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Assessment of the quality of water from Hand-dug wells in Essikado community

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ABSTRACT

The study evaluates the physico-chemical and bacteriological characteristics of water from hand-dug wells in Essikado, Sekondi-Takoradi, Ghana, against World Health Organization (WHO) guidelines. The pH levels of the wells ranged from 6.13 to 7.03, with all samples falling within the WHO acceptable range of 6.5-8.5. However, conductivity levels exceeded the WHO limit of 1000 µS/cm in all wells, with values reaching up to 1411 µS/cm. Color and alkalinity also varied, with some wells showing values below the reporting limits for color, but alkalinity levels were notably high in several samples. Iron concentrations were found to be below the WHO limit of 0.3 ppm in all wells, with values ranging from 0.051 to 0.159 ppm. Manganese levels were problematic in Well 2, reaching 0.348 ppm, exceeding the WHO guideline of 0.08 ppm. Bacteriological analysis revealed total coliform counts in five wells exceeded the WHO guideline of 0 counts per 100 mL, with Well 1 showing 9 counts and Well 3 showing 12 counts. Faecal coliform was absent in all samples, indicating some level of safety. While some parameters met WHO standards, significant concerns regarding conductivity and certain bacteriological counts highlight the need for improved water management practices in the region.

Keywords: Hand - dug wells, physicochemical, bacteriological, coliforms

1. INTRODUCTION

Approximately thirty percent of fresh water on Earth comes from groundwater, which also provides half of the world's drinking water. According to (Siebert et al., 2010), it also provides 43% of the world's consumptive consumption for irrigation. Millions of people, particularly in areas with little or no access to piped water systems, rely on hand-dug wells as a dependable supply of clean and safe drinking water (Bakundukize., 2016). In addition, hand dug wells supply irrigation water, which helps small-scale farming and gardening endeavors. To improve food security and livelihoods, community members use water from wells to irrigate crops, vegetable gardens, and fruit orchards (Borrok et al., 2019). In most parts of the world, groundwater is a major supply of drinkable water for both urban and rural residents. Groundwater, primarily from hand-dug wells and boreholes, provides drinking water to 71% of rural and 62% of urban people in Ghana (Opoku et al., 2018). Through spills, leaks, runoff, or infiltration into the soil, improper disposal of industrial waste, chemicals, solvents, and hazardous materials can contaminate groundwater (Jian, Cherry, and Wan, 2020). Microorganisms including bacteria, viruses, and protozoa can live in groundwater and can infiltrate the aquifer via contaminated sources or the water's surface. Waterborne illnesses and issues with public health can result from microbial contamination of groundwater (Ashbolt., 2004). Due to the leaching of pollutants, septic tanks which are frequently used in homes to treat wastewater in places without centralized sewer systems may have an adverse effect on the quality of groundwater. Solids in wastewater settle to the bottom of a septic tank, while liquids are released into a drain field where they are further treated by the soil and environment. But if the soil is improper or poorly maintained, pollutants from the septic system may leak into the groundwater and cause contamination. Heavy metals can occur naturally in geological formations to initiate natural processes, and their presence in groundwater may result from the leaching of minerals from rocks and soils. Through dissolution and weathering processes, certain heavy metal-rich geological formations can release these contaminants into groundwater (Smedley and Kinniburgh, 2002). Additionally, human activities that release heavy metals into the environment include mining, agriculture, industrial discharge, and inappropriate waste management. Through runoff, leaching, and infiltration processes, these activities contribute to the heavy metal contamination of soil, surface water, and eventually groundwater (Alloway.,2013). Groundwater pollution poses a serious threat to public health. Heavy metal pollution in groundwater, such as that caused by lead, arsenic, cadmium, and mercury, can have detrimental effects on health and parasites. Waterborne illnesses including cholera, dysentery, and hepatitis can result from consuming water tainted with these bacteria (Bain et al., 2014). Essikado is a town in the Western Region of Ghana. Hand-dug wells are one of the most dependable sources of freshwater supply in Essikado. The residents of Essikado rely on hand-dug wells for their everyday needs, since they provide vital access to water for drinking, household use, and agriculture. Hand-dug wells are used to provide household animals and livestock with water. Although hand-dug wells are an essential source of water for the community, there is a substantial lack of information about the actual quality of the water they provide and the possibility of heavy metal pollution. Not as many researches have been done to evaluate these crucial aspects, despite their relevance. There is an urgent need to carry out a complete study in order to assess the water quality characteristics within these wells because there has not been much research done in this area. The findings can help address health issues, safeguard the environment, and raise the general standard of the community's drinking water sources by examining the water quality in hand-dug wells.

2. METHOD

2.1 Brief Description of Study Area

The research was conducted at Essikado in the Western Region of Ghana. Essikado is an Ahanta town located in the coastal zone and Western Region of Ghana, about 12 kilometers from the center of Takoradi. The town is bordered onon the East,on the West,on the North and Gulf of Guinea and Sekondi on the south. and it lies approximately 4.85° N latitude and 1.75° W longitude.

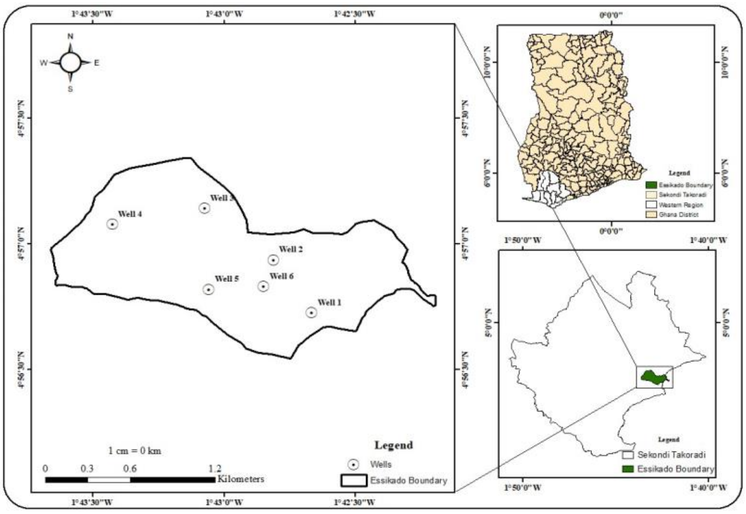


Fig 1: Map Showing Sampling Points and Essikado Community

2.2 Physical and Chemical Parameters of Hand-Dug Well Water

Hand-dug wells are a vital source of water for many communities, particularly in developing regions. Understanding the physical and chemical parameters of the water from these wells is crucial for assessing its safety for consumption. For instance, a study in Bida Metropolis, Nigeria, reported pH values ranging from 6.56 to 7.67, indicating generally acceptable alkalinity levels (Ashafa et al., 2020). Turbidity levels varied significantly, with some wells showing values as high as 85.30 NTU, which raises concerns about water clarity and potential contamination (Braimah et al., 2021). Chemical parameters such as total dissolved solids (TDS), nitrates, and chloride content also play a significant role in water quality. TDS levels between 47.10 mg/l and 553.00 mg/l, with nitrates sometimes exceeding safe limits due to agricultural runoff and poor sanitation practices have also been reported (Barimah et al., 2023). Overall, while many hand-dug wells meet WHO standards for drinking water, factors like proximity to waste sources can lead to contamination, necessitating regular monitoring and proper well construction practices to ensure safe water access for communities (Braimah et al., 2021).

2.3 Microbiological Contamination of Hand-Dug Wells

Microbiological contamination of hand-dug wells is a significant global health concern, particularly in developing regions where these wells serve as primary water sources. Studies have consistently shown that hand-dug wells are highly susceptible to microbial pollution, primarily due to their proximity to sanitation facilities and inadequate construction practices. For instance, a study in Ghana revealed that over 70% of hand-dug wells were located within 10 meters of contamination sources, such as latrines and wastewater dumps, leading to the presence of fecal coliforms and E. coli in water samples (Lutterodt et al., 2018). Microbiological contamination of hand-dug wells can result from various sources, including human and animal fecal matter, agricultural runoff, and sewage leakage. Pathogens such as bacteria, viruses, and parasites can contaminate the water, leading to waterborne diseases such as cholera, typhoid fever, and diarrhea. The prevalence of microbiological contamination in hand-dug wells varies across regions and is influenced by factors such as population density, sanitation practices, and environmental conditions. In developing countries, where access to clean water and sanitation facilities is limited, the risk of contamination is particularly high. The quality of water from these wells varies significantly with seasonal changes, often showing higher contamination levels during the wet season. Factors such as poor maintenance, lack of protective barriers, and the use of contaminated water collection materials exacerbate the situation (Gnimadi et al., 2024). To mitigate these risks, it is essential to implement regular maintenance protocols, educate communities about safe water handling practices, and establish guidelines for well construction that prioritize distance from potential contamination sources. Addressing these issues is crucial for ensuring the safety of drinking water from hand-dug wells globally (Akple et al., 2011).

2.4 Factors Affecting Water Quality in Hand-Dug Wells

Hand-dug wells are important sources of water for many communities, especially in rural areas where access to piped water systems is limited. However, the water quality in hand dug wells can be influenced by various factors that may lead to contamination and pose risks to public health. Below are some key factors affecting water quality in hand-dug wells; i. Geology and Hydrogeology: The geological and hydrogeological characteristics of the area where a hand-dug well is located can significantly impact water quality. Factors such as soil composition, groundwater flow patterns, and aquifer vulnerability to contamination can affect the presence of pollutants in the water. ii. Land Use and Land Cover: The type of land use surrounding a hand-dug well, such as agricultural activities, urban development, or industrial operations, can introduce contaminants into the groundwater. Runoff from fertilizers, pesticides, and other chemicals can seep into the ground and contaminate the well water.

2.5 Water quality standards for Hand-Dug wells

Hand-dug wells are essential water sources for many rural communities, yet they often face significant challenges regarding water quality. Regulatory guidelines are crucial for ensuring that the water from these wells is safe for human consumption. The World Health Organization (WHO) has established comprehensive guidelines for drinking water quality, emphasizing the need for monitoring and maintaining acceptable limits for microbial, chemical, and physical contaminants (Mitchell et al., 2023). For instance, the presence of E. coli in water samples should be non-detectable in 100 mL, reflecting a critical standard for microbial safety. To enhance water quality, it is essential to implement protective measures around hand-dug wells, including proper construction techniques, regular water quality testing, and community education on hygiene practices (Rao et al., 2019). Engaging local communities in monitoring efforts can significantly improve awareness and adherence to safety standards.

Table 1.1 Water Quality Standards of Physicochemical Parameter, Microbial Agents and Some Heavy Metals In Drinking Water

PARAMETER	UNIT	WHO STANDARDS
pH	-	6.5-8.5
Lead	µg/L (ppb	10
Nitrate	mg/L (ppm)	50

Sulphate	mg/L (ppm)	500
Iron	mg/L (ppm)	0.3
Copper	mg/L (ppm)	2
Aluminium	mg/L (ppm)	0.2
Zinc	mg/L (ppm)	5
E. Coli (Microbial)	CFU/100 mL	0
Total Coliform	CFU/100 mL	0
Color	TCU	<15
Conductivity	µS/cm	<250
Alkalinity	mg/L (ppm)	500
Manganese	mg/L (ppm)	0.1

2.6 Sample Collection

Six hand-dug wells in the research region provided water samples, which were analyzed for physico-chemical and bacteriological characteristics. Following their geospatial position, they were gathered into new 1.5 L Voltic bottles and labelled Well 1, Well 2, Well 3, Well 4, Well 5, and Well 6. The samples were stored at 4oC before analysis were made at the Environmental Monitoring Laboratory (UMaT Lab), University of Mines and Technology, Tarkwa. Moreover, in order to prevent contamination, the samples were put in a makeshift ice box. The well locations were selected using a map coordinate. The coordinates were used to create a geospatial map using Arc GIS version 10.3. Additionally, Google Earth was used to derive the research map's boundaries, and a comprehensive analysis of the data was provided using MS Excel 2016 version in the form of charts for exposed parameters. The outcomes were then contrasted with the recommendations for household water consumption issued by the World Health Organization (WHO). Lastly, water quality parameters were analyzed using standard methods.

2.7 Data Collection

2.7.1 pH Measurement

Method: pH is typically measured using a pH meter equipped with a glass electrode.

•.. Calibration: The pH meter was calibrated using standard buffer solutions with known pH values (commonly at pH 4.00 and 10.00).

•.. Sample Measurement: The glass electrode was immersed in the water samples. The meter measures the voltage difference between the glass electrode and a reference electrode.

2.7.2 Conductivity Measurement

Method: Conductivity is measured using a conductivity meter and probe.

•.. Probe Setup: The probe, which contains two electrodes, is immersed in the water sample. A voltage is applied between the electrodes.
•.. Measurement Principle: The resistance of the water to the flow of electrical current is measured.

2.7.3 Color Measurement

Method: The color of water is measured using a colorimeter.

- Sample Preparation: A water sample is placed in a clear container.
- Measurement: The device shines light through the sample and measures the intensity of light absorbed at specific wavelengths. The results are expressed in True color Units (TCU).
- Calibration: The instrument is calibrated using standard color solutions to ensure accuracy.

2.7.4 Alkalinity Measurement

Method: Alkalinity is typically measured through titration.

- Titration Process: A known volume of the water sample is titrated with a standard acid solution (usually sulfuric or hydrochloric acid) until a specific endpoint is reached, indicated by a colour change using a pH indicator.
- Calculation: The amount of acid used to reach the endpoint is used to calculate alkalinity, expressed in parts per million (ppm) of calcium carbonate ($CaCO_3$).

2.7.5 Iron and Manganese Measurement

Method: Both iron and manganese concentrations are commonly measured using colorimetric methods.

- Sample Preparation: A water sample is mixed with a reagent that reacts with iron or manganese to produce a colored complex.
- Atomic Absorption Spectroscopy (AAS) was used to quantify the concentrations of the two metals (Iron and Manganese) in the water samples. AAS was chosen for its sensitivity and accuracy in detecting trace levels of these metals.

2.7.6 Total and Faecal coliform

A membrane filter with particle sizes of 0.45 micrometers is used to filter a specified amount of water, usually 100 mL. Water may flow through the filter, but microorganisms are retained. After that, the filters were placed in a Petri dish with a selective growth medium, which promotes the development of coliform bacteria while suppressing the growth of nontarget species. For a 24-hour period, the dish is incubated at a high temperature (often 44.5°C). This temperature suppresses other bacteria while favouring the development of faecal coliform. Colonies that grow on the filter after incubation are tallied. The concentration of faecal coliforms in the water samples were determined by counting the colonies. The results are often represented as CFU (colony-forming units).

3. RESULTS AND DISCUSSION

The result of the physico chemical characteristics of Hand-Dug wells in Essikado compared with WHO guidelines.

Table 3.1: Physico-Chemical Characteristics of Hand-Dug Wells in Essikado Compared with WHO Guidelines

Sample ID / Parameters	pH (pH Units)	Conductivity (μS/cm)	Colour (TCU)	Alkalinity (ppm)
Well 1	7.03	1411	9	190
Well 2	6.13	1300	0	129
Well 3	6.95	1115	12	7
Well 4	6.36	137.4	13	26
Well 5	6.19	1349	0	43
Well 6	6.40	1003	0	65
WHO GUIDELINE	6.5-8.5	1000	15	

The six water samples had varying amounts of manganese, ranging from less than 0.003 ppm to 0.348 ppm. Most of the samples has their manganese levels below detection limit, however, well 2 had manganese level of 0.348 ppm exceeding the WHO standard, which might cause unpleasant taste, stains, and iron accumulation, according to WHO. It could also accumulate in iron delivery networks. Although concentrations as low as 0.1 mg/l are tolerated by consumers, manganese often deposits as a coating on pipes that may ultimately peel off as a black precipitate. Increased manganese levels may result in neurological difficulties, especially in young toddlers and babies, as well as concerns with water's flavour and odour.

The World Health Organization (WHO) sets acceptable iron concentration limits in drinking water, typically not exceeding 0.3 mg/L. From table 3.2, detected iron levels are low, with an average of 0.121 ppm below this cut off, making the iron concentration in wells typically acceptable. Laundry and plumbing fittings become stained by iron at concentrations higher than 0.3 mg/l. At iron concentrations below 0.3 mg/l, turbidity and color may emerge, although taste is typically not present. Prolonged exposure to high iron levels may potentially cause health problems, including liver damage (Kontoghiorghes.,2023).

The wells' alkalinity values, ranging from 7 to 190 ppm, indicate potential differences in water quality, potentially impacting corrosion potential, taste, and scaling. High alkalinity levels, particularly those near or over 100 ppm, may cause harsh taste, potentially affect consumer acceptability and cause complaints. Values greater than 6.5 are deemed too acidic for human consumption and can result in health issues like acidosis, while values greater than 8.5 are deemed too alkaline because they accelerate the formation of scale in pipes and water heaters and lessen the germicidal potential of chlorine.

Table 3.2: Traces of Iron and Manganese in Hand-Dug Wells Compared with WHO Guidelines

Sample ID / Parameters	Iron (Fe) (ppm)	Manganese (Mn) (ppm)
Well 1	0.159	<0.003
Well 2	0.152	0.348
Well 3	0.051	<0.003
Well 4	0.158	<0.003
Well 5	0.051	<0.003
Well 6	0.157	<0.003
WHO GUIDELINE	0.3	0.08

Table 3.3 Showed That, The Presence of Total Coliform (T-Coli) in Wells 1, 3, And 4 Suggests Potential Contamination Which May Due To Surface Runoff, Low-Grade Well Construction, Or Animal Faeces. The Absence of Total Coliform in Wells 2, 5, And 6 Suggests They May Be More Protected or Less Prone to Contamination.

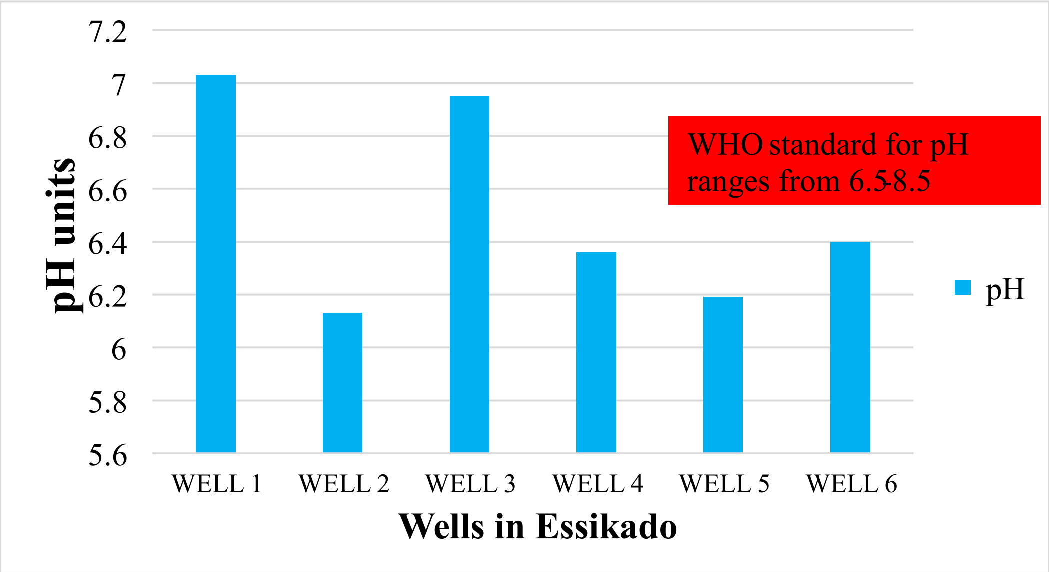
Faecal coliforms (F-Coli) are linked to faecal pollution, indicating a greater risk of pathogens causing waterborne illnesses. The absence of F-Coli in wells is encouraging, but the discovery of T-Coli raises concerns about potential contamination that may result in faecal coliforms. The World Health Organization recommends 0 counts/100 mL for both total and faecal coliform. The detection of coliform bacteria suggests the possibility of faecal contamination, which may lead to serious health hazards such as infections and gastrointestinal disorders.

Table 3.3: Bacteriological Characteristics Compared with WHO Guidelines

Sample ID	**Total Coliform count/100mL**	**Faecal Coliform count/100mL**
Well 1	9	0
Well 2	0	0
Well 3	12	0
Well 4	13	0
Well 5	0	0
Well 6	0	0

WHO GUIDELINE	0	0

Figure: 3.1 A Graph of Ph Values of Wells in Essikado



The result of the physico-chemical analysis compared with WHO standard for drinking water is presented (Table 1). pH values range from 6.13 to 7.03 with a mean of 6.51 compared to WHO limit (6.5 – 8.5). The research area's hand-dug wells have varying degrees of acidity and alkalinity, which affects how the study area's basement rock complex weathers. The reason behind the acidic nature of Well 2, Well 4, Well 5 and Well 6 may be due to inadequate sanitation and the discharge of residential sewage into hand-dug wells. They may also be connected to the erosive processes that cause clayey and loamy soils in agricultural areas to become more concentrated in ions (Masoud., et al 2017). A pH value over 8.5 are deemed too alkaline for human consumption because they speed up the formation of scale in pipes and water heaters and lessen the germicidal potential of chlorine. pH values less than 6.5 are considered too acidic for human consumption and can result in health issues like acidosis.

Figure: 3.2 A Graph of Iron (Fe) Values of Wells in Essikado

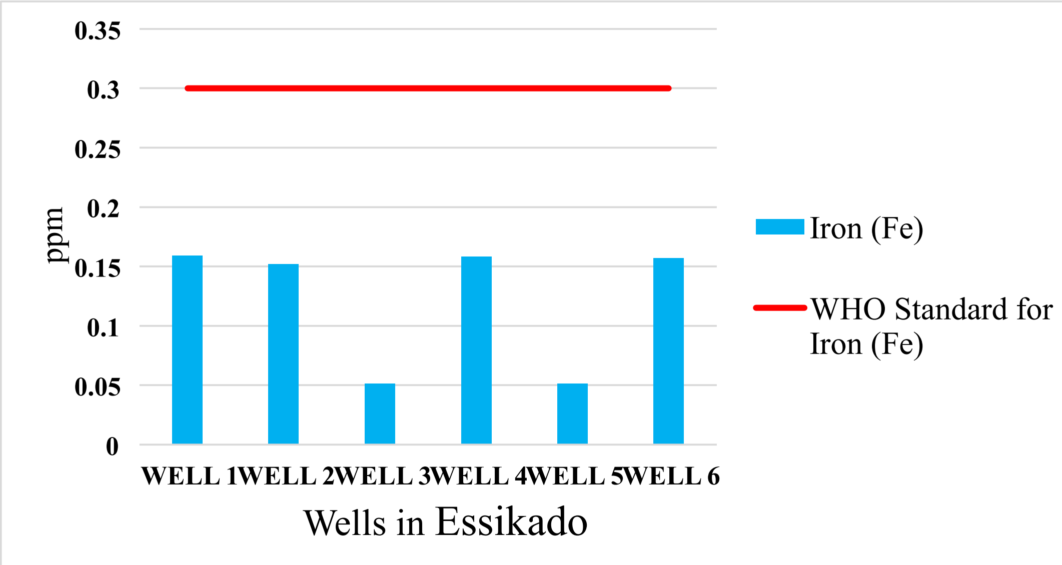
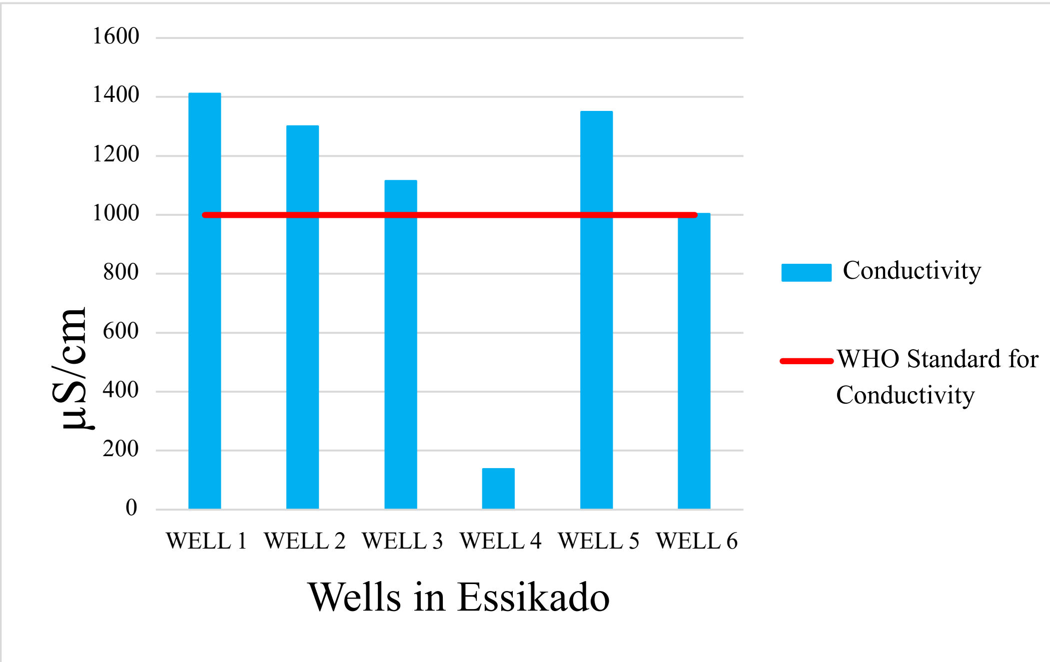


Figure: 3.3 A Graph of Conductivity Values of Wells in Essikado



The conductivity levels range from 137.4 to 1411 µS/cm, indicating the presence of dissolved ions from mineral deposits or human-caused pollution. Conductivity levels over

1000 µS/cm may indicate water unsafe for human consumption without treatment. Elevated conductivity indicates a greater level of dissolved ions, perhaps indicating pollution from sewage or agricultural runoff and dissolution of ions from weathered underground rock materials in the well. High concentrations may have an impact on the safety and flavour of drinking water, and if ingested often, they may cause gastrointestinal problems.

4. CONCLUSIONS

The geospatial location of the hand dug wells in the study area have been determined. The following findings on the quality of hand-dug wells in the research area were drawn from the physico-chemical and bacteriological tests done on the water samples.

i. All of the wells' total bacterial counts, which range from 0 to 13 counts/100 mL for total coliform to 0 counts/100 mL for faecal coliform, were below the WHO standard, with the exception of Wells 1, 3, and 4, which had total coliform counts that were higher.

ii. With the exception of Well 4, which fell below the WHO guideline of the conductivity criterion, the conductivity values observed for the wells in the research region were above the WHO guideline. Sekondi-Takoradi is a coastal city; most underground water is usually salty and high in conductivity.

Having access the quality of hand dug wells in the study area. The following suggestions are made to improve the quality of the water originating from hand-dug wells in the research region after an evaluation of their quality was conducted.

i. Prior to consumption, hand-dug well water should be disinfected or boiled to eliminate risks associated with microbial contamination.

ii. In order to stop the erosion of riparian land usage, it is necessary to promote positive and well-engineered methods.

iii. Covers and protection against animals hanging above wells are necessary.

iv. Modern restrooms should be installed in each residence, and sanitary facilities should be supplied to communities within the research area to prevent open defecation.

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