoirs in many countries (Mutisya and Tole, 2010). The concentrations of nitrogen and phosphorus are known to play a key role in determining the ecological status of aquatic systems (Jarvie ., 1998). These nutrients in excess may lead to diverse problems such as an increase in the occurrence and extent of algal blooms, loss of oxygen, taste and odour problems, fish deaths and loss of biodiversity. Nutrient enrichment seriously degrades aquatic ecosystems, impairing the use of water for drinking, industry, agriculture, recreation and other purposes (Carpenter., 1998). Agricultural and urban activities

are considered to be major sources of N and P to aquatic ecosystems (Conley., 2009; Duan., 2007; Turner ., 2003; Voutsas ., 2001).

In recent years, a number of investigators have developed models for quantitatively relating nutrient loads to the eutrophication responses of a water body resulting from these loads. The response reflect a wide range of water quality impairment, including increased algal biomass, fish productivity, total phosphorous, concentration, oxygen depletion and hypolimnion, water clarity, taste and odors and shortened filter runs for domestic supplies (Bhumbla, 2004). Metal contamination in aquatic environments has received much concern due to its toxicity, abundance and persistence in the environment, and subsequent accumulation in aquatic habitats (Sin . 2001, Cook, 1990). Heavy metals enter a river from a variety of sources; either natural or anthropogenic (Adaikpoh., 2005, Akoto., 2008). Usually in unaffected environments, the concentration of most of the metals in rivers is very low and is mostly derived from weathering of rock and soil (Reza and Singh, 2010). The main anthropogenic sources of heavy metal contamination are mining and smelting activities, disposal of untreated and partially treated effluents contain toxic metals, as well as metal chelates from different industries and indiscriminate

use of heavy metal-containing fertilizer and pesticides in agricultural fields (Macklin., 2006; Martin 2000; Nouri ., 2008; Reza and Singh, 2010)

The Owabi reservoir is designed to produce 20% of the total potable water requirement in the Kumasi metropolis and nearby villages (Akoto., 2008). The rivers, which serve the Owabi reservoir, have been encroached with various human activities due to the high population density within the catchment area. The Rivers that serve the dam are kept in bad conditions. Most of the rivers have car repair shops and car washing bays situated just by them. Some of rivers are also used as refuse dumps. Another issue has been the infestation of bloodworms in the Owabi River, which dramatically diminishes the quality of the water from that source (Maoulidi, 2010). These organisms contaminate the water by invading the filtration system and breeding in distribution tanks. Agrochemical usage has been quite intense by many farmers in Ghana (Ntow, 2001) Chemicals used by farmers and fishermen have been polluting streamlets that feed streams, which, in turn, supply water to the Owabi dam. The discharge of liquid waste from sewers and drains into rivers also threatens water quality. The effects of the very polluted nature of the feeder water bodies then translates into the dam and because of that, over the years, there has been a problem of high pollution in the dam. Algae bloom is experienced during the dry season and water with high color and turbidity is obtained during the rainy season increasing the cost of treatment of the water. This study focused on the effects of anthropogenic activities on the water quality parameters in the Owabi reservoir and its feeder water sources.

## MATERIALS AND METHODS

The Owabi reservoir is designed to produce 20% of the total portable water requirement in the Kumasi metropolis and nearby villages. The rivers which serve the Owabi reservoir have been encroached

with various human activities due to the high population density within the catchment area. The major source of water in the owabi reservoir is River Owabi which flows through agricultural land close to the village of Maase, upstream of Kumasi; other sources are Akyeampomene, Akonsu and Punpunase. River Owabi joins other tributaries from the urban area at Atafoa a rapidly-urbanizing agricultural village (McGregor *et al.*, 2002). Another main source of the water in the Owabi reservoir is River Akyeampomene which flows through Bremang and Suame townships. In the Bremang Township all the drain and gutters in the entire township is channel into the stream (Fig. 1). Five sampling sites from different community locations were chosen, namely Bremang, AbrepoKuma, Atafoa, river Owabi and the Owabi dam (Fig.1). A total of fifteen samples were taken. Samples were collected into sterile screw capped plastic containers. Prior to sample collection, all bottles were washed with dilute nitric acid followed by distilled water and were dried in an oven and labeled with dates and sampling source. Collected water samples were stored in a cooler at 4°C. Temperature, conductivity and pH of samples were measured on site using standard methods according to APHA AWWA (1992).

The water was taken to the Owabi Head works laboratory of the Ghana water company for the testing of ammonia, nitrates, phosphates, sulphates and heavy metals such as iron, Copper, Zinc, Aluminum, Manganese, and Chromium were all analyzed using Palintest photometer methods as described by Mutisya and Tole (2010) with slight modification.

**Statistical methods:** Statistical analysis of the results at each site was carried out using both Microsoft excel (2008) and the Graphpad prism software. Grubbs' test, also called the ESD method (extreme studentized deviate), was used to determine the most extreme significant outlier.

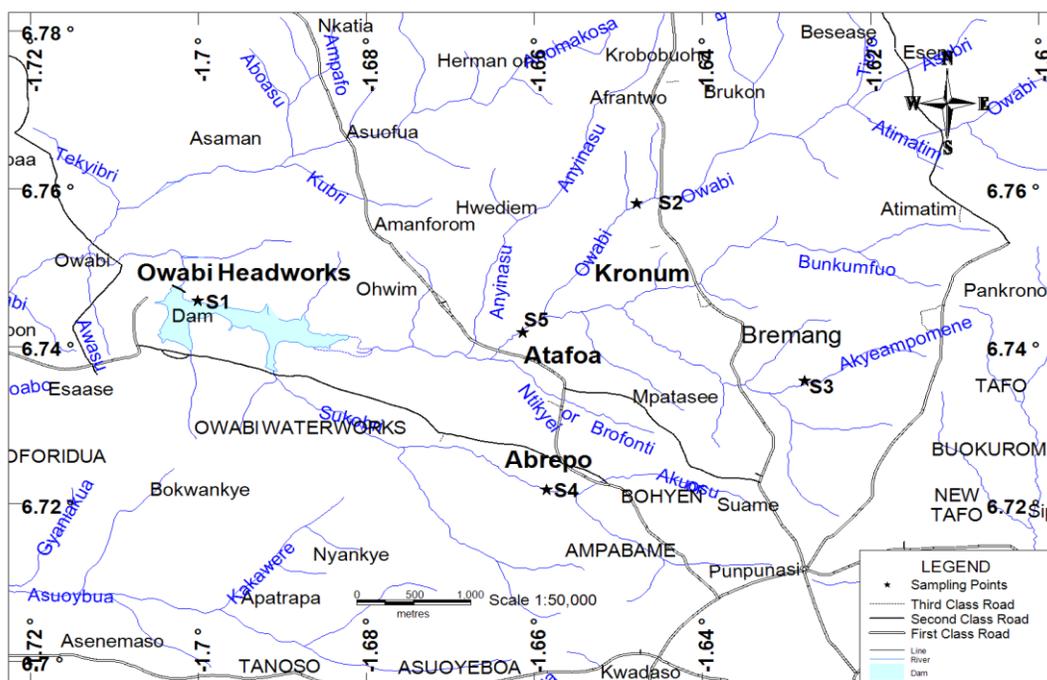


Fig 1 Map of the study site showing the watershed and the five collection sites

## RESULTS AND DISCUSSION

All the water samples showed alkaline pH (Table 1). Their mean values ranged from  $7.28 \pm 0.11$  at FB-105 to  $7.54 \pm 0.13$  at S1. The lower pH of 7.20 were obtained for the S5 samples; while the highest pH of 7.79 was obtained for the FB-103 samples. No significant difference was noticed in the observed pH ranges at each site and the variation in pH due to change in sampling location was also not significant ( $p > 0.05$ ). The pH levels were within the WHO optimum limits for drinking and portable water, which is 6.5 and 8.5 (WHO, 2006). All the mean values of pH obtained for the streams fell within the WHO range but were slightly above the natural background level of 7.0. This increase in pH of the water samples above the normal background levels may be due to the presence dissolved carbonates and bicarbonates present in the water, which affects the pH of surface water (Chapman, 1992).

The temperatures of the water samples were normal. The average temperature ranged from  $22.45 \pm 1.06^\circ\text{C}$  at River Akyeampomene to  $26.85 \pm 1.77^\circ\text{C}$  at the Owabi dam. There was noticeable variation in temperature of samples from S1 to S5 but not significantly different ( $p > 0.05$ ). Akoto et al., (2008) studied the heavy metal pollution profiles in the streams serving the Owabi reservoir. They found

temperature variations in the river Owabi at Kronom and Atafoa with temperature range of  $22.1 - 27.48^\circ\text{C}$  and  $23.3 - 28.44^\circ\text{C}$  respectively. Electrical conductivity (EC) is the numerical expression of an aqueous solution to carry electrical current and is a useful indicator of the mineralization in a water sample (Jain et al., 2005). The lowest EC of 263 was obtained for S1 samples; while the highest EC of 648 was obtained for S4 samples. The ECs varied between  $263 - 298 \mu\text{Scm}^{-1}$  (with a mean of  $280.50 \pm 24.75 \mu\text{Scm}^{-1}$ ) at S1 and  $596 - 648 \mu\text{Scm}^{-1}$  (with a mean of  $622 \pm 36.77 \mu\text{Scm}^{-1}$ ) at S4 (Table 1). The WHO limit for EC for drinking and potable water is  $700 \mu\text{Scm}^{-1}$ . All samples were within this limit. Akoto et al., (2008) reported high EC values of 804 -1817  $\mu\text{Scm}^{-1}$  in Pumpunase stream at Ampabame which also serves as a tributary to the Owabi reservoir. Health effects in humans for consuming water with high EC may include disturbances of salt and water balance; and adverse effect on certain myocardic patients and individuals with high blood pressure (Fatoki and Awofolu, 2003).

The mean turbidity values ranged from a minimum of  $8.74 \pm 2.16$  NTU, to a maximum of  $39.01 \pm 11.36$  NTU (Table 1). These values were recorded for S1 and S4 respectively. These values were within WHO guideline value of 75 NTU for drinking water.

**Table 1: Results for physical parameters of the sample; including the mean and their standard deviation (SD)**

Parameter site	Temperature (°C)	pH	Conductivity ( $\mu\text{Scm}^{-1}$ )	Turbidity (NTU)	Colour (PtCo)
S1	25.60 -28.10	7.44 – 7.63	263 – 298	7.21 – 10.27	60 – 130
Mean $\pm$ SD	26.85 $\pm$ 1.77	7.54 $\pm$ 0.13	280.5 $\pm$ 24.75	8.74 $\pm$ 2.16	95 $\pm$ 49.50
S2	22.20 -23.10	7.31 – 7.64	568 – 590	19.50 – 26.85	140 – 180
Mean $\pm$ SD	22.65 $\pm$ 0.63	7.48 $\pm$ 0.23	579 $\pm$ 15.56	23.17 $\pm$ 5.20	160 $\pm$ 28.28
S3	21.70 -23.20	7.28 – 7.79	270 – 303	7.31 – 16.33	50 – 85
Mean $\pm$ SD	22.45 $\pm$ 1.06	7.54 $\pm$ 0.36	286.5 $\pm$ 23.33	11.82 $\pm$ 6.38	67.50 $\pm$ 24.75
S4	21.80 -24.30	7.37 – 7.60	596 – 648	30.97 – 47.04	250 – 395
Mean $\pm$ SD	23.05 $\pm$ 1.77	7.49 $\pm$ 0.16	622 $\pm$ 36.77	39.01 $\pm$ 11.36	322.5 $\pm$ 102.53
S5	24.10 -25.40	7.20 – 7.35	399 – 421	27.00 – 35.10	120 – 195
Mean $\pm$ SD	24.75 $\pm$ 0.92	7.28 $\pm$ 0.11	410 $\pm$ 15.56	31.05 $\pm$ 5.73	157.5 $\pm$ 53.03

The nutrient levels generally at each site varied slightly but there was no statistical significance ( $p > 0.05$ ). The ammonia levels in the samples ranged from 0.03 to 0.53 mg/L. Average ammonia levels were within the WHO permissible values. The highest was recorded for S3 at 0.445 mg/L and the lowest was recorded for S1 at 0.145 mg/L (Table 2). Ammonia occurs as a breakdown product of nitrogenous material in natural waters. It is also found in domestic effluents and certain industrial wastewaters. Ammonia is harmful to fish and other forms of aquatic life and the ammonia level must be carefully controlled in water used for fish farms and aquariums (Conley *et al.*, 2009). Phosphate ( $\text{PO}_4^{3-}$ ) ranged from 1.06 to 3.16 mg/L (Table 2). The maximum concentration was observed for S2 at 3.16mg/L. Results of nitrate in the investigated samples as showed in table 2 ranged from 0.15 to 0.47mg/L. Nitrate is considered to be a non-cumulative toxin (Huang *et al.*, 2007). High concentrations of nitrates may give rise to potential health risks such as methemoglobinemia or 'blue-baby-syndrome' particularly in pregnant women and bottle-fed infants (Nkansah *et al.*, 2010). Nitrates at elevated concentrations are also known to result in cyanosis in infants (Nkansah *et al.*, 2010). The sulfate ( $\text{SO}_4^{2-}$ ) in the samples ranged from 8.0 to 20.50 mg/L (Table 2). The values recorded for nitrate and sulfate were all below the WHO permissible limits.

Monitoring studies of the Subin river, which flows through the industrial and commercial areas of Kumasi, the capital city of the Ashanti Region of Ghana, indicated water pH that ranged from 6.89 to 7.65, electrical conductivity (EC)- from 822 to 1,821  $\mu\text{Scm}^{-1}$  (Adomako., 2008). Concerning groundwater, Fianko., (2009) also investigated the relationship between land use and groundwater quality in the Eastern Region of Ghana and reported the following range of results: pH (4.49 – 6.95), conductivity (107 – 1,053  $\mu\text{Scm}^{-1}$ ), nitrate (0.01 – 66.0 mg/L), sulfate (0.03 – 181mg/L) and chloride (5.1 – 158 mg/L). Akoto., (2010) have reported the ranges for physicochemical parameters of surface water in the Owabi watershed: pH (6.75-7.40), nitrate (0.01-0.17mg/L), Sulfate (12.1-32.0 mg/L) and chloride (18-61 mg/L). The physicochemical data recorded in our present study for the Owabi watershed and its tributary rivers were consistent with the ranged of values reported in the above mentioned studies. This suggests that common physicochemical parameters such as pH, EC, turbidity, and some major ions in the Owabi reservoir and its feeder waters, following the various human activities in their surroundings were not differently affected in comparison to water quality-land use relationships from other parts of the country.

**Table 2: Results for Nutrient content of the sample; including the mean and their standard deviation (SD)**

Parameter site	Sulfate (mg/mL)	Nitrate (mg/mL)	Phosphate (mg/mL)	Ammonia (mg/mL)
S1	7.00 – 9.00	0.33 – 0.47	0.82 – 1.30	0.03 – 0.26
Mean ± SD	8.00 ± 1.41	0.40 ± 0.10	1.06 ± 0.34	0.15 ± 0.16
S2	5.00 – 10.00	0.16 – 0.31	3.05 – 3.26	0.12 – 0.34
Mean ± SD	7.50 ± 3.54	0.24 ± 0.11	3.15 ± 0.15	0.23 ± 0.16
S3	13.00 – 28.00	0.10 – 0.53	2.00 – 4.20	0.41 – 0.48
Mean ± SD	20.50 ± 10.61	0.32 ± 0.30	3.10 ± 1.50	0.45 ± 0.05
S4	18.00 – 21.00	0.08 – 0.21	2.79 – 3.20	0.26 – 0.53
Mean ± SD	19.5 ± 2.12	0.15 ± 0.09	3.00 ± 0.29	0.40 ± 0.19
S5	7.00 – 16.00	0.42 – 0.51	2.20 – 2.58	0.39 – 0.48
Mean ± SD	11.5 ± 6.36	0.47 ± 0.06	2.39 ± 0.27	0.44 ± 0.06

Trace metal levels generally at each site showed variations but they were not statistically significant ( $p > 0.05$ ) (Table 3). The highest average concentrations of the analyzed trace metals equaled  $3.07 \pm 0.9$  mg/L for iron at S4,  $0.175 \pm 0.035$  mg/L for Aluminum at S5,  $0.10 \pm 0.049$  mg/L for zinc at S5,  $0.125 \pm 0.035$  mg/L for chromium at S4,  $0.045 \pm 0.02$  mg/L for copper at S5 and  $0.019 \pm 0.00$  mg/L for manganese at S4. Table 3 reports the range of values and the mean concentrations of heavy metals in the study area. Background concentrations (BRC) are also reported in order to give an idea of the concentrations that would be expected to be found in surface water in the absence of any human activity. The concentration of essential nutrients (Zn, Fe, Mn, and Cu) is similar to the values measured in the main tributaries of the Densu River and some selected streams in the Brong Ahafo region of the Republic of Ghana (Akpabli and Drah, 2001; Akoto and Adiyiah,

2007). Akoto *et al.*, (2008) in their work reported on similar concentrations of iron, zinc, manganese and copper in the main tributaries of the Owabi waterworks in the Ashanti region of Ghana. The tolerance limit for Zn in water for domestic supply is 5mg/L (USEPA, 2003). Therefore, Zn concentration is adequate if the water is used for only domestic purposes. However, Zn could be a problem in water for other uses, for example, for the use of aquatic ecosystem. The range for Zn in water for the use of aquatic ecosystem is 0 – 0.02 mg/L. This limit is exceeded in the samples from site S4 and S5. Thus, water from these areas is unsuitable for the use for aquatic ecosystem as it could be detrimental to fish and other aquatic lives. The highest concentrations of most of the heavy metals (Fe, Zn, Cu and Mn) were obtained at sample site FB-104 (S4) from river Akonsu which runs through the Suame Township which has a large activity of vehicle repairs.

**Table 3: Results for Heavy metal content of the sample; including the mean and their standard deviation (SD)**

Parameter Site	Iron (mg/L)	Zinc (mg/L)	Copper (mg/L)	Aluminum (mg/L)	Chromium (mg/L)	Manganese (mg/L)
S1	1.16 -1.53	0.001 – 0.04	0.001 – 0.03	0.02 – 0.13	0.06 – 0.10	0.008 – 0.016
Mean ± SD	1.35 ± 0.26	0.02 ± 0.02	0.02 ± 0.02	0.08 ± 0.08	0.08 ± 0.03	0.012 ± 0.006
S2	2.73 – 2.95	0.001 – 0.02	0.001 – 0.06	0.07 – 0.07	0.06 – 0.09	0.007 – 0.016
Mean ± SD	2.84 ± 0.16	0.01 ± 0.014	0.03 ± 0.04	0.07 ± 0.00	0.08 ± 0.02	0.012 ± 0.006
S3	0.67 – 1.10	0.001 0.03	0.001 – 0.05	0.03 – 0.12	0.05 – 0.11	0.002 – 0.007
Mean ± SD	0.89 ± 0.30	0.015 ± 0.02	0.03 ± 0.04	0.08 ± 0.06	0.08 ± 0.04	0.005 ± 0.004
S4	2.93 – 3.20	0.07 – 0.13	0.02 – 0.06	0.09 – 0.15	0.10 – 0.15	0.018 – 0.019
Mean ± SD	3.10 ± 0.19	0.1 ± 0.04	0.04 ± 0.03	0.12 ± 0.04	0.13 ± 0.04	0.019 ± 0.001
S5	2.03 – 2.73	0.04 – 0.11	0.03 – 0.06	0.15 – 0.2	0.05 – 0.06	0.006 – 0.01
Mean ± SD	2.38 ± 0.49	0.075 ± 0.05	0.05 ± 0.02	0.18 ± 0.04	0.06±0.007	0.008 ± 0.003

## CONCLUSION

In summary, among the trace metals considered, Chromium posed significant environmental risk from three of the sample areas at Akyeampomene, Akonsu and Owabi. This conclusion followed the fact that Cr concentrations at these areas exceeded the WHO guidelines value. We assumed that the chromium was introduced as a contaminant in chemicals used in vehicle repair and maintenance, agrochemicals and other chemical used as a result of human activities along the banks of the rivers. The physicochemical characteristics of the all the streams were consistent with data from the literature. In this study, the concentrations of the investigated, Nutrients in the water samples from the water bodies were found to be acceptable according to the guidelines the source of raw water for drinking water provided by the World Health Organization (WHO). The occurrence of algae blooms in water bodies due to presence of the nutrient in the water bodies. Once pollution trends set into a water body, it generally accelerates to cause greater deterioration of the watershed. It is therefore recommended that close monitoring, appropriate education on the proper handling, use and disposal of agrochemicals, proper planning of vehicle repair and maintenance shops and good location of car washing bars. All measures should be taken by local authorities in order to make such monitoring mechanisms available which allow implementation of the necessary protective measures.

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