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Analysis of water quality from boreholes within Africa University, Mutasa district, Zimbabwe

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Abstract
Groundwater, which is mainly extracted through boreholes, is considered the most reliable source of drinking water in many developing countries. This study evaluated borehole drinking water quality. The assessment was based on the laboratory analysis of sampled boreholes and comparing the findings to the recommended values for drinking water quality established by the World Health Organization (WHO). The laboratory analysis was based on the physicochemical and bacteriological water quality of five boreholes water. The water quality parameters measured were: the potential of hydrogen (pH), turbidity, electrical conductivity (EC), magnesium (Mg), zinc (Zn), iron (Fe), mercury (Hg), and total coliforms. The results showed that the analyzed total coliform, for B1, B2, B3, B4, and B5 were above the WHO's recommendation for potable water of 0.00 count per 100 ml, which is an indication of fecal contamination in the water sampled. However, physicochemical and heavy metals quality analysis of all selected parameters were within the WHO's recommendation for potable water, except for iron in borehole two (B2), and mercury for all water samples. The study recommends a sanitary survey around boreholes to determine the sources of contamination. The results underscore the importance of implementing comprehensive water quality monitoring programs to identify and address the different types of contaminants in drinking water.

Keywords: Water quality, boreholes, contamination, physico-chemicals, bacteriological, water quality, WHO drinking water guidelines

Introduction

Although water is regarded as an important resource for all living organisms and their environment, it is not of the recommended quality and is not accessible to a large number of people (Nkansah, Boadi, & Mercy, 2010) [5]. Boreholes water designated for consumption purposes may be potentially contaminated with different pollutants. Existence of these contaminants in water sources poses significant threats to the well-being and health of the community. Assessing water quality ensures the safety and sustainability of water resources. Gaging the physicochemical and biological parameters of water quality enables evaluation of the various physicochemical parameters, including pH, temperature, electrical conductivity, turbidity, dissolved oxygen, total dissolved solids, and heavy metals such as mercury. These parameters provide important information about the overall characteristics of the water and help in understanding its suitability for various purposes. The study aimed to analyze water samples for the presence of contaminants, including heavy metals, organic pollutants, and pathogens. Identify the types and concentrations of contaminants, provides information on the potential risks associated with water usage. Comparison with the present regulatory standards provides a basis for evaluating the compliance of the water sources with the established benchmarks for quality and recognizing areas where remedial actions are critical.

Assessing water quality ensures the safety and sustainability of water resources. Gaging the physicochemical and biological parameters of water quality necessitates the evaluation of various physicochemical parameters, comprising of pH, temperature, electrical conductivity, turbidity, dissolved oxygen, total dissolved solids, and heavy metals such as mercury. These parameters provide important information about the overall characteristics of the water and help in understanding its suitability for various purposes. The study aimed at analyzing water samples for the presence of contaminants, including heavy metals, organic pollutants, and pathogens, and identify the types and concentrations of contaminants, which assists in assessing the potential risks associated with water usage. Comparison with the present regulatory standards provides a basis for evaluating the compliance of the water sources with the established benchmarks for quality and recognizing areas where remedial actions might be indispensable.

The analysis of water quality from boreholes holds a significant implication for public health and environmental sustainability. Understanding the suitability of the water for consumption and identifying potential contaminants, allows informed decision-making regarding water treatment and usage. Due to the high groundwater vulnerability to pollution, which degrades its quality, this study aimed at analyzing the physical, chemical, and biological parameters to establish the suitability of the boreholes water.

Methodology

Study site: The site of the boreholes studied falls within the coordinates of approximately 18°53' to 19° 10' south latitude and 32° 24' to 32° 48' longitudes.

Research Design

A Complete Randomized Design was used in the study and measurements were taken weekly for three weeks.

Parameters Measured

Total coliforms, potential hydrogen, electrical conductivity, Turbidity, magnesium, and heavy metals including, zinc, mercury, and iron, were determined.

Determination protocol

Water samples were collected from 5 different boreholes and labeled accordingly. The 5 boreholes were designated as B1 to B5. Samples for physicochemical and heavy metals analysis were collected in clean 500 ml plastic bottles while autoclaved bottles were used for bacteriological samples. Data on pH, turbidity, electrical conductivity, magnesium, iron, zinc, mercury as well as total coliforms were collected and measured. pH meter, conductivity meter, and turbidimetric meter were used to determine pH, conductivity and turbidity respectively. Magnesium, iron, zinc, and mercury were determined using an atomic absorption spectrophotometer. The membrane Filtration Method was used to determine total coliforms.

The buffer solutions used for calibration were pH 4.0, pH 7.0, and pH 10.0. The pH electrode was rinsed with distilled water immersed into the water sample and fully submerged without touching the sides or the bottom of the container to prevent the accuracy of the measurements. After standardization the readings were recorded as displayed on the screen.

Turbidity determination

Water samples were transferred into the sample cell turbidity meter up to the horizontal mark, then wiped with tissue paper and subsequently placed in the turbidity meter such that the vertical mark in the sample cell coincided with the mark in the turbidity meter, and covered. The readings displayed on the screen were recorded.

Electrical conductivity determination

The conductivity meter was calibrated before use and the conductivity probe was rinsed with distilled water and submerged in water samples ensuring that it did not reach the bottom or the sides of the container. After stabilization, the EC meter displayed consistent conductivity values that were recorded.

Alkali, Alkaline, and Heavy metals determination of

5.0 ml of nitric acid was added to 100 mL of water sample in 250 mL conical flask. The mixture was evaporated to half of its volume on a hot plate after which it was allowed to cool before filtering. The digestion water samples were analyzed for the presence of magnesium, iron, zinc, or mercury using atomic absorption spectrophotometer. The concentration of each heavy metals was calculated using the standard calibration plot for each metal (Momodu & Chimezie, 2009) [4].

Total coliforms Determination

The membrane filter, vacuum filtration manifold, petri dishes, and forceps were properly sterilized using ethanol and the methylated spirit flame before use. A bacterial growth medium, sterile pipettes, and an incubator set at 37 °C temperature were used**.** Pad dispenser's applicator was used to place the pad on the petri dishes. The media was applied to the pad and the petri dishes were closed to prevent multiplication of inappropriate bacteria. A membrane filter was placed on the filtration manifold to filter the water sample. 100 ml was transferred into the membrane filter. An extraction pump was used to draw the water sample through the filter. Bacteria were retained on the filter surface. The membrane filter was then transferred to the petri dishes containing the bacterial growth medium using sterile forceps. The Petri dishes were then incubated and set to a temperature of 37 °C for 24 hours to allow bacterial colonies to grow. After the incubation period, the petri dishes were carefully examined to count visible colonies that had grown on the membrane filter and differentiated coliform colonies (yellow) from other colonies.

Data Analysis

Data collected was analyzed using the following model:

$Y_{ij} = \mu + t_i + e_{ij}$

Where μ is equal to overall mean effect

t_i is equal to true effect of the i^{th} treatment

e_{ij} is equal to error term of the j^{th} unit receiving i^{th} treatment

Results

Tables 1, 2, and 3 shows the mean variations in water quality for Physical, Chemical, and bacteriological analysis within the three weeks of sampling. pH values ranged from 6.68 to 7.41, indicating slightly acidic to neutral conditions while Electrical conductivity (EC) values ranged from 396 to 667, indicating varying levels of dissolved salts.

Turbidity values ranged from 0.49 to 1.63 NTU. Mean variations in water quality for heavy metals, magnesium, iron, zinc, and mercury concentrations varied across the different boreholes. Mean variations in water quality for bacteriological analysis. A bacterial indicator of water quality varied across the boreholes. Tables 4 and 5 indicates that most parameters fall within the acceptable range, except for iron in borehole 2. Total coliforms and mercury in all samples exceeded the standards. The potential of hydrogen, turbidity, electrical conductivity, magnesium, iron, zinc, mercury, and total coliforms. are depicted in Figures 1 to 8

Table 1: Mean variations in water quality for Physical and Chemical Analysis by the three weeks of sampling

Sample	Ph	EC	Turbidity
Borehole 1	6.68	396	0.49
Borehole 2	7.08	667	1.63
Borehole 3	6.77	518.6	0.74
Borehole 4	6.8	613	0.92
Borehole 5	7.41	636.6	1.36

Table 2: Mean variations in water quality for Heavy metals analysis by the three weeks of sampling

Sample	Magnesium	Iron	Zinc	Mercury
Borehole 1	6.153	0.023	0.002	0.985
Borehole 2	1.3	0.404	0.019	1.078
Borehole 3	1.039	0.107	0.003	0.881
Borehole 4	1.995	0.042	0.019	1.351
Borehole 5	3.173	0.014	0.002	1.056

Table 3: Mean variations in water quality for Bacteriological analysis by the three weeks of sampling

Sample	Total coliforms
Borehole 1	52
Borehole 2	32
Borehole 3	26
Borehole 4	42
Borehole 5	38

Table 4: Physico-Chemical, Biological and heavy metals and World Health Organization (WHO) Recommended Standard Values

Physico-chemical parameters mg/l	B1	B2	B3	B4	B5	WHO	Remarks
PH	6.68	7.08	6.77	6.8	7.41	6.5-8.5	Okay
EC	396	667	518	613	636.6	1000	Okay
Turbidity NTU	0.49	1.6	0.74	0.92	1.36	5	Okay
Magnesium	6.153	1.3	1.039	1.99	3.173	50	Okay
Iron	0.023	0.404	0.107	0.042	0.014	0.3	Okay Except B2
Zinc	0.002	0.019	0.003	0.019	0.002	5	Okay
Mercury	0.985	1.078	0.881	1.351	1.056	0.006	Exceed
Total Coliforms	51	31	26	42	37	0	Exceed

Table 5: Mean, Minimum, and maximum, standard deviation of the parameters studied relative to to the World Health Organization (WHO) values for drinking water

Parameter	Mean	Minimum	Maximum	Standard Deviation	WHO values
Ph	6.94	6.68	7.41	0.26	6.5-8.5
Turbidity	1.02	0.49	1.63	0.41	5
EC	566.4	396	667	98.59	1000
Magnesium	2.73	6.15	1.03	1.86	50
Iron	0.11	0.01	0.4	0.14	0.3
Zinc	0.009	0.002	0.019	0.008	5
Mercury	1.07	0.881	1.35	1.15	0.006
Total coliforms	37.4	26	52	8.89	0

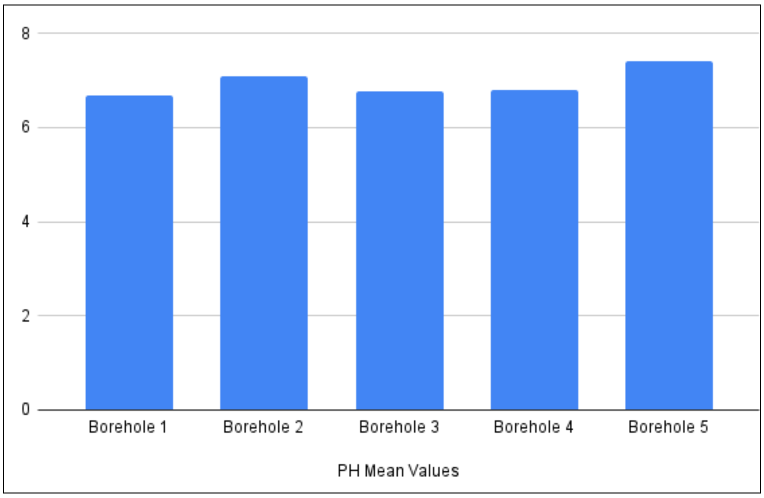

Fig 1: Potential hydrogen means values of the five boreholes

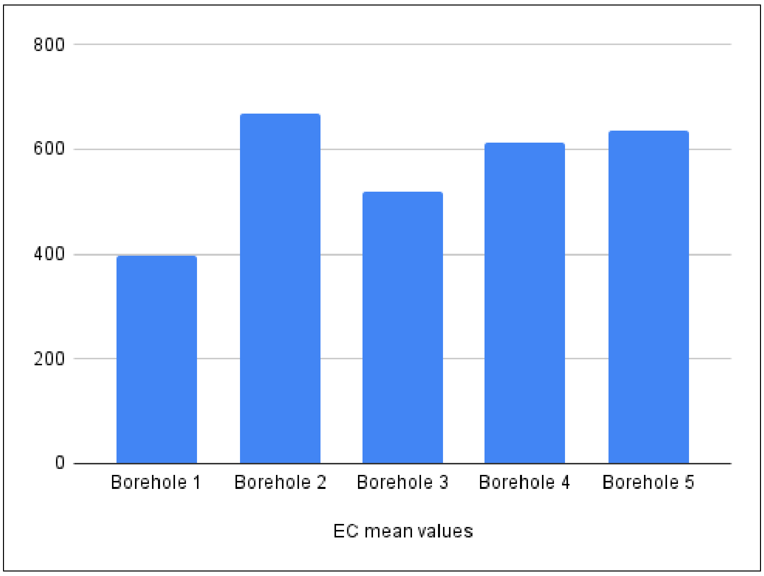

Fig 2: Electrical conductivity mean values of the five boreholes

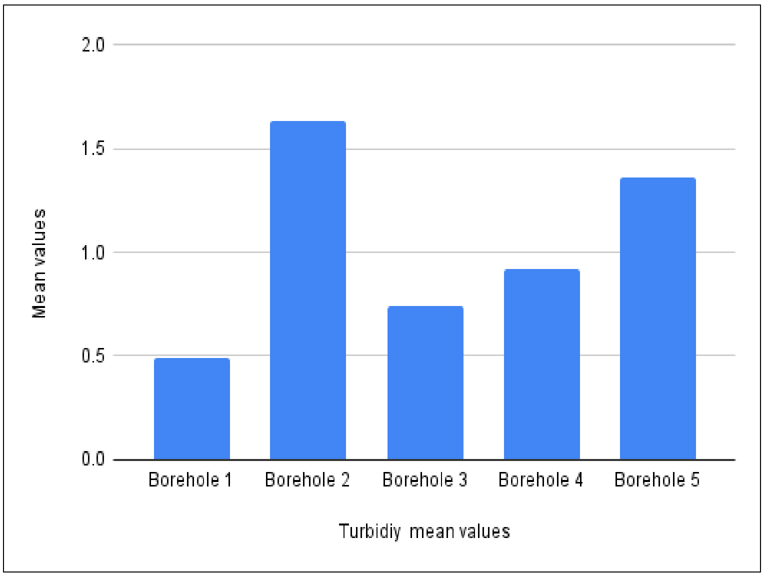

Fig 3: Turbidity mean values of the five boreholes

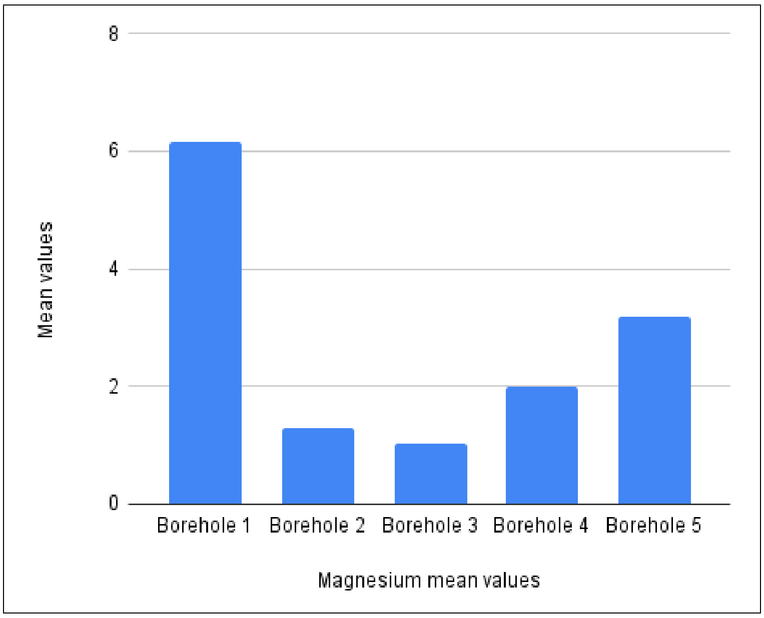

Fig 4: Magnesium mean values from the five boreholes

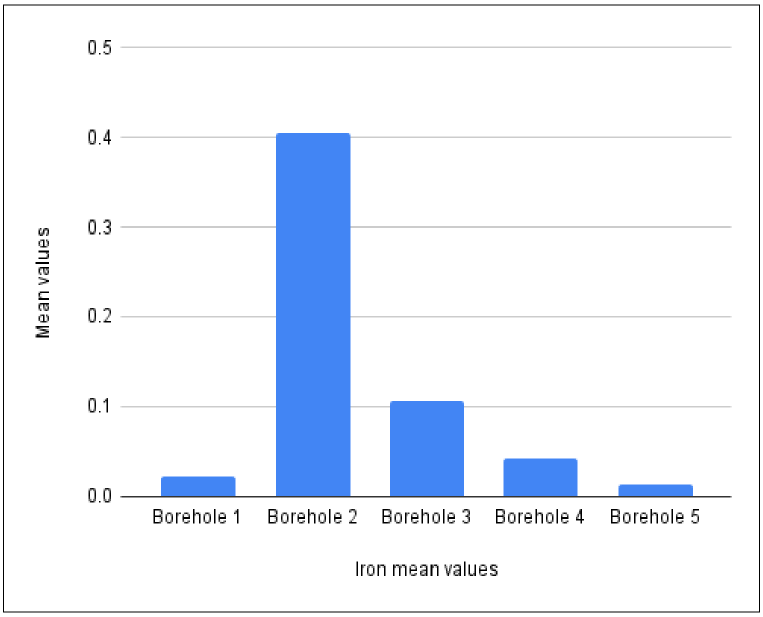

Fig 5: Total iron mean values of the five boreholes

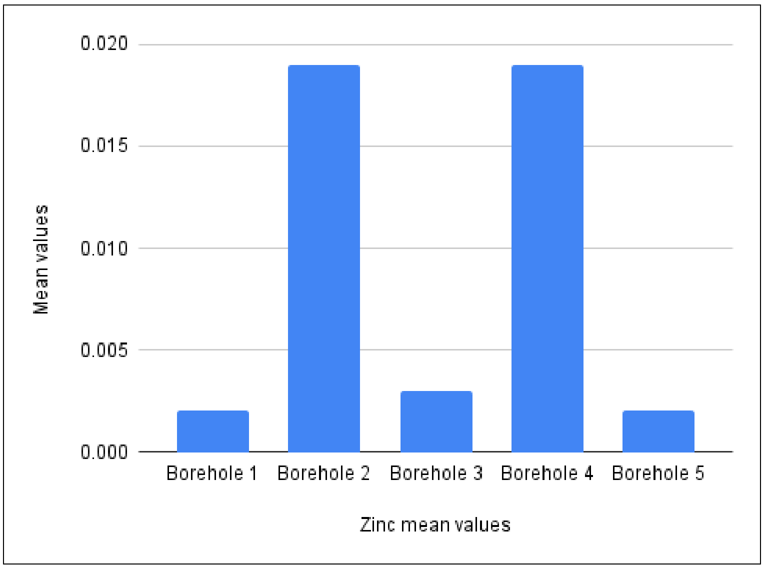

Fig 6: Total zinc mean values of the five boreholes

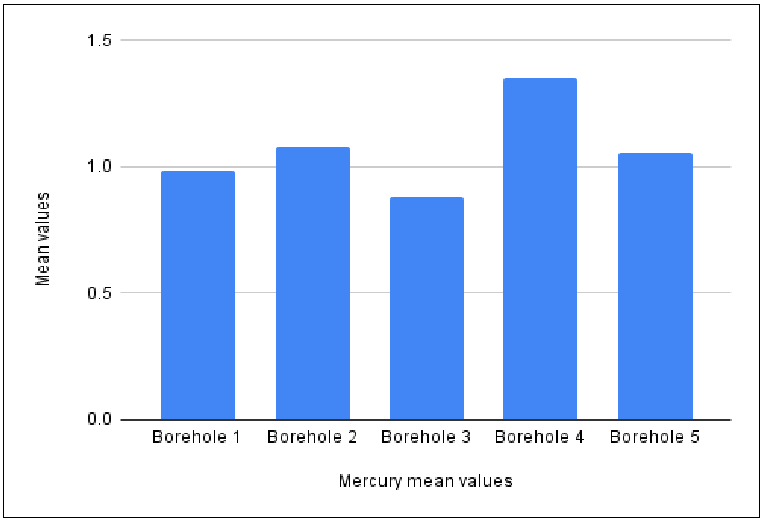

Fig 7: Mercury mean values of the five boreholes

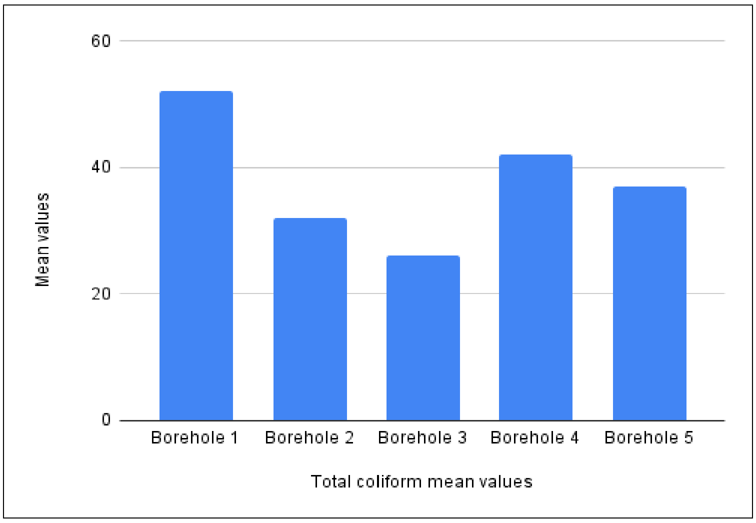

Fig 8: Total coliform mean values of the five boreholes

Discussion

Through the physical, chemical, and bacteriological quality analysis carried out it was evident that standards of the most water samples were within the World Health Organization's recommendation. However, Borehole B2 revealed a slightly high iron concentration. All water samples contained mercury traces and tested positive for pathogens, pointing to the importance of regular quality assessment measures by responsible agencies.

Potential of hydrogen

The pH of the water samples ranged from 6.68 to 7.41. The highest pH value of 7.41 was recorded in B5 and the lowest pH of 6.68 in B1. The pH values were generally within the WHO guideline value which ranges from 6.5 to 8.5. Low pH in groundwater is generally because of the presence of carbon dioxide which is produced in the soil by both aerobic and anaerobic microbial processes. CO_2 dissolve in water forming carbonic acid, which lowers the pH (Hussain, Gupta, & Pandey, 2017) [3]. Anthropogenic factors such as agricultural runoff can contribute to the introduction of acidic pollutants into groundwater affecting its pH. This might be the probable reason why the three boreholes had slightly acidic water. 40% of the boreholes' pH was identified to be slightly alkaline with pH values of 7.08 and 7.41 for B2 and B5. Anthropogenic factors and high mineral content such as sodium bicarbonate ($NaHCO_3$) can raise groundwater pH, which is considered to be the most significant parameter determining the corrosive nature of the water. Exposure to extreme pH levels of less than 4 or higher than 11 can irritate mucous membranes and the eyes. The pH of the boreholes was generally within the WHO guideline value which ranges from 6.5 to 8.5) indicating permissibility for use.

Electrical conductivity

Conductivity is generally affected by the presence of dissolved ions in water. The significance of EC is its measure of salinity, which basically affects the taste and hence, impacts the user acceptance of the water (Ahmed, *et al*., 2010). The EC values for the samples varied from 396 to 667 µS/cm which compares favorably to the limit of electrical conductivity value (1000 µS/cm) in drinking water as per WHO guidelines indicating the favorability for drinking and agricultural purposes.

Turbidity

The maximum limit of turbidity in drinking water per WHO guidelines is 5.0 NTU. All borehole water samples had turbidity within the recommended value ranging between 0.49 and 1.63. Therefore, all the studied boreholes' water turbidity level was considered to be satisfactory for consumption.

Magnesium

As the maximum concentration of magnesium recommended by WHO is 50 mg/ for drinking water, the concentration of magnesium ions (1.039 mg/l to 6.153 mg/L) is below the maximum recommended permissible value.

Iron

Iron concentration was generally found within the WHO guideline value of 0.3 mg/l. However, the concentration of iron in borehole B2 (0.404 mg/l) was well outside the WHO guideline value. As the mean iron concentration of the samples from the five boreholes was 0.118 mg/l, the water is considered satisfactory for consumption except the one from Borehole 2. Iron in groundwater may come from natural sources and steel pumps and casings (Samuel, Sixtus, & Sebiawu, 2014) [6]. A high amount of rainfall increases the concentration of iron in boreholes. The process of rainfall infiltrating into the soil and underlying geologic formations is known to dissolve iron leading into aquifers (Abubakar & Adekola, 2012) [2]. Consuming large amounts of iron causes iron overload which results in hemochromatosis known to damage organs of the body.

Zinc

Excess zinc can affect the taste, odor, and appearance of the water, making it less desirable to consumers. It also presents many health risks including, kidney and liver failure, blood urine, and anemia. As the permissible level of zinc in drinking water recommended by WHO is 5 mg/l, the values of Zinc obtained from the study (0.002 to 0.019 mg/l), which is within the permissible limits for drinking water.

Mercury

The maximum mercury value determined by WHO for drinking water is 0.006. The observed values for mercury ranging from 0.881 to 1.351 mg/l is higher than the permissible level implying that that water from the five boreholes is considered unsuitable for human consumption**.**

Total Coliforms

The total concentrations of coliform samples of water from five boreholes were more than the zero value recommended by WHO. The presence of coliforms in most of the samples may be associated with the absence of residual chlorine, which may be an indication that water had not been chlorinated. Low levels of coliforms (≤ 16 per 100 ml) may not be a threat to the health of consumers. However, levels of coliforms greater than 16 per 100 ml as observed in all water samples render the water insalubrious and undesirable as high levels of coliforms in water can cause the spread of waterborne diseases such as Dysentery, Gastroenteritis, ear infection, Typhoid, and Hepatitis.

Conclusion and Recommendation

As the total coliform count, iron levels and mercury concentration in all analyzed water sources exceeded the recommended values by World Health Organization's there is need for comprehensive water quality monitoring, improved sanitation practices, and appropriate treatment measures to ensure the provision of safe drinking water to safeguarding public health and preventing waterborne diseases.

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