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Physicochemical and Microbial Assessment of Borehole Water on the Campus of KNUST and its Satellite Towns of Ayeduase and Kotei.

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ABSTRACT

In developing countries boreholes are economically viable option for water production and supplies for domestic and general use. Ground waters are generally considered as 'safe sources' of drinking water because they are produced with low microbial load with little need for treatment of the water before drinking. A physicochemical and microbial analysis of drinking water from six (6) different boreholes on the campus of the Kwame Nkrumah University of Science and Technology (KNUST) and two of its satellite communities; Ayeduase and Kotei was undertaken. The principal aims were to ascertain the wholesomeness of the water by assessing the level of microbes as well as the faecal matters and total coliform and to determine and compare the levels of major elements in the water with international standards. All the water samples passed the physical and chemical tests conducted, except for the pH test which most of the samples failed. The levels of trace metals determined were all below the WHO guideline levels. Only Unity Hall Borehole, UHB and Ayeduase Borehole 1, AB1 failed the microbial test using Mannitol Salt Agar and Bismuth Sulphite Agar respectively. With the exception of the control, all the water samples failed the total and true coliform test.

Introduction

The foundation of water management is partly to understand the interaction of the water sources and the entire ecosystems and the changes it undergoes. This will enable policy makers to put in place strategy and proper mechanisms to assure water safety, security and accessibility. Globally, more than twenty five thousand people die daily as a result of water related diseases [1]; and Ghana has its fare share of this emerging water crises. To achieve the Millennium Development Goals (MDG) targets, for the period 2004 – 2015, data collected by Community Water and Sanitation Agency (CWSA) and Ghana Water Company Limited (GWCL) in 1998, as part of their strategic investment plans estimate that, every year an average of 596,000 people need to gain access to an improved water supply [1].

A physicochemical and microbial analysis of drinking water from six (6) different boreholes on the campus of the Kwame Nkrumah University of Science and Technology (KNUST) and two of its satellite communities; Ayeduase and Kotei was undertaken. The principal aims were to ascertain the wholesomeness of the water by assessing the level of microbes as well as the faecal matters and total coliform and to determine and compare the levels of major elements in the water with international standards.

Water Security

According to the United Nation 'water is a social asset and access to safe drinking water is a fundamental human right [2]. Assessment of water resources to provide its security, safety and accessibility has become urgent globally due to alarming reports in recent times. The global environmental outlook report indicates that about 30% of the world's population lack access to safe drinking water. The consumption of water worldwide increases yearly whilst most of the world's water resources continue to dwindle due to improper environmental management practices [3].

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Groundwater

About 14 % of all freshwater is ground water and that, if only water is considered, 94% is ground water [4]. It is thus one of the most widely available and essential natural resources that support life in general and human activities in particular. In developing countries boreholes are economically viable option for water production and supplies for domestic and general use. Ground waters are generally considered as 'safe sources' of drinking water because they are produced with low microbial load with little need for treatment of the water before drinking [5]. Groundwater, however, can be contaminated from its recharge source or through interaction with the local geology. Dissolved elements such as arsenic, boron, selenium and radon; a gas formed by the natural breakdown of radioactive uranium in soil may find their way into groundwater through faults and fractures in the geology. These natural contaminants become a health hazard when present in high doses. Human induced contamination may also occur from chemical spillage from industries. Microbial and faecal matters are other contaminants of borehole water. These may arise as a result of improper siting of underground septic and crude tanks and discharge of industrial liquid waste into groundwater recharge zone.

Materials and Tools Required

Materials i.e. tools and reagents required for physical, chemical and microbial analyses of samples of the boreholes are given in table 2.0 below:

Table 2.0: Tools and Reagents for the Physicochemical and Microbial Analyses

Reagents For Chemical Analysis	Equipment Required For Analysis	Physical Parameter	Equipment Required	Reagent For Microbial Analysis	Equipment Required
Mordant black II	pH meter	Colour	Glass test tube	Brilliant green broth	Autoclave
Disodium edetate	Conductimeter	Turbudity	Glass test tube	Nutrient agar	Incubator
Zinc sulphate heptahydrate	Analytical balance	pH	pH meter	Bismuth sulphite agar	Bunsen burner
Ammonia	500ml volumetric flask	Temperature	Thermometer	Mannitol Salt agar	Water bath
Silver nitrate	1000ml volumetric flask	Conductivity	Conductimeter	MacConkey agar	Platinum loop
Ammonium chloride	100ml volumetric flask			Distilled water	Syringes
Potassium chromate indicator	250ml beakers, 10ml beakers, 25ml pipette, 50ml burette, test tubes, funnel, conical flasks, spatula, wash bottles			Water samples	Sterilized Petri dishes, Sterilized Test tube

METHODOLOGY

Borehole water samples were taken from six (6) boreholes from KNUST campus (Indece Hall Borehole, IHB and Unity Hall Borehole, UHB), Kotei (Kotei Borehole 1, KB1 and Kotei Borehole 2, KB2) and Ayeduase (Ayeduase Borehole 1, AY1 and Ayeduase Borehole 2, AY2). The boreholes were first purged and stable readings of the physical parameters such as pH and EC measured using portable pH and EC metres respectively. Samples were taken following carefully all sampling procedure. Samples were transferred into a clean 500 ml polyethylene bottles with a tight lid and sent to the laboratory for analyses.

Chemical Analyses

Atomic Absorption Spectroscopy (AAS) was used to analyze major elements (metals and non-metals) and nutrient loads in the water samples. The samples were first acid-digested and then transferred into test-tubes. The AAS was calibrated with a standard reference material followed by running a blank test.

Microbial analyses

Seven 9ml test tubes each of Nutrient Agars, Bismuth sulphite Agar and Mannitol Salt were melted at 100°C for about 15 minutes and then stabilized at 45°C for 15 minutes. 1ml each, of the seven different water samples were inoculated into the seven different test tubes. Each tube was rolled in the hands to effect uniform mixing before it was poured into a sterile petri dish under the disinfected screen, covered and allowed to set. The petri dishes were then inverted and incubated for 48 hours.

Total Coliforms Analyses

About 15 tubes of MacConkey Agar were stabilized at 45°C for 15 minutes. 1ml of each water samples was inoculated differently into the first five test tubes of MacConkey Agar. Each tube was rolled in the hands to

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effect uniform mixing before it was poured into a sterilized petri dish and allowed to set. Three tubes were then incubated aerobically at 37°C for 48 hours and two tubes incubated for 72 hours. Further dilution of 1 in 10ml of the water samples were done to make counting of the water colonies easier. 1ml of these dilutions were also incubated into the agar and kept under the same conditions as in the above.

RESULTS

Physical Parameters

Table 4.1: Physical Properties of Water Samples

Sample	Colour	Turbidity	Odour	Temperature range/°C
Indece Hall Borehole (IHB)	Colourless	Clear	Unobjectionable	26-29
Unity Hall Borehole (UHB)	Colourless	Clear	Unobjectionable	26-29
Kotei Borehole 1 (KB1)	Colourless	Clear	Unobjectionable	26-29
Kotei Borehole 2 (KB2)	Colourless	Clear	Unobjectionable	26-29
Ayeduase Borehole 1 (AB1)	Colourless	Clear	Unobjectionable	26-29
Ayeduase Borehole 2 (AB2)	Colourless	Clear	Unobjectionable	26-29

Microbial Analyses

Table 4.2: Results for water samples using Nutrient Agar

Sample	Observation	Inference
Indece Hall Borehole (IHB)	White colonies and zones observed	Bacteria or fungi may be present
Unity Hall Borehole (UHB)	White colonies and zones observed	Bacteria or fungi may be present
Kotei Borehole 1 (KB1)	White colonies and zones observed	Bacteria or fungi may be present
Kotei Borehole 2 (KB2)	White colonies and zones observed	Bacteria or fungi may be present
Ayeduase Borehole 1 (AB1)	White colonies and zones observed	Bacteria or fungi may be present
Ayeduase Borehole 2 (AB2)	White colonies and zones observed	Bacteria or fungi may be present

Table 4.3: Results for water samples using Bismuth Sulphite

Sample	Observation	Inference
Indece Hall Borehole (IHB)	No black rabbit eye colonies present	Salmonella typhi is absent
Unity Hall Borehole (UHB)	No black rabbit eye colonies present	Salmonella typhi is absent
Kotei Borehole 1 (KB1)	No black rabbit eye colonies present	Salmonella typhi is absent
Kotei Borehole 2 (KB2)	No black rabbit eye colonies present	Salmonella typhi is absent
Ayeduase Borehole 1 (AB1)	black rabbit eye colonies present	Salmonella typhi is present
Ayeduase Borehole 2 (AB2)	No black rabbit eye colonies present	Salmonella typhi is absent

Table 4.4: Results for water samples using Mannitol Salt Agar

Sample	Observation	Inference
Indece Hall Borehole (IHB)	No reddish-purple colonies or yellow zones observed	Staphylococcus aureus absent
Unity Hall Borehole (UHB)	Reddish -purple colonies or yellow zones observed	Staphylococcus aureus present
Kotei Borehole 1 (KB1)	No reddish-purple colonies or yellow zones observed	Staphylococcus aureus absent
Kotei Borehole 2 (KB2)	No reddish-purple colonies or yellow zones observed	Staphylococcus aureus absent
Ayeduase Borehole 1 (AB1)	No reddish-purple colonies or yellow zones observed	Staphylococcus aureus absent
Ayeduase Borehole 2 (AB2)	No reddish-purple colonies or yellow zones observed	Staphylococcus aureus absent

Total Coliform

Table 4.5: Results for 1ml sample using MacConkey Agar

Sample	Observation	Number of colony forming units
Indece Hall Borehole (IHB)	Growth observed	2
Unity Hall Borehole (UHB)	Growth observed	6
Kotei Borehole 1 (KB1)	Growth observed	1
Kotei Borehole 2 (KB2)	Growth observed	1
Ayeduase Borehole 1 (AB1)	Growth observed	1
Ayeduase Borehole 2 (AB2)	Growth observed	1

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Table 4.6: Results for 1 in 10ml water samples using MacConkey Agar

Sample	Observation	Number of colony forming units
Indece Hall Borehole (IHB)	Growth observed	20
Unity Hall Borehole (UHB)	Growth observed	30
Kotei Borehole 1 (KB1)	Growth observed	10
Kotei Borehole 2 (KB2)	Growth observed	10
Ayeduase Borehole 1 (AB1)	Growth observed	10
Ayeduase Borehole 2 (AB2)	Growth observed	30

Table 4.7.1: AAS Results of Physicochemical Parameters

SAMPLE NUMBER/CODE	AB1	AB2	KB1	KB2	UHB	IHB	STD SAMPLES	TEST UNIT	WHO STD	GSA STD
Physical Parameters										
pH	5.36	5.81	5.49	6.50	5.94	6.36	7.07			6.5-8.5
Temperature	26.7	26.7	26.8	26.8	26.9	26.9	26.9	°C		
Conductivity	194.8	220	58.0	227	106.4	174.6	118.7	uS/cm	500-700	
Total Dissolved Solids	97.4	109.2	29.0	112.9	53.1	87.8	59.3	mg/L	1000	1000
Total Suspended Solids	0	0	0	0	0	1	0	mg/L	5	5
Alkalinity	44	128	56	168	108	1700	2200	mg/L	200	200
Turbidity	1	1	0	1	1	2	1	FAU	5	5
Salinity	0.1	0.1	0.0	0.1	0.0	0.1	0.1	ppt		
Apparent Colour	1	1	0	1	1	2	1	PCU	25	
True Colour	0	0	0	0	0	0	0	PCU	5	

Keys: **AB1**- Ayeduase Borehole 1, **AB2**- Ayeduase Borehole 2, **KB1**- Kotei Borehole 1, **KB2**-Kotei Borehole 2, **UHB**- Unity Hall Borehole, **IHB**-Independence Hall Borehole, **PCU**- Platinum Cobalt Unit, **WHO STD**- World Health Organization Standards; GSA STD- Ghana Standards Authority Standards

Table 4.7.2: AAS Results of Physicochemical Parameters

SAMPLE NUMBER/CODE	AB1	AB2	KB1	KB2	UHB	IHB	STD SAMPLES	TEST UNIT	WHO STD	GSA STD
Nutrients And Other Chemical Tests										
Fluoride, F	0.31	0.12	0.07	0.83	0.12	0.16	0.04	mg/L	1.5	1.0-1.5
Chloride, Cl	33.98	25.99	5.99	13.99	1.99	13.99	35.99	mg/L	250-1000	250
Sodium, Na	56.5	38.8	7.2	40.5	8.2	22.0	47.6	mg/l	200	200
Potassium, K	11.6	11.8	2.0	5.4	10.9	12.6	0.0	mg/L	30	
Total Hardness	16.0	24.0	16.0	24.0	24.0	32.0	24.0	mg/L CaCO3	500	500
Nitrate as N	0.116	0.275	0.058	0.311	0.068	0.105	0.077	mg/L	10-45	10
Bicarbonate as HCO3-	53.64	156.0	68.27	204.82	131.67	2075.6	2682.2	mg/L		
Phosphate	0.057	0.050	0.011	0.066	0.047	0.051	0.049	mg/L		
Sulphate	24.36	25.20	19.85	25.35	24.11	24.31	24.61	mg/L	250-500	250-500

Keys : **AB1**- Ayeduase Borehole 1, **AB2**- Ayeduase Borehole 2, **KB1**- Kotei Borehole 1, **KB2**-Kotei Borehole 2, **UHB**- Unity Hall Borehole **IHB**-Independence Hall Borehole, **WHO STD**- World Health Organization Standards, **GSA STD**- Ghana Standards Authority Standards

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Table 4.7.3: AAS Results of Physicochemical Parameters

SAMPLE NUMBER/CODE	AB1	AB2	KB1	KB2	UHB	IHB	STD SAMPLES	TEST UNIT	WHO STD	IDL
	Trace Metals (Total)									
Iron as Fe	0.211	0.218	0.088	0.224	0.105	0.200	0.11	mg/L	1.0	0.0060
Manganese as Mn	0.010	0.014	0.003	0.017	0.006	0.013	0.008	mg/L	0.05-0.5	0.0020
Copper as Cu	<0.003	<0.003	<0.003	<0.003	<0.003	<0.004	<0.006	mg/L	2.0	0.0030
Zinc as Zn	0.021	0.024	0.026	0.029	0.019	0.022	0.020	mg/L	3.0	0.0010
Calcium as Ca	9.62	22.44	9.62	25.65	16.03	16.03	3.21	mg/L	200	0.050
Magnesium as Mg	1.220	0.960	1.230	1.680	1.190	1.400	1.290	mg/L	150	0.0003

Keys: **AB1**- Ayeduase Borehole 1, **AB2**- Ayeduase Borehole 2, **KB1**- Kotei Borehole 1, **KB2**-Kotei Borehole 2, **UHB**- Unity Hall Borehole, **IHB**-Independence Hall Borehole, **IDL**- Instrument Detection Limit, **WHO STD**- World Health Organization Standards, **GSA STD**- Ghana Standards Authority Standards.

DISCUSSION/ANALYSIS OF RESULTS

Analysis of Physicochemical Parameters

Temperature, Turbidity and Colour

Temperature of the water samples ranged from 26.7 to 26.9°C. Temperature of drinking water is often not a major concern to consumers especially in terms of drinking water quality. It is usually left to the individual taste and preference and there are no set guidelines for drinking water temperature.

From the AAS results, the turbidity values ranged from 0 to 2 NTU. All the samples analysed were clear with turbidity values below the WHO standard limit of 5.0 NTU. Turbidity in water causes problems with water purification processes such as flocculation and filtration which normally increases the cost of water treatment. High turbidity values may also increase the possibility of microbiological contamination.

Colour standard is set for reasons of appearance and requires that water be virtually colourless. According to WHO standards for drinking water, the colour limit should be 5 mg/l Pt/Co. from the results obtained all the water samples were within the WHO limit. Colour in natural water usually results from the leaching of organic materials and is primarily the result of dissolved and colloidal humic substances, primarily humic acid and fluvic acid. Colour is also strongly influenced by the presence of iron and other metals [6]. However the overall colour content of the samples analysed do not pose any health threat to those that use the water.

Total Dissolved solids (TDS)

TDS of the samples ranged from 29.0 to 112.9 mg/l. These values were within the WHO standard value of 1000.00. Suspended solids and total dissolved solids (TDS) are indicators of polluted water. Palatability of water with TDS level less than 600 Mg/l is generally considered to be good whereas water with TDS greater than 1200 mg/l becomes increasingly unpalatable [7].

Conductivity and pH

Electrical conductivity is generally the amount of all the dissolved ions in solution. It was realized that the electrical conductivity of all the samples were within the WHO acceptable limits of 500-700 µS/cm with KB2 recording the highest conductivity of 227 µS/cm and KB1 the lowest, 58.0 µS/cm. Generally the conductivity values recorded for all samples do not pose any potential health risk for consumers. All the samples but KB2 failed the pH test. KB2 recorded 6.50 which is within the WHO limits of 6.50-8.50, the rest of the samples recorded pH between 5.36 and 6.36.These deviations could be due to high levels of carbon dissolving to form carbonic acid which lowers the pH. However the overall pH content of the samples analysed do not pose any health threat to those that use the water. In areas where pH is very low boiling of the water should be a solution.

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Analysis of Nutrient loads in the Samples

Chloride, Phosphate, Sulphate and Nitrate

The chloride content of the water samples ranged from 1.99-35.99 mg/l. The WHO standard for chloride in drinking water is 250 mg/l and the samples were all within the acceptable limits prescribed by WHO. Chlorine being an active chemical has disinfecting capabilities. The sources of chlorine in natural water may be from residue of mining and from dissolving rocks. Chloride in water may react with sodium to form sodium chloride. Since sodium chloride has a salty taste, it can be deduced that Chloride in water impacts a salty taste in the water. That is to say, too much of chlorine in water makes the water esthetically undesirable for drinking purposes.

The phosphate content of the samples ranged from 0.011-0.066 mg/l with all of them being within the WHO acceptable limits. The concentration of phosphate encountered in the natural water environment is normally not enough to cause any detrimental health effect on humans or animals. Phosphate like any other nutrient is harmless in lower concentrations but harmful only in higher concentrations. Higher concentrations of Phosphate are known to interfere with digestion in both humans and animals.

The sulphate levels of the water samples ranged from 19.85-25.35 mg/l and were within the WHO limit of 250 mg/l. Sulphate gets into ground water through the dissolution of rocks containing sulphur and mine drainage waste. Increased sulphate levels can cause deficiencies in trace minerals which can contribute to a depressed growth rate and infertility in herd. The most serious is thiamine deficiency. The major physiological effect resulting from the ingestion of large quantities of sulphate leads to catharsis, dehydration, and gastrointestinal irritation.

Nitrate concentrations values ranged from 0.058-0.275 and were within the acceptable limits of 10-45 prescribed by WHO. Nitrogen is present in soils which are normally fixed by nitrogen fixing bacteria. Nitrogen may exist as nitrates and nitrites. Nitrogen like any other nutrient is harmless in lower concentrations but become harmful only in higher quantities.

Heavy metals

From the AAS results it was observed that the following metals Fe, Zn, Cu, Mn, Mg and Ca were all present but in minute quantities and within the WHO limits. Lead was however not detected in any of the samples analyzed.

Microbiological Quality of the Borehole Water Analysed

The result obtained for the microbial analysis indicated that all the water samples were not free from microorganisms. All the water samples showed growth for microbes using the Nutrient Agar including the control as well. Bismuth Sulphite was used to test for the presence of Salmonella species. All the water samples showed negative results but AB1 tested positive with a black rabbit eye colony with metallic sheen growth, suggesting the presence of Salmonella species. The microbial test using the Mannitol Salt agar was done to determine the presence or otherwise of Coagulase positive and negative Staphylococcus Aureus. The Coagulase positive shows yellow colonies with yellow medium whiles the Coagulase negative shows red colonies with no change in media colour. All the water samples tested negative with the exception of UHB which showed a red colony with no change in medium colour suggesting the presence of Coagulase negative Staphylococcus Aureus.

MacConkey Agar was used to test for coliform bacteria and all the water samples but the control showed positive results. Water samples that tested positive for the coliform bacterial test using MacConkey Agar were subsequently inoculated into brilliant broth to confirm the presence or otherwise of pathogenic coliform bacteria. The confirmatory test medium effectively eliminates all organisms except true coliforms or faecal coliforms, depending upon the medium and incubation conditions. Brilliant broth is thus used for presumptive identification for true coliforms bacteria only. Gas production within forty-eight hours is considered a positive result for the presence of coliform bacteria. Al the samples but the control tested positive to the presence of true coliforms. The standard for coliform bacteria in drinking water is “less than 1 coliform colony per 100 milliliters of sample” (<1/100ml).

CONCLUSION

All the water samples passed the physical and chemical tests conducted, except for the p H test which most of the samples failed. The levels of trace metals investigated were all below the WHO guideline levels. Only Unity Hall Borehole, UHB and Ayeduase Borehole 1, AB1 failed the microbial test using Mannitol Salt Agar and Bismuth Sulphite Agar respectively. With the exception of the control, all the water samples failed the total and true coliform test

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Recommendations

i. It is recommended that borehole water be monitored through regular water quality analysis.
ii. Proper site survey should be conducted before siting a borehole. Developers should be well informed of the chemistry of the geology as well as the source of recharge.
iii. Local authorities as well the general populace must be educated about the likely interaction between their borehole water and undesirable substances like septic and crude buried underground; and the need to properly site them to avoid contamination of their drinking water.
iv. Lastly the residents should be advised on water treatment and good storage of borehole water.

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