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Chemical Analysis of Freshwater Bodies in the Kumasi Metropolis and Its Environs, Ghana

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Abstract
One of the main environmental problems facing the city of Kumasi the second largest city in Ghana over the years has been the pollution of water bodies arising from anthropogenic activities. This has become a potential health threat to the inhabitants of the city which was formerly referred to as the garden city of Ghana and its environs. The most affected are the surrounding rural areas that rely solely on the rivers for drinking, domestic and agricultural purposes. This study focused on the extent of chemical pollution of these water bodies through the determination physicochemical parameters such as pH, temperature, conductivity, total dissolved solids (TDS), Total suspended solids (TSS), alkalinity, Total hardness, nitrates, sulphates as well as heavy metals and biological contamination through the determination of total coliform and Escherichia coli. Eight samples were taken from three main rivers in the Kumasi metropolis namely Wiwi, Sisa and Subin. This data showed variations in the parameters in the samples as follows: pH, 6.67-7.50; temperature, 28-29°C; electrical conductivity (EC), 220-2120 μS/cm; TDS,10-1800 mg/l; alkalinity, 24-124 mg/l; total hardness, 25-365 mg/l; nitrates, b/d-0.47 mg/l; sulphate,0.352-40.30 ; phosphates, 5.2-30 mg/l; Pb, 6.620-6.797 mg/l; Fe. 14.81-45.65 mg/l; Mn, 0.726-4.7427 mg/l; Cd, 0.156-0.219 mg/l; Cr, 0.03-0.10 mg/l; Ni, 0.002-0.018 mg/l; Cu 0.113-2.258 mg/l and Zn 0.368-5.255 mg/l. However, all the results obtained for the levels of the metals exceeded the EPA Maximum contaminant level (MCL) with the exception of the zinc where only one of the samples exceeded the MCL level.
Keyword: environmental, chemical pollution, Maximum contaminant level, physicochemical parameters, Kumasi-Ghana

1. Introduction

Freshwater resources all over the world are threatened not only by over exploitation and poor management but also by ecological degradation. Fresh water is a finite resource, essential for agricultural, industry and even human existence without fresh water in adequate quantity and quality, sustainable development will not be possible (Adeyeye and Abulude 2004). The introduction of various kinds of pollutants and nutrients through sewage, dumping of industrial effluents, run-off from agricultural fields, discharge of untreated waste etc. into water bodies brings about a series of changes in the physicochemical and biological characteristics of water, which have been the subject of several investigations (Lannik and Zubenko 2000; Cambell 2001; Lwanga *et al*. 2003 and Lomniazi *et al*. 2007). Industrial growth, urbanization and the increasing use of synthetic organic substances have serious and adverse impacts on freshwater bodies.

The fact that water quality vary widely from depending on the source, has led to the establishment of standards for drinking water used in interstate commerce by many States including the U.S. Public Health Service and the World Health Organization (WHO). Portable water is defined as that having acceptable quality in terms of its physical, chemical, bacteriological and acceptability parameters so that it can be safely used for drinking and cooking (WHO 2004).

Various processes are involved in the treatment, and sanitary disposal of liquid and water-carried wastes from households and industrial plants (Microsoft ® Encarta ® 2006).

The issue of sewage disposal assumed increasing importance in the early 1970s as a result of the general concern expressed worldwide about the wider problem of pollution of the human environment, the contamination of the atmosphere, rivers, lakes, oceans and groundwater by domestic, municipal, agricultural, and industrial waste.

In low-income countries, population growth coupled with urbanization has outpaced the development of sanitation infrastructure, leaving the urban poor, especially, virtually without sanitation facilities in many countries. About 2.4 billion people worldwide lack access to basic sanitation, 80 per cent of them in Asia and 13 per cent in Africa. Although, sanitation coverage is better in urban than in rural areas, still more than 300 million urban residents lack sanitation facilities and the numbers are increasing.

In Ghana, 44 per cent of the total population of about 19 million lives in urban areas (Ghana Statistical Services (2002, 2000). As in most countries in sub-Saharan Africa, Ghana's sanitation infrastructure is not well developed.

The rapid rate of urbanization does not match available urban infrastructure. In particular, the few sanitation facilities have been over-stretched, waste are also discharged indiscriminately in open drains. More than 70 per cent of house-holds in three of Ghana's ten administrative regions have no toilet facilities in or near their homes, and the available sanitation infrastructure for those that have it is inadequate. The consequences are worst in urban areas, which have very high population densities (in larger cities, there are growth rates of up to 4.4 per cent).

Common sights as you walk through Ghana's major cities, for example Accra and Kumasi are open storm-water gutters full of garbage and wastewater, and urban streams that look like large wastewater drains. This current state of environmental sanitation in major cities of Ghana is derived from the increasing amount of waste generated and the inadequacy of waste disposal and treatment facilities. The use of public toilets and open defecation is pronounced, as only 5% of the population is served with a sewerage network while 20 % have no toilets at all. It is a common feature to find open gutters, which were meant for storm water drainage now filled with domestic and industrial wastewater and often choked with solid materials and sediments. This is further aggravated by inadequate drainage systems to manage the large amount of runoff. All these eventually flow into streams and rivers causing severe pollution in the city and downstream (Keraita *et al.* 2002). This affects significantly different sections of urban dwellers that use city water bodies for various purposes. One of these groups is urban and peri-urban farmers.

Moreover, the migration of people from rural areas to the cities in search of 'greener pastures' has increased urban food demands as well as the numbers of urban poor who cannot afford basic amenities of life. In response to this situation, an increasing number of city dwellers have resorted to all kinds of income-generating activities in the urban informal sector. Among this is the intensive irrigated urban and peri-urban agriculture which takes advantage of urban demand for perishable crops and water sources (runoff/wastewater) for all-year or dry-season production.

This practice, which has been on the increase during the last decades, links environmental sanitation to urban food supply.

Kumasi**,** the capital of the Ashanti region is the second largest city in Ghana. Kumasi has one of the largest markets in West Africa. The metropolis covers an area of 223 square kilometers and currently has a population of almost 1.2 million - more than twice the number recorded during the 1984 census. Kumasi is situated approximately 260 meters above sea level, and has a wet, semi-equatorial climate and temperatures averaging 28° C. Rainfall is weakly bi-modal, with an annual average of about 1,340 millimeters. The dry season (November to March) is sharp and pronounced.

Four main streams (Daban, Sisa, Wewe and Subin), flow through Kumasi city, with the Subin originating in and cutting through the city centre. They join the River Oda downstream. Quite characteristic of the drainage system in Kumasi is a concrete drain that was superimposed on the Subin River to avert flooding in the city. This has now turned into 'solid and liquid waste highway 'due to the dumping of all sorts of wastes in the drain. The figure 1 below indicates the drainage network system in Kumasi; (IWMI, RUAF, CPWF 2006).

The principal generators of industrial wastewater in Kumasi are two breweries, soft drinks bottling plant and the Kumasi abattoir which, together, generate a total of about 1,000 cubic meters of effluent daily, which ends up in the city's drains and nearby streams. Light industry generates significant amounts of non-collected waste oil and leachate (Keraita Bernard IWMI).

Many people rely on the stream and its tributaries for their domestic use and for irrigation. The changes in water quality in streams in and around Kumasi are evident, and complaints have been coming from users, especially in Asago village, 9 km from the city centre, just downstream of the Kaase faecal treatment plant where the Sisa enters the Oda River.

It is this therefore imperative that the physicochemical analyses are carried out for some rivers running through the Kumasi city. The changes in water quality in Rivers Sisa, Subin and Wewe are evident and these pose a threat to livelihood.

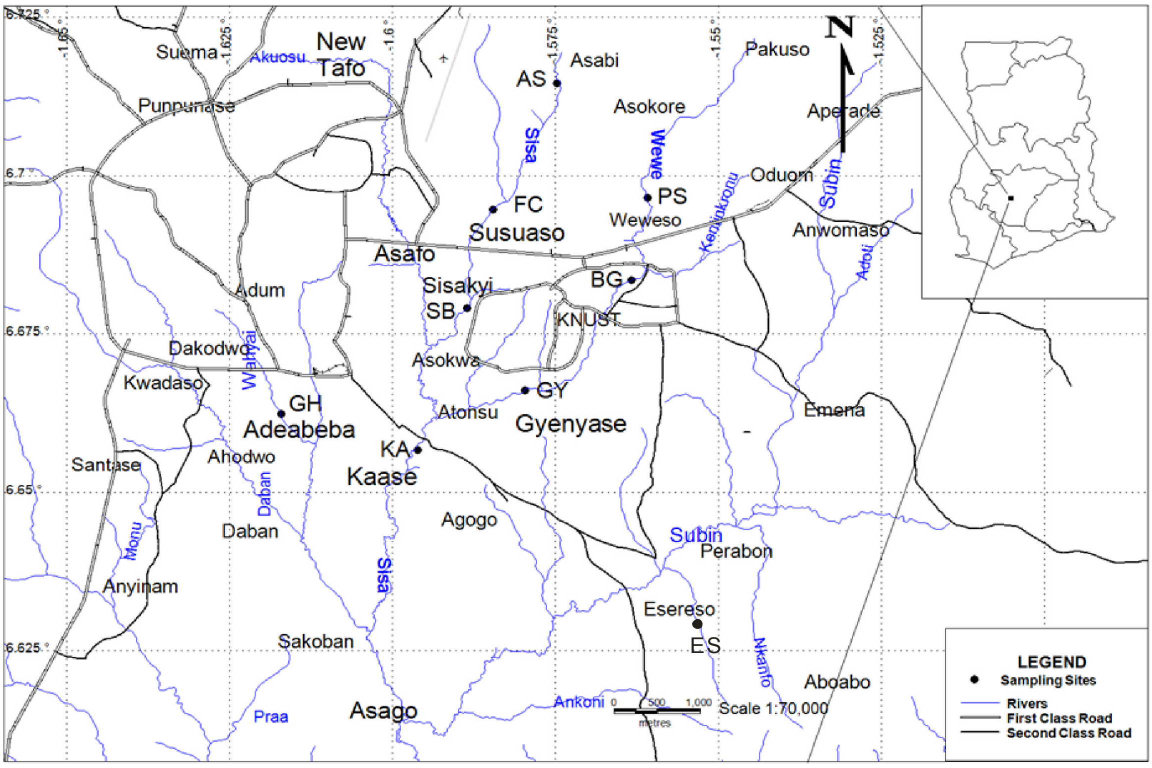

Figure 1. Map showing locations of the water bodies and the sampling points in the Kumasi metropolis and its environs.

Most sewerage infrastructure in Kumasi was built in the 1970s when the population was only one-third its current level, and no significant extension to this infrastructure has taken place since. It was around this time that the two main conventional sewage plants in Kumasi were built, one at a local university (KNUST) and the other at Asafo, which covered some parts of the city centre. Neither has been in operation for over ten years. The university plant needs rehabilitation and enlargement, as the student population has increased from fewer than 1,000 in the 1970s to more than 10,000 now, and efforts are underway to get funds for this. Rehabilitation of the city centre plant is not feasible, but the local authorities are now promoting smaller, community-based treatment plants. Currently, there are three in operation in some suburbs in Kumasi. The authority is also encouraging private establishments, such as the larger hotels, to have their own treatment plants.

The other main problem in the city has been the management of faecal sludge – wastewater from the public toilets, septic tanks and bucket latrines that serve more than three-quarters of the city's population. There has been no permanent faecal sludge treatment in Kumasi. The few sites that the authority obtains are "filled up" in a matter of months, and even obtaining sites is hard as most communities see treatment plants as a nuisance. Over the last few years, the city's main faecal sludge treatment plant has been at Kaase. This was meant to be a temporary plant for use during the African Cup of Nations games in 1998 but, as of March 2003, it was still the main one in use and received an average of 144 cubic metres of sludge per day (Leitzinger and Adwedaa 1999). The volume had reached 500 cubic metres per day 2001 but had gone down to 180 cubic metres per day in 2002 (KMA (2003, 2002). The Waste Management Department (WMD) attributed this mainly to vehicle break-downs The Kaase treatment ponds have long been filled beyond capacity, and untreated faecal sludge has been flowing into the River Subin. However, another plant at Buobai, which can handle 200 cubic metres per day, started operation in April this year.

Various technologies exist for wastewater treatment. Waste stabilization ponds seem to be best suited to Kumasi, as their removal of pathogenic micro-organisms is good and they are more cost-effective than other solutions (Mara and Cairncross 1989). Indeed, apart from the KNUST plant (which is a trickling filter type), all other plants in Kumasi, like most in Ghana, use this technology. As well as the initial design and construction costs, which are often prohibitive for authorities, various other issues come into play. For example, the Asafo plant (which was completed in the mid-1990s) is still operating below capacity (60 per cent of the intended population is connected mainly because of the costs and unreliability of flushing water, the charges for using the plant, and the difficulties in making connections in the heavily built-up surroundings.

Changes in water quality in water bodies in and around Kumasi are evident. This has been mentioned in local daily newspapers and, from time to time, there is a public outcry. Many people rely on the streams for irrigated farming and others even for domestic use. Asago, a village just downstream of the Kaase faecal sludge plant, is one of the most affected locations.

Villagers have reported sickness, mostly among children, and a scarcity of fish such as tilapia in the local river, the Oda.

Worse still, according to a DFID-EPA study carried out between 1999-2000, there is ongoing groundwater contamination from the Oda that is affecting nearby shallow wells (McGregor *et al.* 2001). The study encouraged environmental self-monitoring and the use of simple water quality test kits, which were provided in junior secondary schools. As part of the IWMI project, an analysis of faecal coliform in the River Oda at Asago found levels of 10^{7}–10^{9} per 100 millilitres. Despite dilution from the river, these levels are comparable to those for raw sewage (Feachem *et al*. 1983), which shows the effects of effluents from the broken-down faecal sludge treatment plant at Kaase.

Previous studies show that levels of heavy metals in water bodies in and around Kumasi are not very high (Cornish, *et al*. (1999), as industrial pollution is negligible. However, inter-seasonal variations in water quality can be wide, especially after the first heavy rainfall (Cornish, *et al.* 1999). Heavy metals in water exist in colloidal, particulate and dissolved phases (Adepoju-Bello *et al*. 2009). Their occurrence in water bodies being either of natural origin (for example eroded minerals within sediments, leaching of ore deposits and volcanism extruded products) or of anthropogenic origin (ie solid waste disposa, industrial or domestic effluents, harbor channel dredging) (Marcovecchio *et al*. 2007). Even though some of the metals are essential to sustain lifeeg cobalt, copper, iron, manganese and zinc are needed at low levels as catalysts for enzyme activities (Adepoju-Bello *et al*. 2009), excess exposure to heavy metals can result in toxicity. In a two-week interval, PO_4 levels rose from less than 6 milligrams per litre in three sampling locations to more than 71 milligrams per litre. The high PO_4 levels, which could be of great value to farmers, cannot be attributed only to waste water, but also to flushes from nearby farms where fertilizers and manures are intensively used.

In general, the nutrient load and microbiological pollution levels were low just upstream of the city (ST), reaching their highest just downstream of the city (KA), and decreasing further downstream (Figure for the location of the sites). However, it is worthwhile to note that coliform levels in the stream are still too high (more than 10^6 per 100 millilitres of water even 32 kilometres downstream of the city. WHO guidelines restrict the use of irrigation water at faecal coliform levels higher than 10^{3} per 100 millilitres.

Table 2.1 shows the values of selected chemical and biological parameters of water sources used by farmers in and around Kumasi, sampled at different points along the Rivers Sisa and Oda which pass through the city. The values are averages from a wide range of samples taken during both the dry and wet seasons. Heavy metals had already been shown by Cornish (1999) to be within tolerable limits in Kumasi. The high levels of FC however are an indicator of indiscriminate dumping of untreated faecal waste to water bodies in the sampled areas. The risk is not only to farmers but also to consumers.

The recommended FC levels for irrigation water for vegetables is = 1×10^{3}/100 ml (WHO, 1989) but levels as high as 3.4×10^{10}/100ml are recorded for site A, which is the site closest to the city being only 4 km downstream. The faecal sludge treatment plant around this site has an evident negative influence on water quality though the levels decrease downstream.

The objective of this study is to determine the levels of heavy metals in rivers Sisa, Subin and Wewe in and around the Kumasi and to assess the effects of the contaminants to users (domestic and irrigational purposes)

2. Materials and methods

2.1 Sampling sites

The samples were collected from eight different sites from three different rivers namely River Sisa, River Wiwi and River Subin. The choice of the sampling sites were influenced by the activities tanking place around them. The table below represents sampling sites and the activities around that influence the properties of the rivers.GY= Gyinyase–adjacent KNUST campus (Vegetable farms of cabbage, lettuce and tomatoes), BG = KNUST-Botanic Gardens (Conserved species of plants trees), PS = Weweso-behind the Tech Police station (Vegetable farms of cabbage and spring onion), AS = Asabi– between Asokore (Liquid waste from gutters), FC = Susuaso-behind the Family Life Chapel (Car washing bay and deposition of solid waste), SB = Sisakyi- behind Sobolo (Refuse dump, human and animal excreta, liquid waste from gutters, palm nut and gari production), GH = Adeabeba behind Georgia hotel (Plantain and cassava farms. Car washing bay, human excreta), KA = Kaase subin (Plantain farm and car washing bay), ES= Esereso (Plantain farm and car washing bay).

2.2 Sample treatment and preservation

The samples were collected with plastic bottles of volumes of 500 mL and 1.5 mL for each sampling site. Because water is susceptible to change as a result of physical, chemical or biological reactions this may take place between the time of sampling and the analysis. The sample in the 1.5 mL plastic bottle was acidified at the time of collection with nitric acid with an aliquot of about 7 mL and kept in a temperature of about 4 °C in a refrigerator. This was purposely done for the sample used for heavy metal analysis.

2.3 Sample Analysis

The pH, conductivity,salinity and TDS of each water sample were determined using the Hanna multi-parameter meter. The pH meter was calibrated with two buffer solutions of pH 4.0 and 7.0 before the measurements were done. About 50 ml of the water sample was poured in a clean glass beaker and the electrode was rinsed with distilled water and placed in the sample in the beaker. A digital reading appeared upon inserting the probes into the water samples indicating first the pH and temperature. The total suspended solids (TSS), Alkalinity, Total hardness, Magnesium and calcium were determined by the classical methods (APHA, 1998).

Standard solutions of each of the anions (Cl^-, F^-, SO_3^-, SO_4^{2-}, NO_2^-, NO_3^- and PO_4^{3-}) were prepared with concentrations of 1, 5, 10, 50, and 100 ppm. Each standard solution was injected into the Ion Chromatograph (Metrohm 861 Advanced Compact IC) with the appropriate column (polyvinyl alcohol with quaternary NH_4^+ and eluent ($NaHCO_3^-/Na_2CO_3$) to determine the retention time and peak areas of the standards. A calibration curve was drawn for each anion. The sample solutions were then injected into the ion chromatograph to measure their retention times and peak areas. The concentrations of the anions were determined from the calibration curves.

2.4 Digestion procedure

All glass wares were soaked in detergents solution overnight after which they were rinsed with distilled water and soaked in 10 % HNO_3 solution overnight. They were then rinsed again with distilled water and dried. For this purpose, the most common procedure is an acid digestion for total metal determination. 500 ml of each water sample was measured into a 1000 ml beaker and 15 ml of concentrated HNO_3 acid was added. The mixture was then heated on a hot plate in a fume chamber till the volume was reduced to about 20-30 ml. The mixtures was cooled to room temperature and filtered into 50 ml volumetric flasks through whatman No. 41 filter paper and made to the mark with distilled water. A blank solution was prepared in the same manner without the sample.

2.5 Determination of Heavy metals

Calibration standards were prepared by multiple dilutions of the stock metal solutions. Reagent blank and 3 calibration standards in graduated amount in the appropriate range of the linear part of the curve were prepared. The metals in all the digests were determined UNICAM 979 Atomic Absorption Spectrometer. By choosing the correct wavelength of the various metalsand running a known standard curve of the various metals, the absorbance values of the heavy metals present in the samples were determined. Using the standard absorbance of the various heavy metals, the absorbance from the various heavy metals as contained in the samples was converted into mg/l for water samples as their levels of concentrations. This was repeated three times for every sample and the mean concentration was taken as the actual level of concentration of the heavy metal. Finally the entire data was generated by the laboratory analysis of the samples were analyzed by some simple descriptive statistics. The detection limits of the instrument for all the metals determined were approximately 0.01 mg/l. The detection limit is defined as the lowest analytical signal to be distinguished qualitatively at a specified confidence level from the background signal (Kackstaetterand Heinrichs, 1997). The accuracy of analytical procedure was checked by analyzing the standard reference materials (water: SRM-143d, National Institute of Standards and Technology).

The microbial analysis was done using the standard method for the determination of total coliform and fecal coliform (Brenner *et al*. 1993; APHA 1995).

3. Results and discussion

The pH readings were between the ranges of 6.69 to 7.50. They were within the EPA quality guidelines of permissible range of 6.5-8.5 for natural water bodies. Most aquatic plants and animals are adapted to a specific pH range, and natural populations maybe harmed by water that is too acidic or alkaline. Waters, with low pH could contain elevated levels of toxic metals cause premature damage to metal piping and have associated aesthetic problems such as metallic or source taste staining of laundry and characteristic blue green staining of sinks and drains. In very acidic metals which are normally bound to organic matter and sediment, are released into the water. Water with a pH more than 8.5 could indicate that the water is hard (Ameyibor and Wiredu, 1991). Total hardness levels from the various sampling sites ranged from 120-280 mg/l which were much lower than the WHO recommended levels for drinking water of 500 mg/l. Hardness of water does not pose a health risk but can cause aesthetic problems. These problems include the formation of ‘scale’ or precipitation on piping and fixtures causing water pressures and interior diameters of piping to decrease, causes alkali taste in water, formation of scale or deposit on dishes, utensils and laundry basins, difficulty in getting soaps and detergents to foam and formation of insoluble precipitates on clothing.

Sites such as (GY), (PS), (GH) and (KA) obtained high conductivity values. Both KA and GH obtained the same value of 2120 µS/cm which exceeds the EPA limit. The conductivity results of the EPA in February 2002 were lower than those obtained in table 4.1. This might be due to the increase of disposal of waste and other activities along the rivers such car washing bays over recent years.

Table 1. Physicochemical parameters of water sampled from rivers Wiwi, Sisa, Oda and Subin

Parameter	pH	Conductivity (µS/cm)	Temperature(°C)	TDS (mg/l)	TSS (mg/l)	Alkalinity (mg/l)	Total hardness (mg/l) $CaCO_3$	Magnesium (mg/l)	Calcium (mg/l)	Salinity (mg/l)
GY	6.69 ± 0.01	1280 ± 9.8	28 ± 1.06	124 ± 7.4	16.0 ± 0.04	250± 5.75	270± 2.95	2.675± 0.14	20.0± 1.45	0.15± 0.02
BG	6.67 ± 0.03	240 ± 1.65	28 ± 0.90	10 ± 1.32	15.32± 0.70	140± 3.45	230± 1.98	0.685± 0.02	14.0± 0.66	0.09± 0.01
PS	7.50 ± 0.04	1220 ± 8.92	29 ± 1.2	100 ± 6.8	13.00± 0.08	150± 4.05	120 ± 3.76	0.899± 0.00	18.4± 1.11	0.13± 0.01
AS	6.83 ± 0.11	220 ± 3.65	29 ± 1.04	500 ±8.4	14.00 ±0.03	250± 1. 57	220 ± 1.35	0.851± 0.01	60.0± 4.35	0.45± 0.02
FC	6.89 ± 0.08	820 ±6.0	29 ± 0.98	900 ± 10.0	14.53± 0.09	800± 2.95	140 ± 2.25	0.958± 0.02	24.5± 1.37	0.72± 0.05
SB	6.81 ± 0.13	1060 ± 7.6	29 ± 0.70	1200±15.2	13.92 ±0.02	350± 3.15	160 ± 2.85	0.730± 0.03	40.0± 2.31	0.14± 0.02
GH	6.80± 0.34	2.201 ± 0.02	29 ± 0.021	1700± 11.5	14.42± 0.05	700± 2.35	280 ± 1.95	2.456± 0.17	31.2± 1.91	0.45± 0.04
KA	6.75 ±.0.02	2120 ± 18.1	29 ± 1.02	1800± 32.4	13.86± 0.04	200± 3.22	150 ± 3.05	0.899± 0.03	30.4± 2.25	0.29± 0.07
ES	7.20 ±.0.03	252 ±.2.32	28 ± 0.60	125 ± 2.10	10.00 ±0.03	400 ± 3.53	200 ± 4.33	1.459± 0.04	32.0± 3.16	0.12± 0.00
MDL	0.01	0.9	N/A	0.01	N/A	0.1	0.1	0.01	0.01	N/A
MCL	6.50-8.50	1500	30	1000	50.00	200	500	N/A	200	N/A

Abbreviations: b/d, below detection, N/A. not applicable; MDL, minimum detection limit, MCL, maximum contamination limit.

Table 2. Mean levels anion in water sampled from rivers Wiwi, Sisa, Oda and Subin

Parameter	Chloride Mg/l	Fluoride Mg/l	Sulphite Mg/l	Sulphate Mg/l l)	Nitrites Mg/l)	Nitrates (mg/l)	phosphates (mg/l)
GY	15.35± 0.01	0.049 ± 0.00	0.07 ± 0.00	0.352± 0.05	25.58± 0.88	0.18 ± 0.001	6.4 ± 0.75
BG			0.11 ± 0.02		b/d	b/d	5.2 ± 0.96
PS	23.39 ± 0.04	0.078 ± 0.00	0.09 ± 0.00	4.66± 0.12	b/d	0.028 ± 0.00	18 ± 1.42
AS	81.60 ± 0.11	39.14 ± 0.65	0.06 ± 0.00	22.93 ± 0.4	b/d	0.26 ± 0.003	5.2 ± 0.065
FC	125.57± 2.08	0.179 ± 0.09	0.08 ± 0.00	40.30± 0.54	b/d	0.18 ± 0.001	9.9 ± 0.087
SB	13.53 ± 0.13	0.143 ± 0.07	0.09 ± 0.01	4.12 ± 0.52	b/d	0.18 ± 0.001	15 ± 1.02
GH	73.41± 0.34	35.21 ± 0.02	0.11 ± 0.02	36.09± 0.91	b/d	0.22 ± 0.002	20 ± 1.23
KA	54.34 ±0.22	0.083 ± 0.00	0.09 ± 0.02	7.79 ± 0.47	b/d	0.47 ± 0.0021	30 ± 1.53
ES	22.48 ± 0.03	0.078 ± 0.02	0.13 ± 0.02	6.93 ± 0.30	b/d	b/d	b/d
MCL	250	1.5	1.5	250	5.0	50	2.0

Abbreviations: b/d, below detection, MCL, maximum contamination limit.

Table 3. The mean levels of heavy metals in water sampled from rivers Wewe**,** Sisa, Oda, and Subin

Metal (ppm)	Lead	Copper	Zinc	Manganese	Iron	Cadmium	Chromium	Nickel
GY	6.620 ± 0.43	0.628 ± 0.03	1.211 ± 0.0021	2.454 ± 0.005	33.18 ± 1.332	0.145 ± 0.0032	0.10 ± 0.01	0.028 ± 0.020
BG	6.723 ± 0.35	0.123 ± 0.008	0.896 ± 0.0020	0.813 ± 0.00	26.43 ± 1.04	0.165 ± 0.0015	0.06 ± 0.00	0.008 ± 0.001
PS	6.730 ± 0.21	0.128 ± 0.02	0.452 ± 0.0024	2.667 ± 0.0043	26.58 ± 1.13	0.217 ± 0.0023	0.03 ± 0.00	0.007 ± 0.001
AS	6.523 ± 0.09	0.160 ± 0.007	0.368 ± 0.0017	0.726 ± 0.0018	14.81 ± 0.76	0.130 ± 0.0013	0.07 ± 0.01	0.002 ± 0.00
FC	6.975 ± 0.11	0.189 ± 0.011	1.211 ± 0.0032	1.666 ± 0.0011	29.08 ± 0.98	0.199 ± 0.007	0.08 ± 0.01	0.004 ± 0.001
SB	6.723 ± 0.15	0.113 ± 0.09	1.211 ± 0.005	2.782 ± 0.003	39.08 ± 1.03	0.156 ± 0.0011	0.05± 0.01	0.018 ± 0.003
GH	6.797 ± 0.34	2.201 ± 0.02	4.545 ± 0.0021	3.834 ± 0.014	44.81 ± 1.319	0.219 ± 0.017	0.05 ± 0.00	0.009± 0.002
KA	6.562 ± 0.39	2.258 ± 0.05	5.255 ± 0.0041	4.427 ± 0.020	45.65 ± 1.142	0.170 ± 0.0005	0.04 ± 0.01	0.006 ± 0.001
ES	3.20± 0.12	1.845± 0.51	1.11 ± 0.032	0.613 ± 0.00	11.92± 1.01	0.032± 0.002	0.03± 0.01	0.005± 0.00
MCL	0.1	1.0	5.00	0.10	1.0	0.005	2.0	0.50

Abbreviations: b/d, below detection, MCL, maximum contamination limit.

Table 4. The levels of total and fecal coliform in water sampled from rivers Wiwi**,** Sisa and Subin

Sample	Total coliform MPN x 10^{10}/100 ml	Fecal coliform (E-coli) MPN x 10^{10}/100 ml
GY	5.61	3.61
BG	4.34	2.34
PS	5.58	3.58
AS	5.62	3.62
FC	6.42	4.42
SB	6.79	4.79
GH	6.32	4.32
KA	6.15	4.15
ES	3.86	2.34
MDL	20 MPN 100 ml	20 MPN 100 ml

Apart from the presence of dissolved metals, agricultural runoff can also raise conductivity values in water bodies. This accounted for the high levels obtained for GY, PS, GH and KA because of the presence of phosphate and nitrate from the farms around.

The temperature readings were ranging from 28 and 29 °C. The ranges of 26.2 and 30.6 °C of EPA 2002 report were due to the fact that temperatures were taken on sites therefore the disparity. All plant and animal species that live in water are adapted to temperatures within a certain range. It controls the rate of metabolic and reproductive activities. The metabolic rate of fish and aquatic organisms also increases with increasing water temperatures, and additional oxygen is required for respiration. Thermal pollution may even be caused by the removal of trees and vegetation, which normally shade the water body.

However the values obtained for rivers Sisa and Subin are greater than the accepted EPA limit of 500mg/l. due to the increase of deposition of waste the TDS values of the EPA report was lesser compared to these.

Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water.

The nitrates levels obtained and that of the data of the EPA (February 2002) did not exceed the EPA limit of 1.0 mg/l, they were less than 1.0 mg/l. Common sources of nitrate include fertilizers manure, animal feedlots, municipal waste water and sludge, septic systems and nitrogen fixation from atmosphere by legumes, bacteria and lightning. The result for (PS) was 0.028 mg/l which is unexpectedly low. This is because the sample was taken from river Wewe where the site is found along vegetable farms where supposedly fertilizers are used which happens to be one of the main sources of nitrates. Although there was a transmittance reading for BG)-KNUST Botanic Gardens it was too low to be detected. (GY), (FC) and (SB) recorded the same value of 0.18mg/l. These may be due to application of fertilizers on vegetable farms in the case of (GY). This area has the largest urban vegetable farming sites. For FC and SB humans and animals excrete into the river (River Sisa) and nearby houses have the septic tanks leading into the river. There is a faecal treatment plant in Kaase where the Sisa enters the Oda River, this also accounts for the high concentration for KA. However, the concentrations of nitrates increase from river Wiwi to river Subin and this corresponds to the level of waste in the rivers.

The amount of Chloride found in the test samples ranged from 15.345 to 125 mg/l which were far below the WHO value of 250 mg/l and hence does not pose any immediate health risk to consumers. Chlorides enters surface and groundwater from both anthropogenic and natural sources such as run-off from human habitations, discharges of waste waters into water bodies, fertilizer applications, septic tank effluents etc. (Gupta 1999). Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism as reported in congestive heart failure (Gupta 1999). In portable water, the salty taste is produced by the chloride concentrations and its variable and dependence on the chemical composition (Putz 2003).

Fluorides may be discharged as by product from fertilizer and aluminium factories and it can enter ground water bedrock wells to create greater risk for high levels of fluoride. Flouride levels were generally low ranging between 0.049-39.140 mg/l. The levels obtained from GY, BG, PS, FC, SB, KA, and ES were far below the WHO level of 1.5mg/l. However the levels at AS and GH recorded values far greater than the WHO recommended value. WHO (2004) asserts that, fluoride in drinking water occur naturally and can be released from phosphate containing rocks which contains 4 % fluoride. Levels of fluoride up to 10 mg/l results in dental flourosis while concentration below 0,1 mg/l leads to dental decay (Edmunds and Smedely 1996).

Nitrite in water is either due to oxidation of ammonium compounds or due to reduction of nitrate. The presence of nitrite indicates that, the organic matter present in water is not fully oxidized. The amount of nitrite in portable water should be nil. All the samples taken were below detection limit except GY which gave a value of 25.58 mg/l. The general absence of nitrites indicate that the organic matter present in almost all the water bodies were fully oxidized and longer harmful. (APHA 1992)

The levels of phosphate are in appreciable amounts; (BG) and (AS) recorded the lowest of 5.2 mg/l because there is less activity along both rivers and KA recorded the highest of 30 mg/l and is due to deposition of sewage from around the vicinity and the rest for the other river such as rivers Sisa, Wewe etc the joins River subin at Kaase. Phosphate levels give a measure of both inorganic and organic forms of phosphorus. Phosphates are not toxic to human beings or animals unless present in very high concentrations. Digestive problems occur from extremely high levels of phosphates (Oram, 2011). Comparatively, the EPA February 2002 recorded high values such as 36 mg/l and 55mg/l for river Subin for Kaase and Asafo sites respectively. Rivers Sisa and Wiwi recorded the same levels of 31mg/l. The disparity in the values might be due to the location of the sampling sites. The primary sources of phosphates to surface water are detergents, fertilizers, and natural mineral deposits.

The sulphate levels in all the water bodies was in the range of 0.352-51.084 mg/l which is far below the WHO recommended value of 260 mg/l. Sulphate ion occurs naturally in most water supplies and is reduced to sulphide, which in turn combine with hydrogen to form hydrogen sulphide which has a characteristic rotten-egg odour (Spellman 2003; Liu 1999). According to WHO (2004), sulphate in drinking water has a laxative effect which is mostly manifested in concentrations between 1000 and 1200 mg/l.

The concentrations obtained for all the samples were very high and they exceeded the EPA limit of 0.005 mg/l. GH of river Subin recorded the highest concentration of 0.219 mg/l and least was 0.145 mg/l of river Wiwi (GY). However the experiment carried out by the EPA in 2002 did not detect any amount of cadmium.

The cadmium emissions are likely from fertilizer application, galvanized pipe corrosion; natural deposits and sewage sludge disposal which have increase in recent years. Acute and chronic exposure to cadmium in animals and humans results in kidney dysfunction, hypertension, anemia, and liver damage. The kidney is considered to be the critical target organ in humans chronically exposed to cadmium by ingestion. Therefore the rivers are unsuitable for irrigation as well as consumption. The concentrations obtained ranges from 0.113 to 2.258 mg/l of (SB) and (KA). The EPA limit for natural water is 1.3 mg/l and so that concentrations obtained are very high not ideal for natural water.

Copper is often used to plumb residential and commercial structures that are connected to water distribution systems. Copper contaminating drinking water as a corrosion by -product occurs as the result of the corrosion of copper pipes that remain in contact with water for a prolonged period. Copper is an essential nutrient, but at high doses it has been shown to cause stomach and intestinal distress, liver and kidney damage, and anemia.

Lead is used in enormous quantities in storage batteries and bearing metals hence accounts for the levels of sites (KA), (GH) and (FC) located near car washing bays. The levels of lead ranges from 6.562 and 6.975 mg/L from the results obtained. The most commonly found materials include service lines, pipes, brass and bronze fixtures, and solders and fluxes. Some of the waste deposited in the rivers includes these materials. Lead in these materials can contaminate drinking water as a result of the corrosion that takes place when water comes into contact with those materials. Lead can cause a variety of adverse health effects in humans. At relatively low levels of exposure, these effects may include interference in red blood cell chemistry, delays in normal physical and mental development in babies and young children, slight deficits in the attention span, hearing, and learning abilities of children, and slight increases in blood pressure of some adults making the rivers unsuitable for both domestic and irrigation purposes. .

Zinc is recommended nutrient for both plants and animals and the EPA limit allowed in drinking water is 5.0 mg/l. Samples taken from rivers Wiwi and Sisa were less than 2.0 mg/l. however, samples GH and KA recorded concentrations of 4.545 mg/l and 5.255 mg/l respectively. Zinc is found in some natural waters, most frequently in areas where it is mined. It is not considered detrimental to health unless it occurs in very high concentrations. It imparts an undesirable taste to drinking water. The accumulation of the waste in the river Subin accounts for the higher levels since there is no mining site in the Kumasi metropolis. From the results obtained, iron was abundant heavy metal with concentrations ranging from 14.81 mg/l for AS and 45.65 mg/l for KA. Iron is known to be one of the most abundant metals on earth. It is soft, malleable, and ductile and easily magnetized at ordinary temperatures due to these properties widely used and prefers for most metal works at 1.0 mg/l a substantial number of people will note the bitter astringent taste of iron. Also at this concentration, it imparts a brownish color to laundered clothing and stains plumbing fixtures with a characteristic rust color. Commercially pure iron is used for the production of galvanized sheet metal and of electromagnets.

From the February, 2002 EPA report the concentration levels of Zn, Mn and Cu were below 1.0 mg/l. However the levels of Mn exceeded the permissible EPA limit of 0.05 mg/l. The increase in concentrations may be due the increase in the source of polluted materials in the rivers over the past five years.

The EPA MCL of 0.05 mg/l was set to prevent aesthetic and economic damage. Concentrations may cause a dark brown or black stain on porcelain plumbing fixtures. As with iron, manganese may form a coating on distribution pipes. These may slough off, causing brown blotches on laundered clothing or black particles in the water. The results of the concentration levels exceeded the EPA MCL because the least was 0.726 mg/l for AS and 4.427 for KA.

4. Conclusions

The study indicated that the results obtained for pH, temperature, conductivity and the nutrients- nitrates and phosphates were within the EPA Maximum Contaminant Level (MCL). The amount of total solids was environmentally unfriendly and hence corresponded to the high concentrations of the heavy metals. The most predominant metal present were iron and the least being cadmium. All the metals determined (Pb, Fe. Mn, Cd, Cr, Ni, Cu and Zn) exceeded the EPA MCL with the exception of zinc where only one of sample exceeded the MCL. Therefore, from the results obtained and their discussions give the indication that the rivers are heavily polluted and not suitable for either domestic use and irrigation purposes or aquatic life.

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