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GROUND WATER QUALITY AND BOREHOLE MAINTENANCE IN RESIDENTIAL BUILDINGS IN AKWA IBOM STATE

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ABSTRACT

Purpose: This study investigated the impact of borehole well maintenance on water quality in residential buildings in Akwa Ibom State, Nigeria. The study objectives were to assess physical, chemical, and biological qualities of borehole water and evaluate the maintenance practises applied to boreholes in selected residential buildings in Akwa Ibom State.

Design/methodology/approach: To achieve this aim a mixed research design was adopted. Water quality tests were carried on 26 samples gotten from selected residential boreholes; and through well-structured questionnaire, distributed to 150 respondents, the perceptions of borehole owners were elicited on maintenance practices and their frequency. Descriptive statistics were used to analyse survey responses. Laboratory results were compared to World Health Organization (WHO) standards to evaluate water quality

Findings: Results revealed a preference for submersible pumps 129 (90.8%) over hand pumps13 (9.8%), and mild steel casing materials 30 (21.1%) over other options. Plastic tanks 102 (71.8%) and non-black tank colours were favoured for water storage. Respondents exhibited confidence in water source integrity but reported lengthy maintenance cycles and compromised water quality. Most laboratory tests demonstrated compliance with World Health Organization (WHO) standards, though microbial contamination indicators showed deviations, highlighting the importance of regular monitoring and treatment.

Research limitations/Implications: The study's adoption of a purposive sampling technique limited the chances of boreholes and borehole owners being selected randomly, therefore, establishing biases in selection. Findings of the study is also limited to Akwa Ibom state.

Practical implications: It is recommended that measures geared at prioritizing regular maintenance, comprehensive testing, and adherence to best practices in borehole management, be implemented to ensure safe and reliable water sources. Stakeholders must address identified gaps to safeguard public health and ensure environmental sustainability.

Originality/value: The study highlighted the importance of maintenance for the safety and suitability of groundwater for residential uses, within the three sectorial districts in Akwa Ibom state.

Keywords: Ground Water Quality, Borehole Maintenance, Residential Buildings, Akwa Ibom State.

1. INTRODUCTION

Water quality is a very serious and vital issue, due to its link to human health. Water is one of the most important, valuable and renewable resource available for human use (Umeh *et al.,* 2019). There is abundance of it on the earth surface, but the quality, as well as the

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quantity to serve its intended purposes is of immense essence and worry to humans. Water originates from different sources, including rain, earth surface and underground. But ground water is considered most portable as it originates as a result of rainfall infiltration into the ground through the pores of rock and soil, thus, collecting in the water table. It is normally extracted through domestic boreholes and essentially used for human consumption (Reddy, 2018).

Clean water is a priceless and limited resource that man has begun to treasure only recently after the continuous declination of portable water quality (Silderberg, 2016). Portable water is an essential ingredient for good health and the socio-economic development of man (Udom *et al.,* 2022). But it is lacking in so many societies. Generally, all-natural water contains many dissolved substances and contaminants such as bacteria, viruses, heavy metals, nitrates and salt which have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, lack of maintenance of natural water sources, and over-use of limited water resources. Water quality management is an important phase of the water-resources engineering, without which pollution may threaten its utility as discussed by Arora (2017).

Borehole water serves as a major source of drinking water in the local population of Nigeria, since only very few can afford and rely on purified and treated bottle water for consumption. Most domestic households have independently drilled their own borehole point to avoid relying on commercial contractors or government agencies. With no government agency regulating the number of boreholes in each area and how they are maintained, owners of boreholes capitalize on this opportunity to commercialize their borehole for others who cannot drill theirs. Pollution of borehole water is bound to occur where there is no set down rules and regulations for maintenance of borehole water. The major cause for pollution could be avoided if borehole wells are located far from any source of potential pollution. A study by Umeh *et al.* (2018) showed that 48% of the people in Katsina-Ala Local Government area of Benue State are affected by urinary Schistosomiasis, due to increase in water pollution index. Good borehole well design is important in the prevention of its pollution. During the construction of borehole; drilling fluids, chemical casing and other materials may find their way into the well thereby polluting the water (Yusuf, 2017). An open hole during construction stage can also be a direct route for contaminants from the surface of the aquifer thereby providing an ideal opportunity for chemical and bacteriological pollution to occur. Lasting damage can be avoided if the well is completed, disinfected and piped within the shortest time possible. A possibility of contamination increases if there is a lengthy delay in completing the well. Even if no sources of contamination exist, there is potential for natural levels of metal and other chemicals to be harmful to human life. This was highlighted in Bangladesh where natural levels of arsenic in borehole water were found to be causing harmful effects on the population Anawara *et al*., (2022). Unfortunately, this problem arose because the groundwater was extracted for drinking without a detailed chemical investigation. Most of the points highlighted occur mostly during the initial construction of the borehole well. Maintenance of the borehole well poses another problem as it might bring certain problems if not properly done. Since the borehole well is for human consumption, any problem with the well reflects on the health of the humans consuming the water. Monitoring the quality of water is essential for environmental and human safety. The natural water analysis for physical and chemical properties during water maintenance is also important *(*Kot *et al.*, 2020). It is also important to note that the presence of objectionable tastes, odor, color as well as harmful substances in such water no matter how abundant it is, renders it unsuitable for domestic, industrial and agricultural uses. The assessments of the physical and chemical characteristics of water are important parameters as they may directly or indirectly affect its quality (Boniface *et al.,* 2017).

1.1. Aim and objective of the study

The study assesses the physical, biological and chemical characteristics of borehole water in residential buildings in Akwa Ibom State and evaluates the maintenance practises of the boreholes in selected residential buildings in Akwa Ibom State, with a view to establishing their quality in comparison to international acceptable standards. The focus of the study covers both urban and rural settings to provide a comprehensive understanding of the borehole well maintenance practices and their impact on water quality. The study targets household's heads that rely on borehole wells as their primary source of water. It places emphasis on privately-owned and community-managed boreholes within three (3) Senatorial Districts in Akwa Ibom State (Uyo Senatorial District**,** Ikot Ekpene Senatorial District and Eket Senatorial District).

Given the background above, the specific objectives are to:

i. To assess the physical, biological and chemical qualities of borehole water in residential buildings in Akwa Ibom State.
ii. To evaluate the maintenance practises of boreholes in selected residential buildings in Akwa Ibom State.

2. Literature Review

2.1. Physio chemical parameters and borehole water quality

The importance of water quality for human health cannot be overemphasized. Development in terms of social, economic, agriculture is an integral part of a healthy society. If the society is not healthy, every other sector will suffer. Ascertaining the quality of domestic borehole is very crucial especially when its purpose is for drinking (Khan *et al*., 2018). Assessment of domestic borehole water quality is all about investigation of the biological, physical and chemical properties of the borehole water.

The physio-chemical properties of water are a combination of physical and chemical properties of water. The physical qualities include all those qualities of water that can be detected using the human sense of sight, touch, taste and smell. These parameters include; color, taste and odor, temperature, suspended solid, and others. Chemical quality describes all those substances that are soluble or dissolved in water. Their presence cannot be easily detected except upon laboratory analysis. They can also impair the use of that water for its intended purpose. Examples of those parameters include dissolved cations and anions, toxic metals, organic and inorganic compounds, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and others. Some of these compounds appear in quantities that are detrimental to human health (Huq *et al.,* 2020).

Water temperature is an important property that determines water suitability for human use, industrial application and aquatic ecosystem functioning (Khan *et al.,* 2018). Although it is not used to evaluate directly potable water, it governs to a large extent the biological species present and their rates of activities (Olukanni *et al.,* 2015). It also has effect on most chemical reactions that occur in natural water systems and solubility of gases in water. Groundwater temperatures vary based on the depth and characteristics of the aquifer from which they are drawn.

Water pH has no direct impact on consumers. It is one of the most important operational water quality parameters which determine the suitability of water for various purposes with the optimum pH ranging from 7 – 8.5. It determines the acidic and alkaline nature of water (Huq *et al.,* 2020). In general, a water with low pH (< 6.5) could be acidic, soft and corrosive.

Electrical conductivity (EC) is the capacity of electrical current to pass through the water and it is directly related to concentration of ionized substances in water (Njaramba *et al.,* 2020). The salt concentration is measured generally by determining the EC of water. EC is a good measure of salinity hazard to crops (Ishaku *et al*., 2019). Excess of it reduces the osmotic activity of plants and therefore interferes with water absorption and nutrients from the soil.

The Total Dissolve Solid (TDS) in water are represented by the weights of residue left when a water sample has been evaporated to dryness and it gives the general nature of groundwater quality and extent of contaminant (Ramesh and Elango, 2016). They are compounds of organic and inorganic matter that are soluble in water. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals (Khan and Ahmad, 2017). The concentration of dissolved solids in natural water is usually less than 500mg/l and it is satisfactory for domestic use as well as many industrial purposes like dyeing of cloths, manufacturing of plastics and pulp paper (Ishaku *et al*., 2019).

Turbidity is a measure of the extent to which light is either absorbed or scattered by suspended material in water. It is cloudy and prevents visibility (USGS, 2020). It results from vegetable fibres and erosion of some colloidal materials such as clay, silt, rock fragments, etc. The colloidal materials associated with turbidity provide adsorption sites for chemicals and biological organisms that may be harmful and cause undesirable tastes and odour (Wilkes Environmental Centre, 2018).

Total Hardness in water is primarily caused by the presence of calcium and magnesium, anions such as carbonate, bicarbonate, chloride and sulphate in water. It is defined as the sum of their concentration expressed in mg/l. Water with hardness above 200mg/l may cause scale formation in the distribution system, boilers and irrigation pipes (Ishaku *et al.*, 2019). Groundwater exceeding the limit of 300mg/l is considered to be very hard and may cause heart disease and kidney problems World Health Organization (WHO, 2008). Hardness limits its use for domestic, industrial and agricultural activities. Hard water requires considerable amounts of soap to produce foam or lather.

Alkalinity of water may be due to the presence of one or more of a number of ions which include hydroxides, carbonates and bicarbonates. It defines the capacity of water to neutralize acid. Excessive alkalinity may cause eye irritation in human and chlorosis in plants (Njaramba *et al.*,2020). The measurement of alkalinity and pH is needed to determine the corrosiveness of water (Ishaku *et al.*, 2019).

2.2. Maintenance practises and its effect on quality of water

In recent decades, scientists developed sophisticated and highly successful techniques for the treatment of water from many contaminants. These techniques generally focused on the treatment of surface water resources such as water from rivers, lakes and water reservoirs. However, in recent years, scientists and environmental researchers have become more aware of treating underground water, and groundwater has become an essential source of water in most places; it represents about 30% of the freshwater reserve in the world (Njaramba *et al.*, 2020). Groundwater is usually treated by drilling water wells, pumping the polluted water to ground facilities to perform different approaches of treatment such as air stripping and treatment tower and granular activated carbon (GAC). The selection of the effective treatment or remediation procedure depends on the characteristics of contaminants and pollutants, in addition to the reactive media available (Vallero, 2019).

Pump and Treat Method: One of the popular procedures to remediate contaminated groundwater is by dissolved chemicals, solvents, metals and fuel oil (Borton *et al.*, 2020). In this procedure, contaminated groundwater is piped to ground lagoons or directly to treatment units, which treat the groundwater using various methods such as activated carbon or air stripping. Finally, the treated water is to be discharged either to the nearest sewer system or re-pumped to the subsurface (Vallero, 2019). This technique can treat large volumes of contaminated groundwater but has many disadvantages, such as the high cost, spreading of contaminants into the ecosystem, as well as its long operation time; in addition, it may cause a reversal to the hydraulic gradient (Park, 2017) as cited in (Borton *et al.*, 2020).

Regular cleaning and disinfection: Boreholes should be cleaned and disinfected regularly to remove any sediment, bacteria, and viruses that may have accumulated in the water. This can be done using chlorine or other disinfectants, and should be done at least once a month. (Ola-Omole *et al.*, 2002).

Water Quality Monitoring and Testing: Regular monitoring of the water quality should be carried out to ensure that it meets the required standards for drinking water. This includes testing for parameters such as pH, turbidity, total dissolved solids, and bacterial counts. (Pfaender *et al.*, 2002).

Repair and maintenance of equipment: Borehole equipment such as pumps, generators, and pipes should be regularly inspected and maintained to ensure they are in good working condition. Any damaged or worn-out parts should be repaired or replaced immediately (Sterrett, 2007).

Protection of the borehole site: The borehole site should be protected from contamination by covering it with a protective casing or fencing, and by ensuring that no waste or chemicals are disposed of near the site (Lee *et al.*, 2017).

Community involvement: Community involvement is crucial in maintaining borehole water quality. Communities should be educated on the importance of proper maintenance and the risks of contamination. They should also be involved in the monitoring and testing of the water quality. (Louis *et al.*, 2014)

Use of appropriate materials: Use of appropriate materials such as stainless steel or PVC pipes and concrete or steel casing can help to prevent contamination and ensure the longevity of the borehole.

Use of borehole protection programs: Borehole protection programs can be used to prevent contamination and ensure the longevity of the borehole. These programs typically include regular cleaning and disinfection, testing and monitoring, and community education (AWWA, 2019).

Installation of safety measures: Safety measures such as fencing, locking, and alarm systems can be installed to prevent unauthorized access and contamination of the borehole (CDC, 2020).

Training and capacity building: Training and capacity building for community members, local government officials, and maintenance personnel can help to ensure that the borehole is properly maintained and that any issues are addressed promptly (UNICEF, 2019).

2.3. Study area

The study was carried out in Akwa Ibom state, Nigeria. Akwa Ibom State is located in the coastal-southern part of Nigeria, lying between latitudes 4^{o} 32^{o}E and 5 ^{o}33^{o}N and longitudes 7^{o}33^{o}N and 7^{o}25^{o}E and 8 ^{o}25^{o}E. The state is bordered on the east by Cross River State, on the west by Rivers State and Abia State and on the south by the Atlantic Ocean. It has a population of over 5 million people. It consists of three senatorial districts: Akwa Ibom North-West, Akwa Ibom North-East and Akwa Ibom South senatorial districts. These are popularly and unofficially referred to as Uyo, Ikot Ekpene and Eket senatorial districts. Water supply in the urban and semi-urban areas of Akwa Ibom state is managed by the Akwa Ibom Water Company Limited. While the Akwa Ibom State Rural Water Supply and Sanitation Agency is tasked with the development of water supply projects across rural communities of the state. Failure of these establishments to meet the population’s need for clean portable water has resulted in the development of several private water supply facilities within rural and urban communities in the state.

3. METHODOLOGY

This study employed a mixed-method research approach, integrating both quantitative and qualitative methods. Data were collected through structured questionnaires and laboratory analysis of borehole water samples. The study area covered three senatorial districts of Akwa Ibom State: Uyo, Ikot Ekpene, and Eket. Through a purposive sampling technique, 15 villages were selected based on their level of development, across 3 Local Government Areas per senatorial district. The purposive sampling technique was adopted due to the absence of data on the number boreholes available in the area of study. Therefore, difficulty in establishing the population of the study.

A total of 150 questionnaires were randomly distributed to household heads in these villages, who relied on boreholes as their primary water source. Primary data were gathered using self-administered questionnaires, with questions focusing on borehole maintenance practises, water quality awareness, and pollutants. Additionally, 26 water samples were collected from randomly selected boreholes across the 15 villages. Twelve samples were gotten from Uyo, seven samples from Ikot Ekpene and 7 samples from Eket. Samples were analysed for physicochemical and microbial parameters at the Akwa Ibom Ministry of Science and Technology laboratory. Physicochemical and microbial properties included water pH, conductivity, heavy metals, and coliform counts.

Descriptive statistics were used to analyse survey responses. Laboratory results were compared to World Health Organization (WHO) standards to evaluate water quality.

4. PRESENTATIONAND DISCUSSION OF RESULTS

4.1. Physical, biological and chemical qualities of borehole water in residential buildings

To assess the physical, biological and chemical qualities of borehole water in residential buildings, a comprehensive laboratory test result presented in the following tables revealed these qualities accordingly. Various constituents of water were analysed. These included nitrate, sulphate, phosphate, calcium and heavy metal contents; conductivity, salinity and odor. Results of tests conducted are as presented in Tables 1, 2, 3, 4, 5, 6 and 7 below for Uyo (samples 1 – 4), Uyo (samples 5 – 8), Uyo (samples 9 – 12), Ikot Ekpene (samples 1 – 4), Ikot Ekpene (samples 5 – 7), Eket (samples 1 – 4) and Eket (samples 5 – 7) senatorial districts, respectively. It was observed that these constituents generally fell within the recommended limits set by the World Health Organization (WHO).

Table 1, 2 and 3 show that the laboratory result gotten from borehole water samples at different sites in Uyo senatorial district. It was observed that test results generally fell within the recommended limits set by the World Health Organization (WHO). This is in exception of results on pH, zinc, cadmium, nickel, total PC, total CC and yeast mould.

Table 1: Results of laboratory analysis for water samples 1 to 4 from Uyo Senatorial Districts

PROPERTIES	W.H.O LIMIT	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4
P^H	6.5 -8.5	4.66	4.78	4.69	5.41
Temperature °c	27 – 29	27.3	28	28.2	27.5
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Odor	Inoffensive	Inoffensive	Inoffensive	Inoffensive	Inoffensive
Colour (Hu)	Clear	Clear	Clear	Clear	Clear
Turbidity (NTU)	10.00	4.51	4.4	5	4.51
E. Conductivity (µs/cm)	1000	136.2	106.9	97.3	11.8
Salinity (as cl mg/l)	250	17.45	31.95	27.03	35.45
Total Dissolved Solid (mg/l)	500	68.5	52.6	46.2	5.3
Dissolved Oxygen (mg/l)	5.0	3.4	4.5	4	3.9
Total Suspended Solid (mg/l)	<10	0.004	0.008	0.006	0.01
Total Hardness (mg/l)	500	110	80	120	30
BOD (mg/l)	200	3.9	3.1	2.7	3
COD (mg/l)	200	7.85	6.2	5.4	6
Nitrate (mg/l)	200	2.368	2.521	2.434	2.812
Sulphate (mg/l)	500	0.0016	0.028	0.022	0.019
Phosphate (mg/l)	350	4.012	5.783	5.027	4.984
Calcium (mg/l)	750	44	32	48	12
Potassium (mg/l)	150	9.12	11.23	12.48	5.07
Magnesium (mg/l)	50 -150	26.73	19.44	29.16	7.29
Copper (mg/l)	1.0	0.316	0.719	0.587	0.813
Iron (mg/l)	0.30	0.072	0.142	0.113	0.128
Zinc (mg/l)	3.00	4.324	6.134	5.984	5.139
Manganese (mg/l)	N/A	0.324	0.518	0.481	0.472
Arsenic (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.5	0.051	0.104	0.093	0.076
Cadmium (mg/l)	0.003	0.004	0.013	0.024	0.021
Nickel (mg/l)	0.05	0.058	0.094	0.003	0.072
Lead (mg/l)	0.5	0.002	0.084	0.089	0.082
TPC (cfu 1/100 mi)	0	5	8	6	8
TCC (cfu 1/100 mi)	0	4	7	5	4
E. Coli (cfu 1/100 mi)	0	0	1	2	0
Yeast Mould (cfu 1/100 mi)	0	0	1	1	1

Table 2: Results of laboratory analysis for water samples 5 to 8 from Uyo Senatorial District

PROPERTIES	W.H.O LIMIT	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8
P^H	6.5 -8.5	4.38	5.47	6.12	6.03
Temperature °c	27 – 29	28.1	27.2	28.0	28.3
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Odor	Inoffensive	Inoffensive	Inoffensive	Inoffensive	Inoffensive
Colour (Hu)	Clear	Clear	Clear	Clear	Clear
Turbidity (NTU)	10	4..13	3.57	5.07	3.35
E. Conductivity (µs/cm)	1000	179.5	98.4	113	138
Salinity (as cl mg/l)	250	31.95	28.85	35.15	17.35
Total Dissolved Solid (mg/l)	500	89.78	49.2	56.1	68.3
Dissolved Oxygen (mg/l)	5.0	4.1	3.0	4.1	3.5
Total Suspended Solid (mg/l)	<10	0.009	0.010	0.003	0.009
Total Hardness (mg/l)	500	150	110	80	70
BOD (mg/l)	200	2.8	3.2	2.8	1.9
COD (mg/l)	200	5.6	6.4	5.6	3.8
Nitrate (mg/l)	200	2.741	3.118	2.407	2.008
Sulphate (mg/l)	500	0.027	0.017	0.024	0.030
Phosphate (mg/l)	350	5.113	3.184	5.113	4.780
Calcium (mg/l)	75.0	60	44	32	28
Potassium (mg/l)	150	17.31	13.37	9.72	8.51
Magnesium (mg/l)	50 -150	36.8	26.73	19.44	17.01
Copper (mg/l)	1.00	0.819	0.519	0.342	0.584
Iron (mg/l)	0.30	0.121	0.077	0.108	0.139
Zinc (mg/l)	3.00	6.028	4.018	3.421	3.193
Manganese (mg/l)	NA	0.507	0.230	0.417	0.283
Arsenic (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.5	0.072	0.201	0.143	0.093
Cadmium (mg/l)	0.003	0.029	0.009	0.007	0.018
Nickel (mg/l)	0.05	0.078	0.074	0.053	0.049
Lead (mg/l)	0.5	0.072	0.023	0.019	0.072
TPC (cfu 1/100 mi)	0	5	5	6	8
TCC (cfu 1/100 mi)	0	7	3	5	7
E. Coli (cfu 1/100 mi)	0	1	1	1	2
Yeast Mould (cfu 1/100 mi)	0	1	0	0	1

Table 3: Results of laboratory analysis for water samples 9 to 12 from Uyo Senatorial District

PROPERTIES	W.H.O LIMIT	SAMPLE 9	SAMPLE 10	SAMPLE 11	SAMPLE 12
P^H	6.5 -8.5	4.91	5.32	5.97	6.48
Temperature °c	27 – 29	27.1	27.5	28.0	28.3
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Odor	Inoffensive	Inoffensive	Inoffensive	Inoffensive	Inoffensive
Colour (Hu)	Clear	Clear	Clear	Clear	Clear
Turbidity (NTU)	10	4.12	4.80	3.62	4.38
E. Conductivity (µs/cm)	1000	51.8	84.3	107	140
Salinity (as cl mg/l)	250	43.12	35.15	23.10	35.15
Total Dissolved Solid (mg/l)	500	26.5	42.1	53.0	78.4
Dissolved Oxygen (mg/l)	5.0	3.2	3.0	3.2	4.5
Total Suspended Solid (mg/l)	<10	0.015	0.007	0.005	0.003
Total Hardness (mg/l)	500	130	100	90	120
BOD (mg/l)	200	3.0	2.1	2.5	2.3
COD (mg/l)	200	6.0	4.2	5.0	4.6
Nitrate (mg/l)	200	3.241	2.931	2.119	2.714
Sulphate (mg/l)	500	0.028	0.019	0.026	0.021
Phosphate (mg/l)	350	4.139	4.008	5.010	5.382
Calcium (mg/l)	75.0	52	40	36	48
Potassium (mg/l)	150	15.80	12.15	10.94	14.58
Magnesium (mg/l)	50 -150	31.59	24.30	21.87	29.16
Copper (mg/l)	1.00	0.713	0.287	0.336	0.243
Iron (mg/l)	0.30	0.241	0.205	0.193	0.193
Zinc (mg/l)	3.00	5.107	4.204	4.604	4.570
Manganese (mg/l)	NA	0.314	0.319	0.349	0.406
Arsenic (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.5	0.184	0.131	0.146	0.163
Cadmium (mg/l)	0.003	0.013	0.024	0.010	0.004
Nickel (mg/l)	0.05	0.063	0.050	0.059	0.051
Lead (mg/l)	0.5	0.043	0.038	0.033	0.013
TPC (cfu 1/100 mi)	0	5	6	7	4
TCC (cfu 1/100 mi)	0	3	4	6	2
E. Coli (cfu 1/100 mi)	0	0	2	2	0
Yeast Mould (cfu 1/100 mi)	0	1	0	1	0

Tables 4 and 5 shows results of tests on borehole water samples gotten Ikot Ekpene senatorial district. From the results, it was observed that sample properties generally fell within the recommended limits set by the World Health Organization (WHO) for the physical and chemical properties of water while biological aspect such as the Total Plate

Count exhibited values ranging from 2 to 12. The Total Coliform Count ranged from 1 to 5, E. Coli ranged from 1 to 2, and Yeast Mould had values of up to 1. These values deviated from the WHO recommendations, which recommend a value of 0 for Yeast Mould and lower values for Total Plate Count, Total Coliform Count, and E. Coli.

Table 4: Laboratory analysis of ground water samples 1 to 4 from Ikot Ekpene Senatorial District

PROPERTIES	W.H.O LIMIT	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4
P^H	6.5 -8.5	6.98	6.34	6.57	6.84
Temperature °c	27 – 29	28.0	28.0	28.3	27.1
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Odor	Inoffensive	Inoffensive	Inoffensive	Inoffensive	Inoffensive
Colour (Hu)	Clear	Clear	Clear	Clear	Clear
Turbidity (NTU)	10	3.51	4.12	4.07	3.98
E. Conductivity (µs/cm)	1000	214.0	183.0	161	234
Salinity (as cl mg/l)	250	30.18	24.38	17.35	45.32
Total Dissolved Solid (mg/l)	500	107	91.5	80.5	117
Dissolved Oxygen (mg/l)	5.0	2.8	3.1	3.0	3.3
Total Suspended Solid (mg/l)	<10	0.007	0.011	0.008	0.007
Total Hardness (mg/l)	500	170	130	90	110
BOD (mg/l)	200	2.3	3.1	1.9	3.3
COD (mg/l)	200	4.6	6.0	3.8	6.6
Nitrate (mg/l)	200	2.517	4.011	3.208	2.519
Sulphate (mg/l)	500	0.031	0.048	0.027	0.021
Phosphate (mg/l)	350	5.181	5.014	4.312	3.886
Calcium (mg/l)	75.0	68	52	36	44
Potassium (mg/l)	150	10.66	15.81	9.94	7.12
Magnesium (mg/l)	50 -150	41.31	31.59	21.87	26.73
Copper (mg/l)	1.00	0.631	0.418	0.427	0.514
Iron (mg/l)	0.30	0.135	0.139	0.284	0.211
Zinc (mg/l)	3.00	3.918	4.124	5.197	4.307
Manganese (mg/l)	NA	0.431	0.318	0.295	0.337
Arsenic (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.5	0.184	0.093	0.078	0.130
Cadmium (mg/l)	0.003	0.008	0.005	0.017	0.011
Nickel (mg/l)	0.05	0.068	0.098	0.113	0.063
Lead (mg/l)	0.5	0.137	0.093	0.043	0.072
TPC (cfu 1/100 mi)	0	7	12	6	8
TCC (cfu 1/100 mi)	0	3	5	2	4
E. Coli (cfu 1/100 mi)	0	1	0	1	2
Yeast Mould (cfu 1/100 mi)	0	0	1	1	1

Table 5: Laboratory analysis of ground water samples 5 to 7 from Ikot Ekpene Senatorial District

PROPERTIES	W.H.O LIMIT	SAMPLE 5	SAMPLE 6	SAMPLE 7
P^H	6.5 -8.5	6.39	6.91	7.12
Temperature °c	27 – 29	28.1	28.3	28.3
Taste	Tasteless	Tasteless	Tasteless	Tasteless
Odor	Inoffensive	Inoffensive	Inoffensive	Inoffensive
Colour (Hu)	Clear	Clear	Clear	Clear
Turbidity (NTU)	10	3.64	5.18	4.20
E. Conductivity (µs/cm)	1000	98.4	107	158
Salinity (as cl mg/l)	250	31.84	24.38	35.85
Total Dissolved Solid (mg/l)	500	49.2	53.5	79.1
Dissolved Oxygen (mg/l)	5.0	3.7	4.1	3.2
Total Suspended Solid (mg/l)	<10	0.014	0.006	0.003
Total Hardness (mg/l)	500	160	110	120
BOD (mg/l)	200	3.7	2.9	2.1
COD (mg/l)	200	7.4	5.8	4.2
Nitrate (mg/l)	200	2.739	3.121	1.351
Sulphate (mg/l)	500	0.034	0.024	0.015
Phosphate (mg/l)	350	3.218	4.513	4.114
Calcium (mg/l)	75.0	64	44	48
Potassium (mg/l)	150	11.34	7.12	8.17
Magnesium (mg/l)	50 -150	38.86	26.73	29.16
Copper (mg/l)	1.00	0.398	0.473	0.520
Iron (mg/l)	0.30	0.253	0.104	0.071
Zinc (mg/l)	3.00	3.105	5.317	4.111
Manganese (mg/l)	NA	0.481	0.417	0.314
Arsenic (mg/l)	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.5	0.201	0.147	0.314
Cadmium (mg/l)	0.003	0.020	0.009	0.004
Nickel (mg/l)	0.05	0.051	0.121	0.041
Lead (mg/l)	0.5	0.217	0.081	0.051
TPC (cfu 1/100 mi)	0	5	6	2
TCC (cfu 1/100 mi)	0	2	3	1
E. Coli (cfu 1/100 mi)	0	0	1	1
Yeast Mould (cfu 1/100 mi)	0	0	1	0

The laboratory results gotten from borehole water samples in Eket senatorial district are as shown in Tables 6 and 7. It was observed that these constituents generally fell within the recommended limits set by the World Health Organization (WHO) for the physical and chemical properties of water. Total Plate Count exhibited values ranging from 2 to 10, the Total Coliform Count ranged from 1 to 5, E. Coli ranged from 1 to 2, and Yeast Mould had values of up to 1. These values deviated from the World Health Organization (WHO) recommendations, which recommend a value of 0 for Yeast Mould and lower values for Total Plate Count, Total Coliform Count, and E. Coli.

Table 6: Laboratory analysis of ground water samples 1 to 4 from Eket Senatorial District

PROPERTIES	W.H.O LIMIT	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4
P^H	6.5 -8.5	6.34	5.76	6.91	7.10
Temperature °c	27 – 29	27.1	28.0	28.3	28.1
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Odor	Inoffensive	Inoffensive	Inoffensive	Inoffensive	Inoffensive
Colour (Hu)	Clear	Clear	Clear	Clear	Clear
Turbidity (NTU)	10	4.12	4.89	3.91	5.07
E. Conductivity (μs/cm)	1000	78.1	94.8	113	52.3
Salinity (as cl mg/l)	250	35.01	17.59	23.81	45.73
Total Dissolved Solid (mg/l)	500	37.3	47.4	57.1	26.5
Dissolved Oxygen (mg/l)	5.0	4.3	4.0	3.3	3.1
Total Suspended Solid (mg/l)	<10	0.008	0.007	0.005	0.012
Total Hardness (mg/l)	500	90	70	120	100
BOD (mg/l)	200	1.8	2.5	3.2	3.5
COD (mg/l)	200	3.6	5.0	6.4	7.0
Nitrate (mg/l)	200	4.117	3.019	3.431	2.918
Sulphate (mg/l)	500	0.029	0.013	0.038	0.021
Phosphate (mg/l)	350	3.913	5.013	4.114	4.818
Calcium (mg/l)	75.0	36	28	48	40
Potassium (mg/l)	150	9.34	7.05	10.13	9.53
Magnesium (mg/l)	50 -150	21.89	17.01	29.16	24.3
Copper (mg/l)	1.00	0.918	0.704	0.431	0.127
Iron (mg/l)	0.30	0.280	0.143	0.092	0.112
Zinc (mg/l)	3.00	5.841	4.190	4.803	4.179
Manganese (mg/l)	NA	0.217	0.104	0.098	0.914
Arsenic (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.5	0.512	0.341	0.189	0.114
Cadmium (mg/l)	0.003	0.005	0.007	0.009	0.012
Nickel (mg/l)	0.05	0.011	0.007	0.009	0.019
Lead (mg/l)	0.5	0.038	0.049	0.113	0.093
TPC (cfu 1/100 mi)	0	8	6	10	8
TCC (cfu 1/100 mi)	0	4	3	5	4
E. Coli (cfu 1/100 mi)	0	1	1	2	1
Yeast Mould (cfu 1/100 mi)	0	1	0	1	0

Table 7: Laboratory analysis of ground water samples 5 to 7 from Eket Senatorial District

PROPERTIES	**W.H.O LIMIT**	**SAMPLE 5**	**SAMPLE 6**	**SAMPLE 7**
P^H	6.5 -8.5	5.93	6.43	7.38
Temperature °c	27 – 29	29.3	28.4	28.3
Taste	Tasteless	Tasteless	Tasteless	Tasteless
Odour	Inoffensive	Inoffensive	Inoffensive	Inoffensive
Colour (Hu)	Clear	Clear	Clear	Clear
Turbidity (NTU)	10	4.15	4.35	3.84
E. Conductivity (µs/cm)	1000	2.0	99.4	103
Salinity (as cl mg/l)	250	32.11	42.09	19.84
Total Dissolved Solid (mg/l)	500	105	49.9	52.4
Dissolved Oxygen (mg/l)	5.0	3.8	3.0	4.5
Total Suspended Solid (mg/l)	<10	0.010	0.009	0.007
Total Hardness (mg/l)	500	50	110	130
BOD (mg/l)	200	2.1	2.4	3.0
COD (mg/l)	200	4.2	4.8	6.1
Nitrate (mg/l)	200	2.011	3.105	2.148
Sulphate (mg/l)	500	0.018	0.011	0.021
Phosphate (mg/l)	350	3.841	3.137	4.001
Calcium (mg/l)	75.0	20	44	52
Potassium (mg/l)	150	6.10	9.71	11.52
Magnesium (mg/l)	50 -150	12.15	26.73	31.59
Copper (mg/l)	1.00	0.309	0.383	0.291
Iron (mg/l)	0.30	0.108	0.178	0.135
Zinc (mg/l)	3.00	3.981	5.113	5.104
Manganese (mg/l)	NA	0.284	0.175	0.131
Arsenic (mg/l)	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.5	0.215	0.134	0.101
Cadmium (mg/l)	0.003	0.017	0.008	0.004
Nickel (mg/l)	0.05	0.006	0.021	0.004
Lead (mg/l)	0.5	0.058	0.039	0.019
TPC (cfu 1/100 mi)	0	4	7	2
TCC (cfu 1/100 mi)	0	2	3	1
E. Coli (cfu 1/100 mi)	0	1	1	0
Yeast Mould (cfu 1/100 mi)	0	0	1	0

4.2 Borehole maintenance practises implemented in the area of study.

Information on borehole maintenance practises were extracted from questionnaire retrieved from respondents. Of 150 questionnaires distributed, 142 were retrieved and found acceptable after sorting. Findings revealed a preference for submersible pumps 129 (90.8%) over hand pumps13 (9.8%), and mild steel casing materials 30 (21.1%) over other options. Plastic tanks 102 (71.8%) and non-black tank colours were favoured for water storage. Table 8 shows respondents' perception on the borehole maintenance practises, implemented in the study area. It presents the frequency score of the maintenance practises implemented on boreholes in selected residential buildings within the area of study.

Table 8: Level of maintenance of the boreholes in Akwa Ibom State

Variables	Range	Frequency	Percent	Cumulative percent
What is the age of the borehole well? (years)	0-5	6	4.2	4.2
	6-10	16	11.3	15.5
	11-15	37	26.1	41.6
	16-20	36	25.4	67.0
	21-25	22	15.5	82.5
	26-30	25	17.5	100.0
	Total	142	100.0	
How often has any form of maintenance been carried out on the borehole? (years)	0-2	15	10.6	10.6
	2-4	61	43.0	53.6
	5-7	43	30.3	83.9
	More than 7	23	16.1	100.0
	Total	142	100.0	
Maintenance that has been carried out on the borehole.	Dissolved oxygen (DO)	24	16.9	16.9
	pH level	24	16.9	33.8
	Conductivity	23	16.2	50.0
	nitrate (NO_3)	24	16.9	66.9
	Turbidity	23	16.2	83.1
	Hardness	24	16.9	100.0
	Total	142	100.0	
Has the water gotten from this well ever been tested to ensure its quality?	Yes	83	58.5	58.5
	No	26	18.3	76.8
	Not Sure	33	23.2	100
	Total	142	100.0	

Table 8 reveals that the age of borehole well available in each of these senatorial districts as indicated by the respondents were as follows; borehole well between ages 0 - 5 years was 6 (4.2%), age between 6 – 10 years has 16 (11.3%), also, 37 boreholes well have age range between 11 – 15 years (26.1%) while 36 boreholes was between age 16 – 20 years (25.4%). Similarly, 22 number of boreholes was between age 21 - 25 years (15.5%) and 25 number of boreholes was between age 26 - 30 years with percentage of 17.5%. From this analysis, it can be deduced that majority of boreholes across these senatorial districts were within 20 years of age.

In other to understand the form of maintenance carried out on borehole within the three senatorial districts, the result indicates that 15 boreholes undergo maintenance within 0 - 2 times a year (10.6%). 61 boreholes undergo maintenance within 2 - 4 times a year (43.0%). 43 boreholes underwent maintenance within 5 – 7 times a year (30.3%). 23 boreholes undergo maintenance more than 7 times a year (16.1%). It can be deduced that majority of boreholes were usually maintained within every 2-4 times a year.

The result revealed the level of maintenance that has been carried out on the borehole by the respondents. Its shows that Dissolved Oxygen (DO) check has been applied on 24 boreholes which has a percentage of 16.9%. pH level check was conducted on 24 boreholes with percentage of 16.9%, Conductivity has 23 (16.2%), Nitrate (NO_3) has 24 (16.9%), and

Turbidity has 23 (16.2%) while Hardness test has 24 (16.9%). and this result is in line with (Nkono *et al.*, 2018)

4.0 DISCUSSION OF FINDINGS

4.1 The laboratory of borehole quality water gotten from the Three senatorial districts

The findings of this study drew to light the quality of water samples collected, with a focus on various parameters crucial for assessing water safety. However, it's worth noting that most of these values fell within the World Health Organization (WHO) recommended ranges. In a similar study, Ebong *et al*. (2018) observed that the pH of boreholes water sampled from different points in River's State was within the range of 4.38 to 5.41. These values were below the WHO recommended values, like some test results obtained from Uyo senatorial district. In terms of Total Dissolved Solids (TDS), the values ranged from 5.3 to 89.78 mg/l, all below the WHO's limit of 500 mg/l. Lower TDS levels contribute to clearer water, which can enhance photosynthetic activities and maintain water temperature. The findings of this study were in consonant with those of Bitrus and Ibratim (2017). The concentration of magnesium in the samples were below the lower bound of the WHO limit. Where elevated magnesium levels in water may lead to minor health issues like diarrhoea, levels below minimum pose no severe health risks. The principal cations imparting hardness were calcium and magnesium, as also observed by Lina *et al*. (2009).

Of outmost concern is the observed presence of the parasites, yeast mould and E. Coli in many of the borehole water samples. Such observations render such water samples unsafe for human consumption.

4.2 Implemented maintenance practises on boreholes in selected residential buildings in Akwa Ibom State.

On the level of maintenance carried out on borehole water within the three senatorial districts, it was observed that the age of borehole well available in each of these senatorial districts as indicated by the respondents were within 20 years of age. It is of great concern that a total of 41.5% of water gotten from residential building boreholes in Akwa Ibom State have either not been ever tested or cannot be certified as haven been ever tested for their quality. Musa *et al*. (2023) opined that measures should be taken regularly, to ensure proper treatment of water, to safeguard the health of the population.

5. CONCLUSION AND RECOMMENDATIONS

The study emphasised on the critical importance of regular maintenance in ensuring the quality of groundwater from boreholes in residential buildings. The study concludes that while some physicochemical parameters of borehole water fall within World Health Organization (WHO) standards, microbial contaminants like total coliforms and E. coli exceeded permissible limits, posing health risks to the population. Poor maintenance practices, improper siting of boreholes, and lack of regulatory oversight are possible contributors to water quality issues. Addressing these challenges is essential to ensuring safe and sustainable water supply for residents. Results of the study underscore the need for consistent and effective maintenance practices to safeguard the health and well-being of residents.

Consequent upon the findings of this study, it is recommended that improved maintenance protocols, regular water quality testing, and enhanced borehole design and construction would contribute to the protection of groundwater resources and the health of building occupants and also adhering to construction guidelines to mitigate contamination risks, particularly regarding distances from refuse dumps and surface runoff infiltration should be strengthened. Enforce borehole construction standards and regulate siting near contamination sources, promote regular water quality testing to ensure compliance with

World Health Organization (WHO) standards. Educate communities on borehole maintenance and hygiene practices and government should established monitoring systems and incentives for proper maintenance.

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