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Full Length Research Paper

Analysis of quality of water at Kintampo, Ghana

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The aim and purpose of this research work was to ascertain the seasonal variations in water quality at Kintampo. Thirty out of 200 hand-dug wells were random selected for the study. Three mechanized boreholes and treated water from the township supply system (34 sampling points) were also selected. The sampling was carried out on 15th October 2008, 20th December 2008, and 14th February 2009. Fifteen parameters analysed were colour, turbidity, temperature, conductivity, pH, dissolved oxygen, total dissolved solids (TDS), total suspended solids (TSS), total hardness, iron, chloride, calcium, biochemical oxygen demand (BOD), faecal coliform, and *Escherichia coli*. Apart from temperature, turbidity, conductivity, pH, dissolved oxygen, and total dissolved solids, which were analysed on site, all the other parameters were analysed at the Ghana Water Company's Laboratory, Sunyani. One way analysis of variance (ANOVA) was used in the statistical analysis. Assessment of the physical properties of the water samples revealed that only temperature showed significant change ($p = 0.012$) within the study period. This may be attributed to the high daily temperatures averaging 35°C during these periods.For the chemical parameters, only pH of the water samples showed significant difference ($p = 0.003$). The probable cause was the increased infiltrating rain water in October and the absence of rainfall from November - February). Faecal coliform and *E. coli* (biological parameters) had significant changes ($p = 0.004$ and $p = 0.002$ respectively). These could be ascribed to the seasonal variation of recharge rate, faecal matter coming from poorly constructed and poorly sited latrines, and septic tanks, as well as dilapidated hand-dug wells.

Key words: Water quality, faecal coliform, aeration.

INTRODUCTION

Lack of access to safe drinking water is affecting billions of people around the world (Conant, 2005). Kintampo community in the Brong Ahafo Region of Ghana depended mainly on hand-dug wells (13.93 m deep on the average) before the construction and distribution of mechanized boreholes by the Municipal Assembly in December 2001. Most people in Kintampo do not use the treated water (Water from the boreholes) for their domestic activities, especially drinking, because they claim the water does not taste good. Unihydro Limited (2002) stated that, "Kintampo has groundwater sources with elevated iron concentrations slightly higher than the WHO (2006) guideline of 0.3 mg/L, but less than 1 mg/L."

Accordingly, an aeration tank was constructed in 2006 to reduce the concentration of iron in the water, with funding from the German government.

A 16-L bucket of treated water was sold to domestic consumers at four Ghana pesewas. The treated water distributed to the community from the mechanized wells was 800 m^3 per day. According to the officer in-charge of the Kintampo Water Supply System, they started with 84 public stand-pipes, but they had to stop operating about half of them due to low usage (patronage).

Hence, there was the need to test the treated water to ascertain any change in quality. It was also to help in verifying the efficiency of the aeration process. Since iron concentration above 0.3 mg/L may contribute significantly to taste (WHO, 2006), it was necessary for it to be tested with other parameters (Chloride and calcium) which also contribute to taste in water.

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Communal containers for lifting water from hand-dug wells were not washed or cleaned. Construction of toilets in homes was done indiscriminately. These conditions made the hand-dug wells liable to pollution. Groundwater is easily liable to pollution mainly from human activities. The effects of polluted water on health makes it necessary for it to be tested to ensure that its quality (physical, chemical, and biological) meets both WHO and local standards (Ghana Standards Board).

Objectives

Primarily, this study aims to assess the physical, chemical, and biological quality of water from the mechanised boreholes and hand-dug wells at Kintampo in comparison with WHO and local standards (Ghana Standards Board). However, the specific objectives of the research were to:

1) Assess the physical properties (colour, turbidity, and temperature) of water from mechanised boreholes and hand-dug wells in Kintampo.
2) Assess the chemical properties (conductivity, pH, dissolved oxygen, total dissolved solids, total suspended solids, total hardness, iron, chloride, and calcium concentrations) of water from mechanised boreholes and hand-dug wells in Kintampo.
3) Determine the biological properties (biochemical oxygen demand, faecal coliform, and *Escherichia coli,*) of water from mechanised boreholes and hand-dug wells in Kintampo.

MATERIALS AND METHODS

Observations on site

Table 1 shows the observations made on site. Letters used to represent hand-dug well, borehole and treated water are W, B, and T respectively.

Seven of the hand-dug wells (W1, W5, W8, W9, W10, W11, and W20) were positioned at the back of the houses, while the rest were in the middle. Most of the hand-dug wells had no locks. This enabled children to play around them.

73% of the hand dug wells had not received any form of chemical treatment since their construction. The rest (27%) were treated periodically, using chemicals like Camphor, Dettol, or alum (Aluminium Sulphate). However, Camphor and Dettol are for external use only. The Alum was used without recourse to the volume of water in the well. The use of incorrect quantity of alum may result in ineffective coagulation (over or under coagulation).

Alum is a coagulant that helps particulate matter to settle and not a disinfectant as some well owners believe. The settled particulate matter which settles at the bottom of the wellmixes with the clear water on top of it during fetching since there is no means of removing or decanting it.

Table 2 shows the condition of the hand-dug wells at the time of sampling. The surroundings of 30% of the hand-dug wells had greenish colouration on their walls and floors due to lack of regular cleaning. Half of the hand-dug wells had no aprons, and their parapet walls were broken, while 10% had no covers. These could permit run-offs and splashes of water from fetching activities getting into the wells directly.

These could also seep through the surrounding soil to contaminate the water. Hence, these wells need reconstruction since their physical states expose them to contamination. Users are consequently at risk of water related diseases like cholera, dysentery, or typhoid fever.

56% of the hand-dug wells had no channels to carry water that pours on the ground to a suitable outfall. Where they existed, they were not desilted and were likely to breed mosquitoes to transmit malaria to the people. The stagnant waters attracted animals like sheep, goats, and cattle which came to drink. The animals urinate and defecate to make the place unsightly. Children and animals can fall into the open wells and die.

The major mode of water lifting system was by pulley, with a common container attached to a nylon rope or the inner tube of vehicle tyres cut into ropes. The lifting containers were not cleaned and hanged either on the pulley or inside the wells. This made the containers easy sources of contamination from dust and hands.

Table 3 shows the location of the boreholes, the water treatment facility, depth of the boreholes, frequency of treatment, and chemicals used. The deepest hand-dug well (W8) was 20.4 m deep, with 15 of them being less than 15 m. Any well below 15 m deep is a shallow well and water from such a well is likely to becontaminated by run-off and infiltrating water (Conant, 2005).

The boreholes were better placed in terms of cleanliness of their surroundings and protection from unauthorised persons. The boreholes, pumping, and treatment sites were fenced with barbed-wires and secured with locks, as well as a 24-h security guard. The surroundings were weeded regularly. Hence, the water and the facilities are secured. Appendix Figure 1 is the map of Kintampo township showing important landmarks.

The Kintampo Water Supply System treats the water from the boreholes after it had been pumped into a reservoir. The water is first brought in contact with atmospheric air to remove some of the iron from it.

Granulated calcium hypochloride ($CaOCl_2$) is used to disinfect the water. Powdered sodium carbonate ($NaCO_3$) is added to correct the pH after chlorination.

Background of the study area

Kintampo is the capital of the Kintampo North Municipal. The indigenous people are Mos and Brongs, with other smaller ethnic groups from most parts of the country living in the municipality. Kintampo had an estimated population of 96,358 comprising 49,137 females (50.9%) and 47,401 males (49.1%), with a growth rate of 2.6%. The municipality is located between latitudes 8°45'N and 7°45'N and longitudes 1°20'W and 2°1'E.

The Municipal has a surface area of about 5,108 km^2, thus occupying a land area of about 12.9% of the total land area of Brong Ahafo Region (39,557 km^2). The Municipal experiences the tropical continental or interior savannah type of climate, which is a modified form of the tropical continental or the wet-semi equatorial type of climate.

However, owing to its transitional nature, the area does not totally exhibit typical savannah conditions. Rainfall is from February to October every year, and the dry season from November to early March. The rock form is voltaian (sedimentary) (Kintampo North Municipal Assembly, 2008).

Selection of sampling points

Kintampo town was divided into five sampling sites for equal representation. Six hand-dug wells were selected at random from each site (30 sampling points because all the 200 wells could not

Table 1. Particulars of sampled hand-dug wells.

Location	Code	House no.	Site	Depth (m)	Treatment	Frequency (month)	Chemical used
Sunkwa	W1	E329/1	Outside	12.13	No	-	-
Sunkwa	W2	E348/1	In yard	16.46	No	-	-
Modern School	W3	E366/1	In yard	11.28	No	-	-
Sewaba	W4	E93/1	In yard	10.5	No	-	-
Dwenewoho	W5	D168/1	Outside	12.4	No	-	-
Dwenewoho	W6	D56/1	In yard	10.2	No	-	-
Kyeremankoma	W7	A124/1	In yard	17.7	Yes	3	Alum
Kyeremankoma	W8	A265/1	Outside	20.4	No	-	-
Kyeremankoma	W9	B58/2	Outside	16.6	No	-	-
Mo-line	W10	A244/2	Outside	12.9	No	-	-
Mo-line	W11	A415/2	Outside	15.2	No	-	-
Mo-line	W12	A342/2	In yard	14.6	No	-	-
K-line	W13	C30/2	In yard	17.1	No	-	-
Market Square	W14	D34/2	In yard	17.6	Yes	6	-
Market Square	W15	D29/2	In yard	15.2	No	-	-
Market Square	W16	D64/2	In yard	16.5	Yes	3	Dettol
Market Square	W17	D53/2	In yard	15.8	No	-	-
Lorry Park	W18	D57/2	In yard	15.5	No	-	-
Pentecost Area	W19	D109/2	In yard	14.9	No	-	-
Pentecost Area	W20	D150/2	Outside	13.1	Yes	12	Alum
Pentecost Area	W21	D129/2	In yard	11.6	Yes	6	Alum
Pentecost Area	W22	D166/2	In yard	14.1	No	-	-
Pentecost Area	W23	D182/2	In yard	13.1	Yes	12	Alum
Nwoase	W24	G25/2	In yard	12.4	Yes	3	Camphor
Nwoase	W25	E244/2	In yard	15.8	No	-	-
Nwoase	W26	F29/2	In yard	16.5	Yes	3	Alum
Nwoase	W27	E264/2	In yard	15.2	No	-	-
Gruma-line	W28	E226/2	In yard	15.3	No	-	-
Gruma-line	W29	E252/2	In yard	12.5	No	-	-
Gruma-line	W30	E354/2	In yard	11.9	No	-	-

Table 2. Condition of hand-dug wells at the time of sampling.

Code	Total no.	Condition
W5, W7, W10, W11, W20, W27, W28, and W29.	8	Had not been scrubbed for a long time. Had greenish colouration (spirogyra) on the walls and floors.
W3, W4, W5, W6, W7, W10, W11, W14, W20, W25, W26, W27, W28, W29, and W30.	15	Had no apron. Parapet walls were broken.
W10, W11, and W28.	3	Had no covers.
W4, W5, W6, W7, W8, W9, W10, W11, W14, W16, W17, W20, W22, W25, W26, W27, W28, W29, and W30.	19	Had no channels to carry water that pours on the ground around them.

Table 3. Particulars of boreholes and treated water.

Location	Code	Designation	Depth (m)	Treatment	Frequency	Chemical used
Catholic School	B1	C 110	55	No	-	-
Catholic School	B2	K 290	86	No	-	-
Catholic School	B3	D 460	75	No	-	-
Hill Top	T	Treated water	-	Yes	Daily	$CaOCl_2$; $NaCO_3$

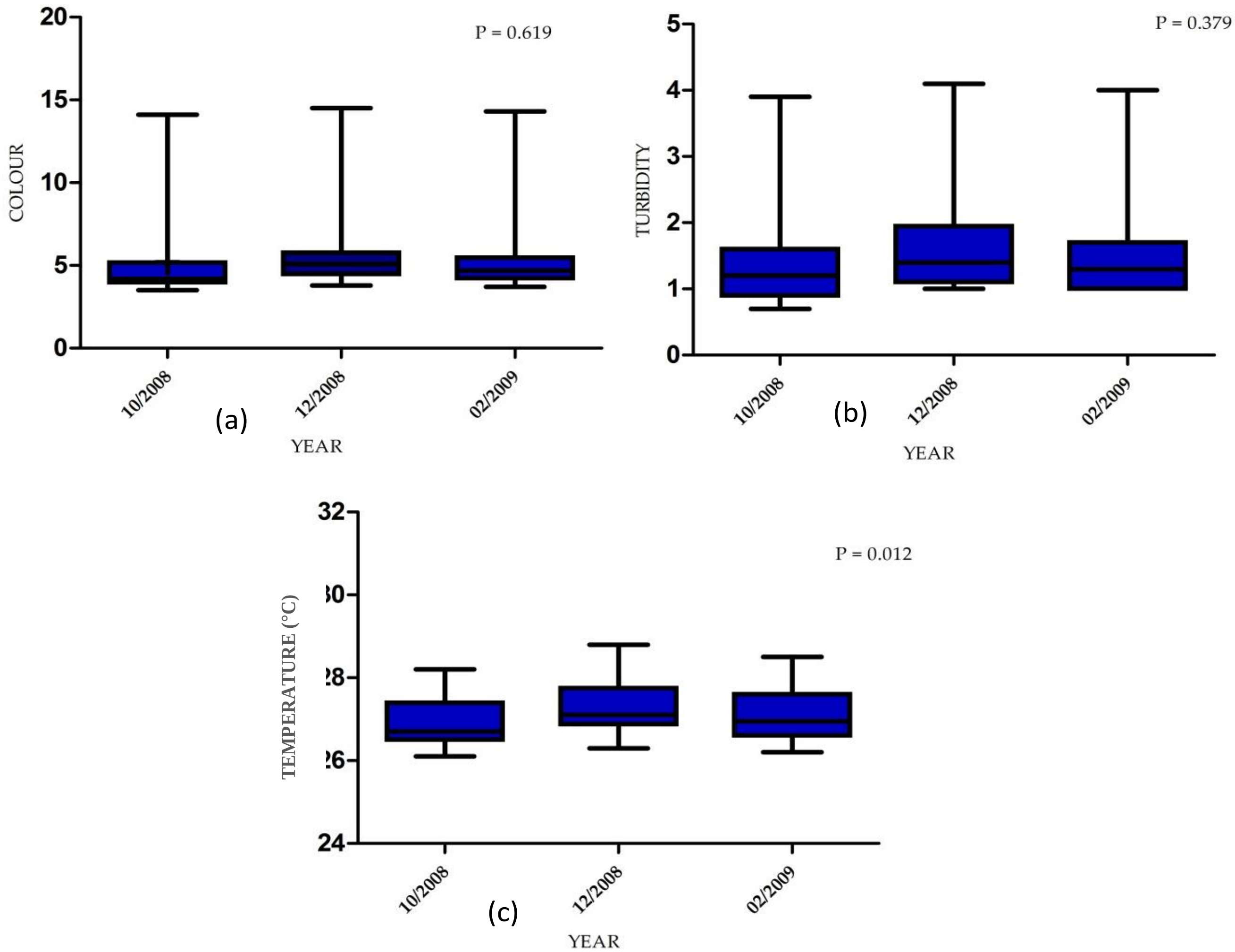

Figure 1. Physical properties of water a) colour b) turbidity c) temperature at different periods.

be sampled due to logistical constraints). This was carefully done (because the wells were not having the same distance apart) to ensure that sampling points were as far apart as possible. Also, four other sampling points (one from the point of distribution and the three boreholes serving as the main sources of the treated water) were included to add up to 34 sampling points. Appendix Figure 2 shows the topographic map of Kintampo.

Preparation for sampling

Samples for the chemical analysis were collected in 1.5 L plastic (because they were found to be convenient) containers. The containers were rinsed with tap water then with distilled water before samples were collected. Samples for the microbial analysis were put in sterile bottles. These were done to avoid the introduction of errors into sampling results. Two plastic buckets and nylon ropes were used to collect samples from the hand-dug wells (USEPA, 2002).

Sampling

Sampling points were observed to ascertain whether the wells had

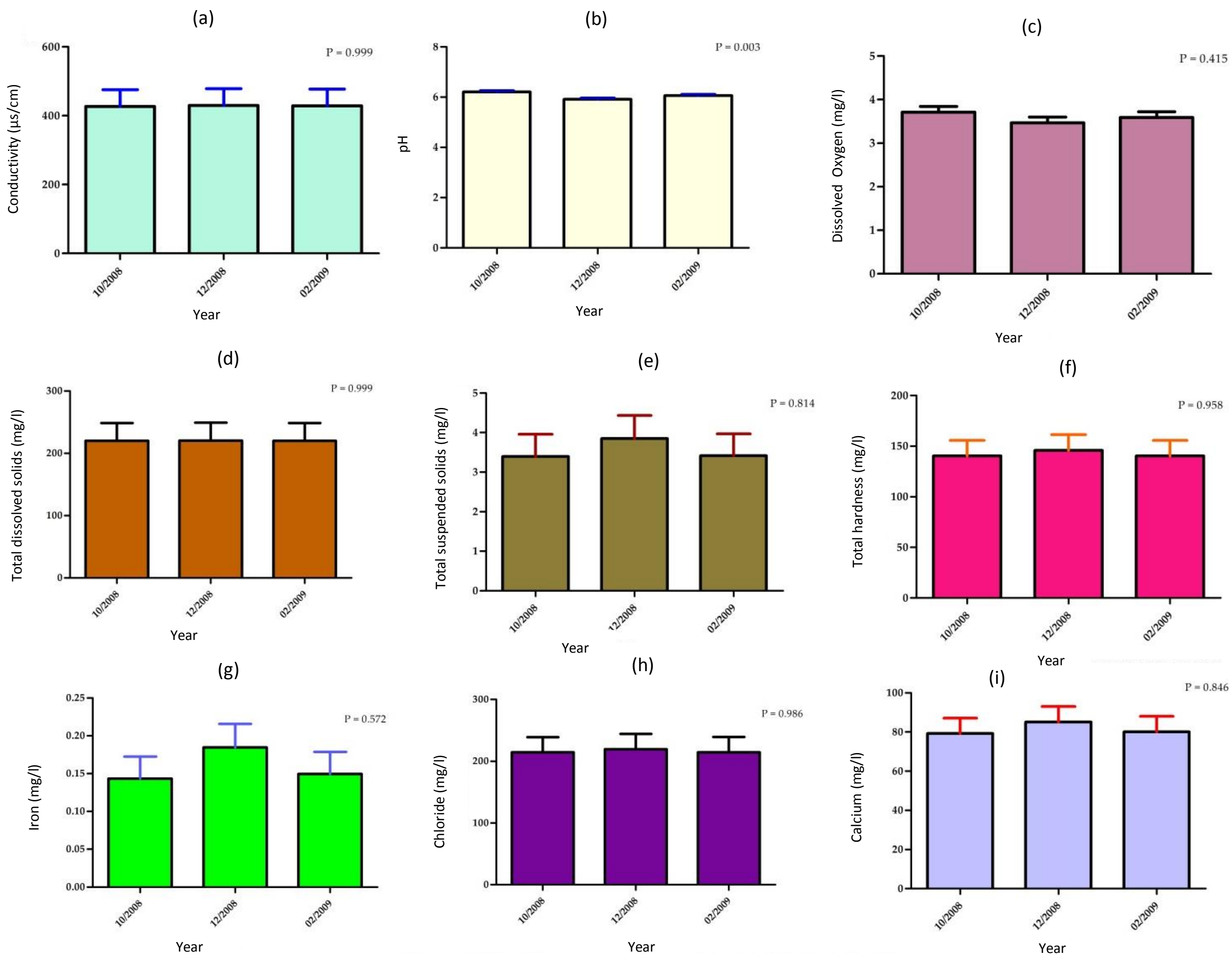

Figure 2. Chemical properties a) Conductivity b) pH c) Dissolved Oxygen d) Total dissolved solids e) Total suspended solids f) Total hardness g) Iron h) Chloride i) Calcium content of water at different periods.

broken walls or in good shape, had fitting covers, fitted with hand-pumps or not. Their depths were also measured. Samples were collected after the wells had been manually purged.

Equipment like conductivity meter EC, pH meter and others which were used on-site were calibrated before use. A Hach digital field equipment (model 44600) was used to measure the temperature, conductivity, and total dissolved solids of the samples collected on site. 1000 mg/l NaCl standard solution was used to calibrate the meter. The probe of the temperature meter was first rinsed with tap water then with some of the sample. A quantity of the sample was poured in a 200-ml beaker, and the stable temperature value in °C was recorded. The probe of the conductivity meter was rinsed with tap water and with some of the sample. The probe of the meter was immersed into the beaker containing the sample, and the stable conductivity value in mg/l was then recorded. The probe of the total dissolved solids meter was rinsed with tap water, then with some of the sample. The probe of the meter was immersed into the beaker, and the stable value of TDS in mg/l was recorded (Hach, 2000).

Sample containers were rinsed with the water to be sampled before sampling. To ensure that representative samples were collected, the buckets were carefully immersed into the water. Sample bottles were filled to the brim to prevent the accumulation and escape of gases into the air space, and taken to the laboratory after 1.5 h of collection. They were then analysed immediately.

In all, three batches of samples (considering the times when samples were collected, accurate results were possible but not necessarily more batches of samples since the concentration of chemicals in ground water can be influenced by the amount of water infiltrating into the ground) were collected on 15th October 2008, 20th December 2008, and 14th February 2009. This was done to reflect the rainy, dry, and beginning of the rainy seasons.

Field analyses

The temperature, conductivity, and total dissolved solids were analysed on site using Hach digital field equipment (model 44600). The pH was measured with a Hach Digital pH meter (UC-23 model). Turbidity was measured using a Jenway Turbidity meter (6035 model). The dissolved oxygen was measured with a Jenway DO meter (9300 model) (Hach, 2000).

Laboratory analyses

The colour (true colour), total suspended solids, and iron concentrations were measured at the laboratory using a Hach Direct Reading Spectrophotometer (DR/2000 model). The chloride ion concentration was measured by precipitation titration method (Hach, 2000). The BOD was measured using an incubator (CB-DN model), Faecal coliform and *E. coli* were analysed using Multiple Tube Fermentation Technique (Hach, 2000). The calcium ion concentration and total hardness were determined by EDTA titration method (APHA, 1992).

RESULTS AND DISCUSSION

One Way ANOVA was used for the statistical analysis of all the results. There was no significant change in colour and turbidity over the sampling period, as per their P values respectively (P = 0.619 and P = 0.379). However, temperature was statistically significant at the p-value (P= 0.012). This can be attributed to the high daily temperatures averaging 35°C during these periods. However, depending on whether it is high or low, may affect other parameters including conductivity and dissolved minerals (Schindler, 1990; WHO, 2006). The chemical state of groundwater is usually defined in terms of pH, temperature, and oxidation-reduction potential. These parameters are influenced by chemical reactions. As temperatures changed seasonally, as a result of the rise and fall of the water table, or where recharge rates vary, the chemical state and composition of groundwater will change. Variations in temperature may also be attributed to the differences in depth of the various wells. For shallow groundwater, larger seasonal variations, related to warming of or cooling at the surface are common, and may be on the order of 5 to 10° or more. Another source of temperature change in shallow groundwater, and occasionally deeper water, is the introduction of water from the surface during high-recharge time periods. To some individuals, an increase in the temperature of their drinking water alone can be perceived as generally less palatable taste (Nelson, 2002).

From Figure 2, there was no significant change in the chemical properties, except pH (p = 0.003). The changes obtained for pH could be attributed to the increased infiltrating rain water in October, when the first sample was taken. Again, the absence of rain due to the prolonged dry season (from November to February) was a contributory factor. Within this period, recharge rate was slower than in the rainy season since virtually all ground water comes from precipitation that soaks into the soil and moves gradually to the aquifer (Nelson, 2002). Natural rainwater is slightly acidic (Krauskopf and Bird, 1994) because it combines with carbon dioxide.

From Figure 3, the BOD (A) had an insignificant change during the sampling period (P = 0.998). On the other hand, faecal coliform (B) and *E. coli* (C) had significant P values of 0.004 and 0.002, respectively. These could be ascribed to the seasonal variation of recharge rate during the period, and from faecal matter coming from poorly constructed and poorly sited latrines, and septic tanks, as well as poorly constructed and dilapidated hand-dug wells. Drinking water should not contain faecal coliform or *E. coli* (WHO, 2006). Hence, the presence of faecal coliform and *E. coli* was an indication of constant faecal contamination. *E. coli* causes diarrhoea that ranges from mild and non-bloody to highly bloody, which is indistinguishable from haemorrhagic colitis.

Conclusion

Assessment of the physical properties of the water samples from the mechanized boreholes and hand-dug wells revealed that only temperature had a significant p-value (p = 0.012). This was attributed to the high daily temperatures averaging 35°C during these periods. Seasonal variations in temperature, the rise and fall of the water table, and variations in recharge rates cause the chemical state of the water to change. Hence, changes in composition of the groundwater. Variations in temperature can be attributed to the differences in depth of the various wells. Another source of temperature change is the introduction of water from the surface during high-recharge time periods. An increase in the temperature of drinking water alone can be perceived as generally, a less palatable taste by some people.

For the chemical parameters, the significant difference was for only pH (p = 0.003). The probable cause was the increased infiltrating rain water in October, when the first sample was taken, and the absence of rain due to the prolonged dry season (from November to February). Within this period, recharge rate was slower than in the rainy season. Again, natural rainwater is slightly acidic because it combines with carbon dioxide.

With regard to the biological parameters, faecal coliform (B) and *E. coli* (C) had significant p-values of 0.004 and 0.002 respectively. These could be ascribed to the seasonal variation of recharge rate during the period, and faecal matter coming from poorly constructed and poorly sited latrines, and septic tanks, as well as dilapidated hand-dug wells. It was an indication of constant faecal contamination. *E. coli* causes diarrhoea that ranges from mild and non-bloody to highly bloody stool.

RECOMMENDATIONS

1) The Kintampo Water Supply System should acquire a more efficient aerator to improve the taste of the water.
2) Owners of hand-dug wells should be helped in the appropriate siting of the wells and constant maintenance to avoid faecal contamination.
3) Further research is needed on the hand-dug wells in Kintampo.

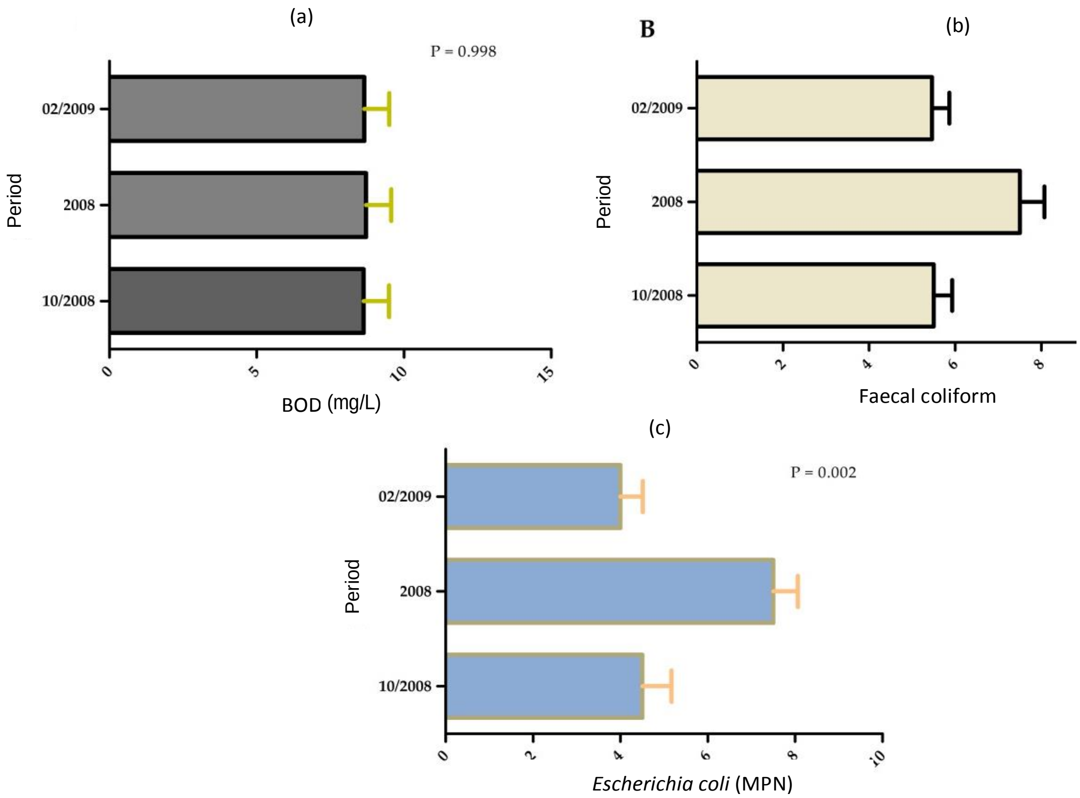

Figure 3. Biological properties a) BOD b) Faecal coliform c) *E. coli* content of water at different periods.

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APPENDIX

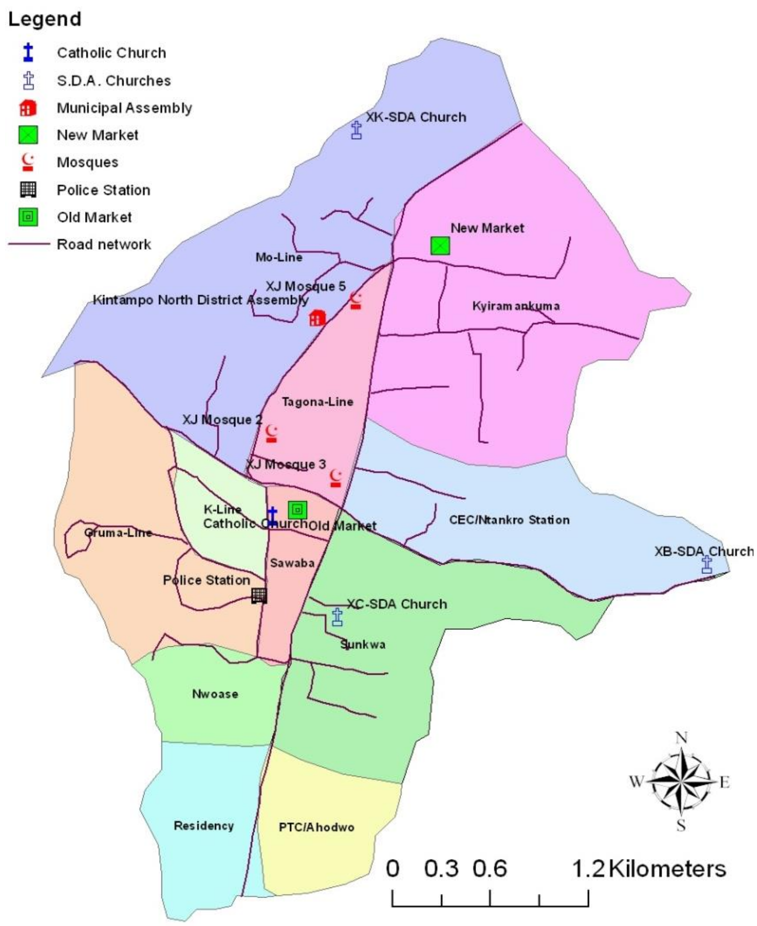

Figure 1. Map of Kintampo township showing important landmarks.

Figure 2. Topographic map of Kintampo. 1. CEC/Ntankoro on the Township map is indicated as Dwenewoho in my sampling area table. 2. Old Market is indicated as Market Square in my work. 3. Sawabe is indicated as Lorry Park and Pentecost Area in my work.