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IMPACT AND MITIGATION OF ANTHROPOGENIC ACTIVITIES ON THE DENSU RIVER BASIN

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ABSTRACT

The Weija Reservoir is an important source of water supply for the western, eastern and central parts of Accra as well as the eastern parts of the Central Region, but the effects of rapid urbanization and increased agricultural activities around the Densu River Basin have impacted on the quality of water in the reservoir. The major environmental concerns are erosion, siltation and pollution of the river caused by growing population densities, progressive industralisation and escalation of agricultural activities. This study presents and discusses the results of physico-chemical analyses of the water quality of Weija Water Works (Reservoir) before and after treatment and compares the results with WHO water quality guidelines to determine the impact of these human factors to the water body. Tougher legislation, stricter enforcement of existing regulations and education of the public on the impacts these human activities have on the river bodies to ensure that environmental laws and regulations are adhered to. This fact is realised in the developed world where rigid legislation is enforced to protect water bodies and severe penalties are imposed on defaulters.

Keywords :-EROSION, SILTATION, POLLUTION, PHYSIO-CHEMICAL, MICROBIAL, WEIJA WATER WORKS

INTRODUCTION

Ghana is well endowed with potential water resources. One of such resources is the Densu River of the coastal river system. In the last few decades, reservoirs like Volta, Vea, Barekese, Kpong and Weija have been constructed in Ghana by damming these rivers. The harnessing and rational development of water resources have often been used as a measure of the level of socio-economic development of nations globally. However, harnessing water resources such as the building of dams in Ghana have often been carried out at great socio-economic, environmental and health costs to the very people whose lives, the projects were to improve. Water quality is influenced by rock weathering, atmospheric precipitation, evaporation and crystallization (Gibbs, 1970; Lester and Birkett, 1999). Apart from natural factors influencing water quality, human activities impact negatively on river water quality.

Commercial activities such as the operation of fuel stations, garages, stone quarries and escalation of agricultural activities in the encroached buffer zones and the banks of the Densu River, make it stands the risk of being polluted. These anthropogenic activities introduce both organic and inorganic pollutants in the form of heavy metals and pesticides respectively into the water. Polluted water is an important vehicle 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).

The Weija Reservoir is an important source of water supply for the western, eastern and central parts of Accra as well as the eastern parts of Central Region. Water quality monitoring is an essential tool used by environmental agencies to gauge the quality of surface water and to make management decisions for improving or protecting the intended uses.

It is, therefore, important to carry out regular water quality assessments for sustainable management of water bodies including the Densu River. It is the objective of this paper therefore to investigate the physico-chemical properties of the raw and treated water of the Weija reservoir to determine the impact of anthropogenic activities to the river basin. Effective approach of mitigating these activities on river bodies in Ghana will also be recommended for implementation.

THE WEIJA RESERVOIR – THE STUDY AREA

The Densu River Basin (DRB) lies between latitudes 5° 30´ N to 6° 20´ N and longitude 0° 10´ W to 0° 35´ W (Fig. 1). The basin covers a total land area of approximately 2564 km^2 with a length of 120 km. It shares boundaries with the Odaw and Volta basins to the east and north, respectively, the Ayensu and Okrudu to the west and the Birim basin to the northwest. The Weija Dam was originally constructed over the Densu River in 1952 and had the capacity to contain five million cubic metres of water at a time to supply water to the western and central parts of Accra. The original dam was washed away due to excessive flooding in 1968 and was

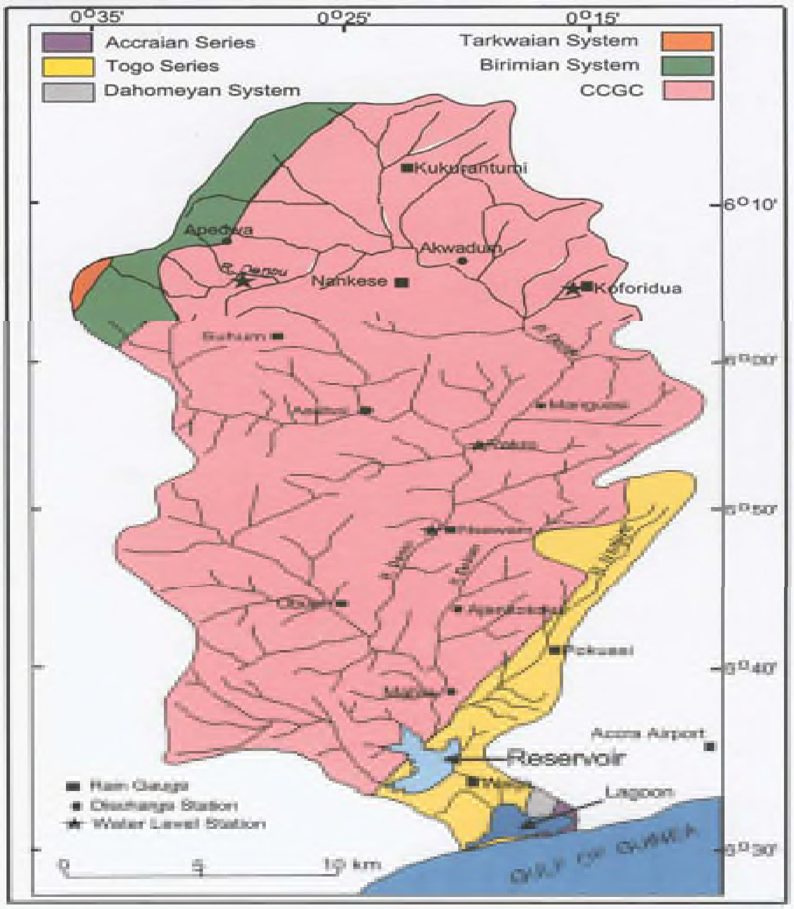

Figure 1. Geological map of the Densu River Basin
(Modified after Kuma & Ashley, 2008)

reconstructed in 1973 to satisfy the increasing demands for water for domestic, commercial and agricultural purposes. The reservoir provides industrial and domestic water supplies to the southwestern part of Accra for irrigation and for fisheries. The reservoir is also the main source of water supply to the Accra-Tema metropolitan area. The total population within the Densu River basin is estimated to be about 1.3 million people (2010 census). This river takes its source from the Atewa -Atwiredu mountain range near Kibi in the Eastern Region of Ghana and has the following tributaries Dobro, Suhyien and Jei Adaiso, Made, Nsakyi, Doboro, and Kuia which form the Densu River Basin (DRB) Fig. 1. The Reservoir with a normal water level of 14.33 m covers an area of 20.5 km^2 with a storage capacity of 113.5 × 10^6 m^3(Kuma & Ashley, 2008).

GEOLOGY AND HYDROGEOLOGY

About 86.6 % of the DRB is underlain by granite and granodiorite of the middle Precambrian Cape Coast Granite Complex (CCGC) while 8.8 % consists of the Togo Series (Table. 1). These two rock formations control the groundwater conditions in the basin. The remaining 4.6 % of the basin comprises the Birimian Volcanics, Tarkwaian, Dahomeyan and the Accraian rocks. At the source of the River, the rocks are metamorphosed lava, phyllite, schist, tuff and greywacke of the Birimian and towards its mouth it is underlain by quartzite, shale and phyllite of the Togo Series. The bulk of the CCGC is a granitic to quartz-diorite gneiss which changes gradationally from a fine to medium-grained foliated biotite-quartz-diorite

Table 1. GHIE - Stratigraphic Succession (younging upward) and Summary of the Expected Water bearing properties of Rocks of the Densu

SYSTEM	ROCK TYPE	EXPECTED WATER BEARING PROPERTIES	AREA (%)
Accraian (Mid-Devonian)	Sandstone, grit and shale	Finely layered, soft rock with horizontal or near horizontal beds. Fine grain sandstone and silt; low permeability	0.15
Togo Series (Upper Precambrian)	Quartzite, sandstone, shale, phyllite, schist and silicified limestone, phyllite, schist	Highly folded, jointed and fractured layers of quartzite. Moderate to high secondary porosity and permeability in some localities which produce low to medium yielding aquifers	8.8
Dahomeyan (Upper Precambrian)	Acidic, ortho- and paragneiss and schist and migmatite, many of which are rich in garnet,hornblende and biotite	Primary porosity as well as fracturing of the massive paragneiss is very low. The lower weathered zone builds low yielding aquifers. Recharge is low and ground water potential is poor.	0.15
Tarkwaian Supergroup (Mid Precambrian)	Quartzite, phyllite, grit, conglomerate and schist, including basic intrusive	Generally low primary porosity and permeability. Secondary features result in production of low tomedium yielding aquifers.	0.14
Cape Coast Granite Complex (CCGC) (Mid Precambrian)	Granitoid undifferentiated	Some few areas have highly foliated, jointed and weathered granodiorite resulting in secondary permeability. Moderate water bearing properties expected in these areas with regolith aquifers. On the whole, the CCGC has poor ground water potential	86.6
Birimian Volcanics (Mid Precambrian)	Metamorphosed lava and pyroclastic rock and hypabyssal basic intrusive, phyllite and greywacke	Secondary porosity and permeability through weathering and fractures in some places lead tomoderate yield of groundwater.	4.1

gneiss in the west to an exclusively hornblende-quartz-diorite gneiss in the east. Granitic rocks associated with the Birimian have no regular pattern of jointing and depth to bedrock hardly exceeds 6 m. The Birimian rocks are strongly foliated with widespread faulting and jointing with deep weathering in valleys. The phyllites of the Birimian are especially known to form aquifers due to intensive fracturing (Ahmed et al., 1997).

FIELD WORK AND SAMPLING

The study was conducted at the Weija Dam Intake. Monthly sampling in the dry and rainy seasons on daily basis was carried to monitor changes caused by the seasonal hydrological cycle. Sampling of the raw water was mainly confined to the mid portion of the water. Treated water was sampled directly from the clean-water outlet from each treatment plant. Raw and treated water samples were taken from locations that are representative of the water source, treatment plant, storage facilities, distribution network, points at which water is delivered to the consumer, and points of use.

Sampling points were selected such that the samples taken are representative of the different sources from which water is obtained by the public or enters the system.

Sampling points and frequency were uniformly distributed taking population distribution into account and the mean values were estimated. The points chosen generally yield samples that are representative of the system as a whole and of its main components. All the raw water samples were taken with a water sampling stick. The reservoir was sampled under base flow conditions, about 20-30 cm deep from the surface.

LABORATORY ANALYSES

Water samples for physico-chemical analyses were collected directly into clean 1- litre plastic bottles. Temperature and pH were measured in situ, using mercury-in-glass thermometer and portable pH meter, respectively. For dissolved oxygen (DO) determinations in the laboratory, separate samples were collected into plain glass bottles and the DO fixed, using the azide modification of the Winkler's method (APHA, 1998). Samples for biochemical oxygen demand (BOD) were collected into dark glass bottles and were incubated at 20 ºC for 5 days before the DO was determined. All the samples were stored in cold boxes and, on return to the laboratory analysed for physico-chemical constituents. Physico-chemical parameters determined at the sites and chemical analyses on collected water samples formed the basis of assessing the quality of the reservoir water. The physico-chemical parameters were determined according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998). Conductivity was measured with Cybersan 510 conductivity metre and turbidity with a HACH 2100 P Turbidimeter. Sodium (Na) and potassium (K) were measured by flame emission photometry (FEP), trace metals by atomic absorption (SP 600) spectrophotometer (AAS), and calcium (Ca) and magnesium (Mg) by EDTA titration. Sulphate was determined by the

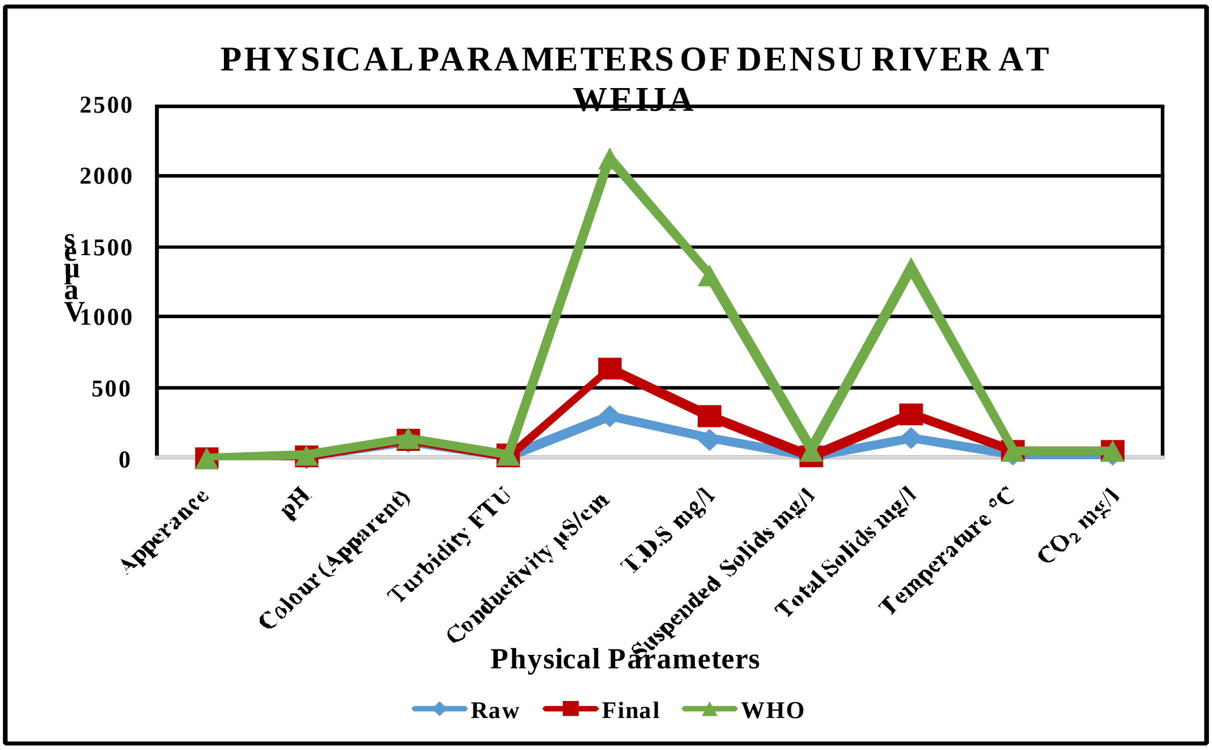

Figure 2. A Graph of Physical Parameters of Densu River at Weija Reservoir

turbidimetric method, colour by colour comparator and chloride by argentometric titration. Other analyses included alkalinity by strong acid titration method. Nutrients (nitrate-nitrogen and phosphate-phosphorous) were determined using a Dionex-80 ion analyser and ammonium by direct nesslerisation and spectrophotometric determination at 410 nm. Fluoride by SPADNS method, total dissolved solids and suspended solids were measured gravimetrically after drying in an oven to a constant weight at 105 oC. Total and faecal coliforms were determined by membrane filtration method using M-Endo-Agar Les (Difco) at 37 °C and on MFC Agar at 44 °C respectively.

RESULTS AND DISCUSSIONS

A summary of the results of the in-situ measurements and the trace element concentrations in the sampled water and sediment of River Densu are shown in Figures 2 and 3 respectively. The results are compared to the standards for drinking water given by the World Health Organization (WHO).

pH

The reservoir water before treatment is slightly alkaline with an average pH of 7.50 which is within the range of 6.5-8.5 stipulated for drinking and domestic purposes (WHO, 2006). The pH of water affects treatment processes, especially coagulation and disinfection with chlorine-based chemicals. Changes in the pH of source water should be investigated very often as it is a relatively stable parameter over the short term and any unusual change may reflect a major event. The pH is commonly adjusted as part of the treatment process and was reduced to 6.8 after the final treatment which also falls within the WHO standard for drinking water.

TEMPERATURE

The water temperature decreased slightly from 24.5 °C (before treatment) to 24 °C (after treatment). The WHO does not recommend any limit values, however a temperature higher them 15 °C facilitates the development of microorganisms and at the same time intensifies the organoleptical parameters such as odour and taste, and activates chemical reactions.

DISCUSSION

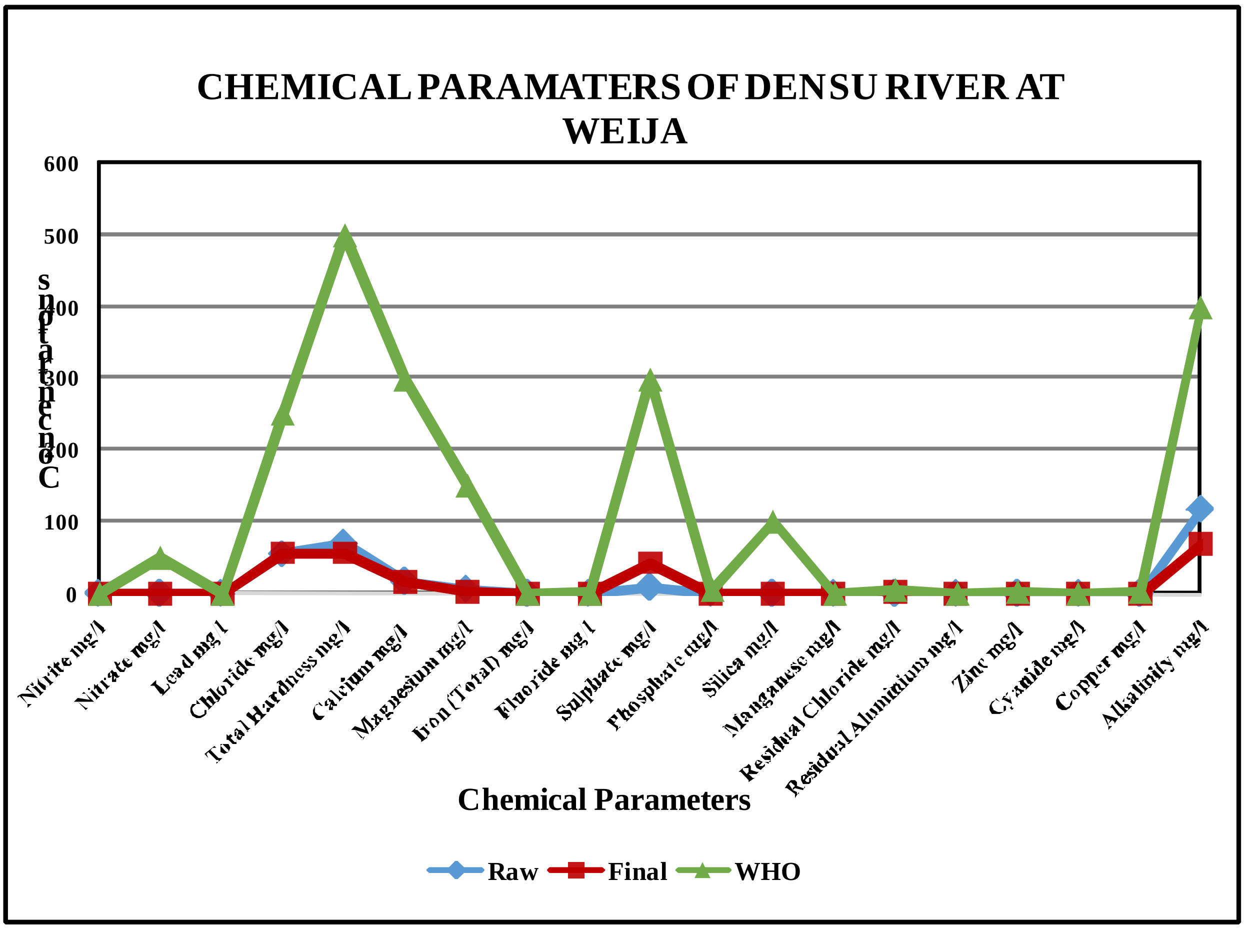

Figure 3. A Graph of Physical Parameters of Densu River at Weija Reservoir

TURBIDITY

Turbidity values recorded for untreated and treated water from the reservoir is 18 NTU and 1 NTU respectively. The turbidity of the raw water exceeded the WHO maximum value of 5 NTU. The excessive turbidity in water causes problems with water purification processes such as flocculation and filtration, which may increase treatment cost (DWAF, 1989). Elevated turbid water is often associated with the possibility of micro-biological contamination as high turbidity makes it difficult to disinfect water properly (DWAF, 1998). Soil erosion and runoff from the catchments could be the source of high turbidity in the reservoir water. Turbidity may be due to organic and/or inorganic constituents. Organic cause of turbidity may harbour microorganisms and this may increase the possibility for waterborne diseases. For this reason, it is important to know the turbidity characteristics of water sources and to respond to unexplained changes in turbidity. Nonetheless, inorganic constituents have no notable health effects

COLOUR

Colour is an important physical property of water because of its implications for water supply, and the need to reduce it to acceptable levels by water treatment is highly recommended. Increase in the colour of water in reservoirs results in increase in treatment cost. The colour for the untreated reservoir water was recorded to be 122 HU. This value is above 15 HU which is WHO recommended limit for no risk. The high colour value of the untreated reservoir water indicates that the water is highly polluted with respect to the WHO standard for colour. Colour in natural water usually results from the leaching of organic materials and is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. Determination of colour can help in estimating costs related to discolouration of the water.

The treatment process removed much of the suspended matter reducing the colour of the treated water to 2 HU. The final value falls beneath the WHO limit for drinking water.

ELECTRICAL CONDUCTIVITY (EC)

The electrical conductivity (EC) for the untreated water was 298.7 μS/cm. The measured EC value indicates that the untreated reservoir water examined had value which was within the WHO maximum allowable EC level of between 50-1500 μS/cm for drinking water. This also shows that contamination due to dissolved ions is low. Therefore, this parameter does not give cause for concern and it makes the water suitable for direct domestic use. The EC of the water however after treatment increased to 333 μS/cm; probably due to chemicals that are used in the treatment process. The EC value for treated water still falls within the WHO standard, hence making the treated water safe for drinking so far as EC is concerned

TOTAL DISSOLVED SOLIDS

The total dissolved solids (TDS) obtained for the untreated water sample is 136.8 mg/l and that for the treated water sample is 158.8 mg/l. These amounts of TDS measured in the untreated water are within acceptable level (1000 mg/l) recommended by WHO. According to WHO (2006), the palatability of water with a TDS level less than 600 mg/l is generally considered to be good and becomes increasingly unpalatable at TDS level greater than 1000 mg/l.

IONS AND NUTRIENTS

The amount of chloride ions found in the raw reservoir water sample was 55 mg/l. However, the treatment process increased the amount to 58 mg/l. These amounts of chloride ions are below the WHO allowable level of 250 mg/l. Natural background of chloride in drinking water is usually 10 mg/l and anything above that is an indication of human influence. The reservoir water may have been contaminated by septic systems, landfill, fertilizers or animals. Alkalinity levels of the untreated and treated water samples were found to be 118 mg/l and 71 mg/l respectively. The recorded alkalinity levels were within the acceptable WHO standard of 400 mg/l.

The sulphate contents of 9 mg/l and 44 mg/l of the raw and treated water respectively were within the WHO recommended guideline (300 mg/l). The nitrate concentrations obtained for both raw and treated water were very low (0.04 mg/l and 0 mg/l respectively). The examined water samples (raw and treated) recorded nitrate concentrations values within the acceptable level (50.0 mg/l) recommended by WHO (2006) for drinking water.

The phosphate levels recorded in the untreated and treated water samples were also very low with values of 0.42 mg/l and 0.02 mg/l respectively. The level of calcium was also low as compared to the WHO limits, Calcium ion is readily dissolved from rocks rich in calcium minerals, particularly carbonates and sulphates. Industrial, as well as, wastewater treatment processes can also contribute calcium to surface water. Acid rain can also encourage leaching from soil. Contribution of this source, through surface runoff could be attributed to the higher calcium levels compared to Magnesium (Anim et al., 2011).

TRACE METALS

Trace metals have been referred to as common pollutants, which are widely distributed in the environment with sources mainly from the weathering of minerals and soils (Marian, 1991; O'Neil, 1993). However, the level of these metals in the environment has increased tremendously in the past decades as a result of inputs from human activities (Prater, 1975; Marian, 1991).

The concentration of Fe in the untreated water is 0.5 mg/l. The value exceeded the background level and the WHO limit of 0.3 mg/l. This means that the water should be treated for the removal of iron before use. The Densu basin is basically by granite and analyses of rocks in Ghana (Kerbyson & Schandorf, 1966) have shown that Fe_2O_3 composition in granite is about 2.8%. This could primarily be the source of Fe in surface waters. It has also been demonstrated by Langanegger (1987) and Pelig-Ba (1989) that corrosive materials contribute significantly to the amount of Fe in the waters. The Fe of the raw water after treatment had reduced to 0 mg/L, making the treated water safe for drinking (WHO, 2006).

The magnesium concentration measured in the raw water samples was 6.075 mg/l. The treated water had a concentration of 3.888 mg/l. All the concentrations measured were less than WHO permissible limit (150 mg/l) for potable drinking water.

HARDNESS

The total hardness of the raw water was 70 mg/l, with calcium contributing 45 mg/l and magnesium contributing the remaining 25 mg/l. The hardness is a function of the geology of the area with which the surface water is associated (Karikari and Ansa-Asare, 2006). The results indicate that the raw water is slightly hard based on water hardness classification by Shelton and Scibilia (2005). When hardness exceeds 18 mg/l, it generally causes problems, and a water softener should be considered. Water softened to zero hardness is corrosive. It is therefore desirable to blend a proportion of non-softened water with extremely soft water (Shelton and Scibilia, 2005).

CONCLUSIONS

The raw water of the Densu River is basically polluted in terms of its colour, turbidity and higher concentration of Fe. The high water colour and turbidity may be as a result of the dumping of waste into the dam, the springing up of illegal structures and escalation of agricultural activities cost the Ghana Water Company Limited millions of cedis in their operations, particularly in treating the water. Some of the pollutants are non-degradable, can bioaccumulate in the tissues of aquatic organisms and enter the food chain with dangerous consequences for the ecosystem and humans as final consumers in the food chain.

Unless an all – embracing approach is adopted to deal with these problems enumerated above, the dam will eventually cease to be the source of drinking water for residents of Accra and some parts of Central Region This, therefore, calls for the enforcement of existing laws and/or promulgation of tougher legislation against improper disposal of urban wastes and the release of untreated wastes/effluents into water bodies to ensure sustainable environment. This fact is realised in the developed world where rigid legislation is enforced to protect water bodies and severe penalties are imposed on defaulters. Matching of non-technical and techno-social remedial measures is recommended. These include sensitization of polluters on merits of environmental protection practices such as cleaner production and strict enforcement of environmental protection laws. Another important issue for pollution mitigation measures pertains to the need to educate all stakeholders such as the perpetrators, the affected, policy and legal authorities, river basin management boards, and other interested parties, and include them in planning and decision making exercises. There should be enforcement by government to relocate the encroachers of land close to the reservoir.

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