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Efficiency of Water Treatment at the Barekese Headworks

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Abstract

Physicochemical, bacteriological and heavy metal analyses of raw and treated water at the Barekese Headworks were carried out between December, 2017 and February, 2018.This study was undertaken to ascertain the efficacy of the treatment processes employed at the Headworks by comparing the recorded values of the water samples analysed to the World Health Organisation (WHO) guideline limits for quality drinking water. Physicochemical parameters (temperature, pH, turbidity, colour, chloride ions, magnesium ions, calcium ions, total hardness, magnesium hardness, calcium hardness, total alkalinity, total dissolved solids and electrical conductivity), bacteriological (total and faecal coliform) and heavy metals (Iron (Fe), Lead (Pb), Copper (Cu), Aluminium (Al)) were assessed. The Barekese raw water showed temperature 25.0℃ ± 0.26℃, pH 6.7 ± 0.10, turbidity 27.87 ± 7.32 NTU, E.C 190.33 ± 8.52 µS/cm, total hardness 63.53 ± 2.36 mg/l, TDS 72.97 ± 9.85 mg/l, calcium hardness 41.63 ± 1.65 mg/l, magnesium hardness 21.90 ± 1.93 mg/l, calcium 16.63 ± 0.65 mg/l, magnesium 5.33 ± 0.47 mg/l, total alkalinity 56.43 ± 4.27 mg/l, chloride 17.97 ± 2.08 mg/l, apparent and true colour 257.97 ± 53.75 Hz and 14.33 ± 6.02 Hz respectively, total and faecal coliform 2.923 x 102 ± 1.0002 x 102 cfu/ml and 2.3 x 101 ± 0.692 x 101 cfu/ml respectively. The values of the treated water obtained for the aforesaid parameters were within the WHO acceptable limit with the exception of temperature which was 0.6℃ above the maximum acceptable limit. This study revealed that the raw water is unsafe for drinking and domestic purposes without prior treatment.

Keywords: Physicochemical; Barekese headworks; World Health Organisation (WHO); Heavy metals; Bacteriological

Introduction

The Millennium Development Goals (MDGs) adopted in 2000 by 189 countries (including Ghana) consists of eight goals. Goal 7 which addresses ensuring environmental sustainability is of great importance. To ensure full implementation of the goals, annual progress reports as well as biennial special reports are prepared. Target 7C of goal 7 is aimed at halving the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015.There has been a significant increase in the proportion of people with access to improved source of water sources between 1990 and 2013.Some of the policy interventions which were carried out under the urban and rural management programme which resulted in the improvement of access to safe drinking water include: Rehabilitation and expansion of various Treatment plants including that of Barekese, Kpong, Essakyir, Mampong and construction of five water treatment plants in five towns in the Eastern Region; completion of over 1,000 boreholes under the government 20,000 Borehole project; Teshie Nungua Desalination Water Project [1-5]. Rivers are the most important freshwater asset of man. Social, financial and political development has, previously, been to a great extent identified with the accessibility and distribution of fresh waters contained in riverine system. Major river water uses can be outlined as follows; wellspring of drinking water supply, irrigation of farmlands, industrial and municipal water supplies, industrial and municipal waste disposal, navigation, fishing, boating and body contact recreation and aesthetic value [3]. Barekese Reservoir and its feeder streams are a wellspring of drinking water for the surrounding communities. The majority of the people have for the most part utilized the of in River and its tributaries for their domestic water needs, recreation, water system, fish cultivating and washing commercial vehicles over the previous decades. The Ayensua Fufuo, Nkwantakese and Denasi communities, however, have no access to pipe borne water, depending rather exclusively on Barekese Reservoir and its feeder streams [6]. The Barekese Head works which draws water from the Barekese Reservoir supplies more than 80% of the day to day water demands of the Kumasi metropolitan area and its environs.

One of the key challenges to the attainment of the MDG 7 is pollution of water bodies through human activities particularly in rural areas. Many countries including Ghana have their water supplies contaminated, which has affected the health and the economic status of many people. In recent times some residents and consumers in the Metropolis have been expressing concern about the quality of water supplied by the water headwork [1].The Ghana Water Company Limited (GWCL) is challenged with the continuous deterioration of the quality and quantity of the Barekese Reservoir over the past three decades. According to Kumasi et al. the cost of treating raw water from the reservoir has increased as its quality has been degraded and as water demands have increased with the increasing numbers of water consumers. Water is said to be contaminated when a foreign substance is introduced into it either through direct or indirect human intervention. When water is contaminated to a level such that it cannot be used for its intended purpose, it is said to be polluted. Pollution parameters have been classified as physical, chemical and biological on the basis of analytical tests. Physical pollution can be determined by parameters such as temperature, colour, turbidity, electrical conductivity, light permeability, suspended matter and dissolved matter. Chemical pollution is determined by values which are derived from parameters such as total hardness, total alkalinity, phosphate content, and different heavy metal ions present in water. Biological pollution may be determined by the presence of microorganisms such as faecal coliform bacteria (*Escherichia coli*), *Cryptosporidium parvum* and *Giardia lamblia*. The accurate determination of trace element concentrations and other physical, chemical and biological parameters of ground and surface waters are important for controlling their pollution [7].

According to the World Health Organization, Guidelines for Drinking Water Quality, safe drinking water is water that does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages suitable for all usual domestic purposes, including personal hygiene. Thus, drinking water quality is essential for the wellbeing of all people. As a result of heavy pollution, the cost of water treatment by the GWCL has increased substantially [6]. Intake of polluted water leads to the frequent breakdown of equipment and destruction of water pumps and filters reducing the efficiency of the equipment. However, potable water supplied to consumers must be of the highest quality and its biological and chemical contaminants should be reduced or totally eliminated. Thus, it is imperative to assess the quality of water treated to ascertain how effective the processes of water treatment at the Barekese Headworks are carried out.

Materials and Methods

Location, drainage and geology of the study area

The Barekese reservoir is located approximately 26km north of Kumasi. It lies within latitude 6°44' N and longitude 1°42'W. It is an earth filled dam with rock protection constructed between 1967 and 1971.The overall crest length is 6.1 m (13 km) above sea level with a maximum width of 91.7 m (1.25 km). It was formed by building a 549 m long earth and the concrete dam transversely across the off in River, which originates from the Mampong Ridge [6]. The reservoir has a surface area of approximately 6.4 km^2 with an average depth of 33 m and a catchment area of 565 km^2. The reservoir's major inflowing and outflowing river is the Offin River, with several undulating catchments of small tributaries [6,8]. The area extends from the Kumasi - Barekese Road to the Kumasi Offinso Road to the east. The area is approximately 90 m long situated on a dissected [6]. The feeder streams in the Barekese reservoir catchment area are located in the study communities, including Penten, Nkwantakese, Pampatia, Esaase, Denase, Ayensua Fufuo and Ayensua Kukuo.The study communities are located in areas containing semi deciduous vegetation and having 2 rainfall seasons [6]. Barekese headwork is the biggest conventional water treatment plant located in the northern part of Ashanti Region. The source of water for treatment is the Offin River, which is about 505m long with varied depth as shown in **Figures 1 and 2** [7].

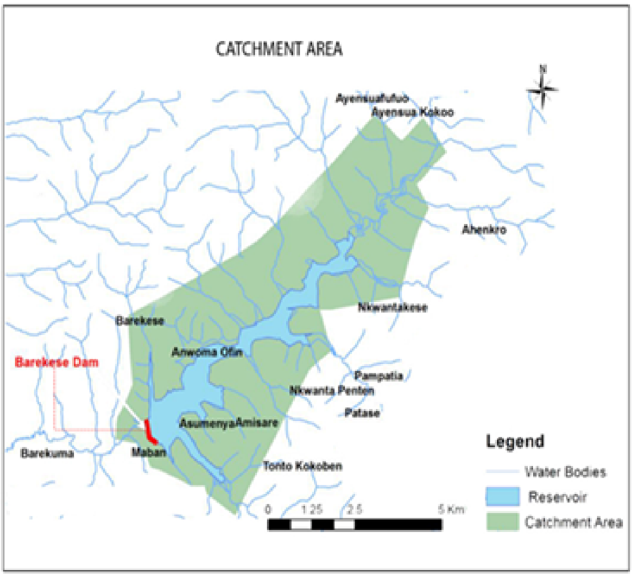

Figure 1: The map of the study area showing the catchment area and tributaries.

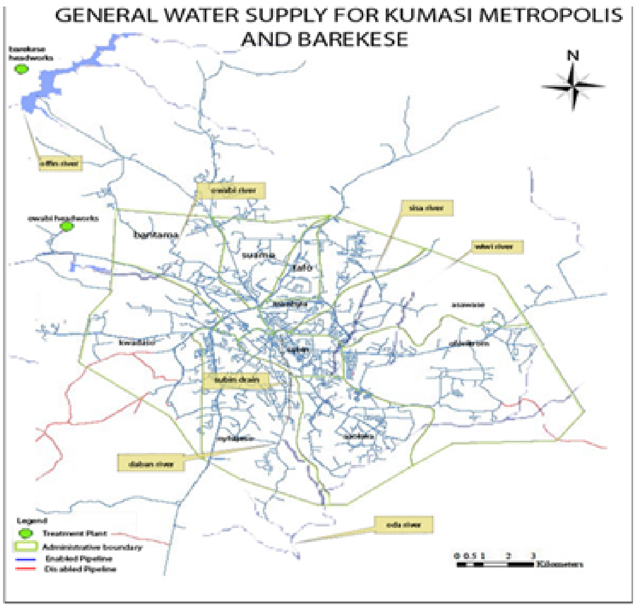

Figure 2: A map showing the general water supply for kumasi metropolis and barekese.

Determination of physicochemical parameters

All physicochemical parameters were determined in the Laboratory at the Barekese Headworks

Temperature: An aliquot of 100 ml was measured into a 500 ml beaker and the thermometer probe was immersed into the water and the temperature was recorded.

pH: The pH was determined using the calibrated HI 2216 pH/ORP/ISE meter at the Barekese Headworks' laboratory. The water sample was placed in a beaker and the electrode was rinsed with distilled water and lowered into the sample in the beaker [8]. The pH meter was allowed to stabilize and the pH of the samples read.

Turbidity: The turbidity was determined in the laboratory using the Palin test turbid meter. The cuvette was rinsed in the sample to be tested; the sample was fetched up to the 10ml mark. The light shield cap was replaced and the outside surfaces were cleaned and made dry using a tissue paper. The cuvette was placed into the instrument's light cabinet. Readings were taken when the turbid meter stabilized.

Colour: The colour was determined in the laboratory using the HACH DR 5000 colorimeter. The instrument was blanked using distilled water. The sample was fetched up to the 25ml mark of the cuvette, cleaned and made dry using a tissue paper and inserted into the instrument's cabinet. Readings were recorded.

Alkalinity: 50ml sample was measured into a 250ml conical flask. 5 drops of methyl orange indicator were added to the contents and titrated against a standard 0.1M HCl (aq) till an end point indicated by a first permanent pink colour was obtained.

Alkalinity (mg/l)=titre value x 20

Total hardness: Ethylene Diaminete Traacetic Acid (EDTA) Titrimetric method: 50 ml of the water sample was put into a 250ml conical flask. 1ml of NH_3 (aq) was added to the contents of the flask, followed by the addition of a small quantity of the Erichrome black T indicator [9]. The contents in the flask was titrated against a standard EDTA solution until the contents of the flask changed from dark red to blue black at the end point. Titration was repeated until a consistent titre was obtained. The value of average titre was recorded.

Total Hardness (mg/l)=Titre value x 20

Calcium Hardness: 50 ml of the water sample was put into a 250 ml conical flask. 1ml of aqueous NaOH was added to the contents of the flask, followed by the addition of a small quantity of the murexide indicator. The content of the flask was titrated against EDTA to the end point which is indicated by Pink colouration. Titration was repeated to obtain a consistent titre.

Calcium Hardness (mg/l)=Average titre value x 20

Magnesium hardness (mg/l)=Total hardness - Calcium hardness

Calcium (mg/l)=Calcium Hardness (mg/l)/2.5

Magnesium (mg/l)=Magnesium Hardness (mg/l)/4.1

Chloride: 50 ml of the water sample was put into a 250 ml conical flask. 1 ml of KCl (aq) was added to the contents of the flask and titrated against standardized $AgNO_3$ (aq) to the end point which is indicated by a permanent red colour. The volume of the titre was recorded.

Chloride (mg/l)=titre value x 10

Electrical Conductivity (EC) and Total Dissolved Solids (TDS):

The total dissolved solids and Electrical conductivity was determined using a calibrated HANNA HI 5521/HI 5522 bench meter. The meter was calibrated as follows: small quantities of standard solutions were poured into beakers. The calibration mode was entered by pressing CAL. Previous calibrations were cleared by pressing CLEAR CAL. The probe to be calibrated was immersed into the standard solution till a stabilised reading was obtained. ACCEPT was pressed to finish calibration. After calibration the cells were immersed into the sample. For TDS measurement, MODE was pressed and TDS was selected. The probe was immersed into the sample to measure the TDS value. For conductivity measurement, MODE was pressed and COND. was selected to enter the conductivity measurement mode [10]. The electrode was immersed into the sample and a stabilised value was recorded.

Microbial indicators analyses

All microbial parameters were determined in the Laboratory at the Barekese Headworks.

Enumeration of total and faecal coliforms using plate counts

Total and faecal coliform were determined using the Pour plate method. A sample of 1 ml was measured and inoculated into an empty petri dish. 10 ml of molten MacConkey agar was added to the petri dishes containing the samples. The content was swirled to ensure uniform mixture of the sample and the agar. The agar was allowed to solidify and the petri dishes were inverted and incubated at a temperature of 37oC and 44oC for 24 hours for enumeration of total and faecal coliform respectively. Total viable counts were determined and reported as colony forming units per 1ml of sample (cfu/ml).

Heavy metals analyses

The water samples were digested in the laboratory. The type of digestion employed was the Nitric acid digestion and the procedures used are as follow: 50 ml of water sample was measured into a 100 ml conical (Erlenmeyer) flask. 10 ml of conc. HNO_3 was added to the content of the flask, shook to ensure uniform mixture. The content of the flask was placed on a Wagtech hot plate digester for about 30 minutes. The content was allowed to cool and transferred into a 50 ml volumetric flask, diluted to the 50 ml mark with doubledistilled water. The content of the volumetric flask was transferred into pre-washed PET bottles and sent for analysis at the KNUST central lab. The concentrations of Iron (Fe), Lead (Pb), Copper (Cu) and Aluminium (Al) were determined in the Atomic Absorption Spectrophotometer (Analytikjena NovAA 400p) using acetylene (C_2H_2) gas and nitrous oxide (N_2O) as the fuel depending on the metal to be analysed and air as the oxidizer. Acetylene gas provided the energy needed to atomize iron, lead and copper whilst a combination of both C_2H_2 and N_2O was required for atomization of Aluminium. Hollow Cathode Lamps (HCL) was burnt to produce single beam of light of wavelength specific to each metal. Light of wavelengths 248.3 nm, 324.8 nm, 283.3 nm and 309.3 nm were produced for the analysis of Fe, Cu, Pb and Al respectively. Calibration curves were prepared for each metal by running suitable concentration of the standards solutions

[11,12]. Standard solutions of concentration interval of 0, 2, 4… 10 ppm and 0, 1, 2…5 ppm were used in preparing the calibration curve for Al, Pb, Cu and Fe respectively. The digested samples were aspirated into the Acetylene/N_2O air flame and the concentration of the metal ions was determined from the calibration curve. Average value of triplicates was taken for each determination. After each sample was analysed, deionised water was used to clean the system from any residual sample. The absorbance of the blank and a standard solution was taken after the analysis to confirm the results.

Statistical analyses

Each treatment was triplicated. All values were expressed as mean ± standard deviation. All data analyses were done with SPSS v. 20 and all graphs plotted with origin lab 2019. The significance of treated water and raw water was determined using one way ANOVA. Difference between two statistically significant groups were shown as those having a value of $P<0.05$.

Results and Discussion

Physicochemical characteristics

Parameters	Raw water	Treated water	WHO Limit
Temperature (℃)	25.80 ± 0.26	25.67 ± 0.64	15-25
pH	6.70 ± 0.10	6.70 ± 0.10	6.5-8.5
Turbidity (NTU)	27.87 ± 7.32	1.67 ± 0.12	5
Apparent colour (Hz)	257.97 ± 53.75	2.90 ± 1.99	15
True colour (Hz)	14.33 ± 6.02	0.00 ± 0.00	15
Electrical conductivity (μS/cm)	190.3 3 ± 8.52	211.40 ± 10.95	1500
Total dissolved solids (mg/l)	72.97 ± 9.85	77.37 ± 11.37	1000
Total hardness (mg/l)	63.53 ± 2.36	58.23 ± 7.99	500
Calcium hardness (mg/l)	41.63 ± 1.65	37.87 ± 1.67	500
Magnesium hard-ness (mg/l)	21.90 ± 1.93	20.37 ± 6.57	500
Calcium (mg/l)	16.63 ± 0.65	15.17 ± 0.68	200
Magnesium (mg/l)	5.33 ± 0.47	4.95 ± 1.62	150
Total alkalinity (mg/l)	56.43 ± 4.27	49.77 ± 2.36	NA
Chloride (mg/l)	17.97 ± 2.08	25.43 ± 1.25	0.3
NA-Not Applicable			

Table 1: Physicochemical parameters of the raw and treated water assessed from December 2017 to February 2018.

According to Kumar et al. temperature is an abiotic factor that plays an essential role in the environment as it regulates the various biological and physic-chemical activities. Temperature of water increases during the day and decreases at night. The temperature of the raw and treated water was averaged between 25.5℃ to 26.0℃ and 25.2℃ to 26.4℃ respectively. This shows that the temperature recorded for the various water sources were above the WHO recommended range of water for drinking and domestic purposes (15℃-25℃). The sampling was done in the morning between the hours of 8:00 and 11:00 GMT and so the deviations could be as a result of the sampling time since the sun was high up. The water temperature was influenced by the temperature of the surrounding environment where the sampling was done. There is no statistically significant difference between the means of the raw and treated water (p value=0.757). The efficiency of the treatment process was 0.5%. Thus, the treatment process had no significant effect on the temperature values. The pH of the water samples ranged between 6.6 and 6.8. All the pH values obtained were within the WHO recommended range of 6.5-8.5. This indicates that the water samples are suitable for drinking and domestic purposes as far as pH is concerned. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. The efficiency of the treatment process was 0%. The treatment process did not alter the pH of the raw water **(Table 1)**.

The mean turbidity values for raw and treated water ranged from 22.1 to 36.1 NTU and 1.6 to 1.8 NTU respectively. According to WHO, the recommended value for turbidity is 5.0 NTU. This indicates that the raw water values recorded greatly exceeded the acceptable level whilst that of the treated water fell below this level. According to DWAF, high turbidity normally signifies poor water quality. However clear water does not necessarily imply healthy water. The high level of turbidity recorded in this study for the raw water may be due to soil erosion, washing of commercial vehicles along the river banks and the decay of organic matter from improper disposal of domestic waste within the catchment area. High turbidity levels in water causes problems with water purification processes such as flocculation and filtration, which may increase treatment cost. The efficiency of the treatment process was 94% indicating how effective the process was [13-15].

Water for drinking should ideally have no visible colour. Treatment of water to reduce its colour to permissible levels is highly recommended since colour is an essential physical property of water. The mean apparent/true colour values obtained for treated water i.e. 2.9/0.0 Hz fell below the WHO acceptable limit of 15 Hz. Raw water however recorded a mean of 258 and 14.3 Hz for apparent and true colour respectively. All the apparent colour values exceeded the permissible level of 15 Hz. The high values recorded for the raw water may be due to the presence of organic matter associated with the humus fraction of soil. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. Increase in the colour of water in reservoirs results in increases in treatment cost [3].

Conclusion

Some physicochemical parameters of the raw water did not meet the WHO standards. These parameters are temperature, turbidity and apparent/true colour. The deviation of the latter two can be attributed to excessive pollution from domestic waste, animal faeces, heavy metals whilst temperature values fluctuated with prevailing atmospheric or ambient temperature. All physicochemical parameters of the treated water with the exception of temperature conformed to the WHO guideline limits. Bacteriological analyses revealed that the raw water is heavily polluted with total and faecal coliforms as opposed to the 0 cfu/ml value recorded for both total and faecal coliform of the treated water. The microbial water quality of the treated water was within the WHO standard. Also, all the heavy metals analysed were below the WHO maximum recommended level. Generally, the quality of treated water produced at the Barekese Headworks is appreciable. This validates that the water treatment processes employed at the Barekese Headworks are of high efficacy.

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