WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Water Quality Assessment (Physicochemical and Bacteriological Analyses). A Case Study of Some Certain Streams and Boreholes in Itigidi Community Abi Local Government Area, Cross River State, Nigeria

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ABSTRACT

Water quality has been linked to health outcomes across the world. This study evaluate the bacteriological and physico-chemical parameters of certain surface water and boreholes in Itigidi Community Abi Local Government Area of Cross River State, Nigeria for drinking, domestic and other industrial uses. Two (2) central surface water and three (3) boreholes were chosen for data collection. The study results showed that the water samples were relatively normal to alkalinity.(6.9 = P^H = 7.4), soft (hardness 20 - 23 mg/l as $CaCO_3$), fresh (conductivity < 140us/cm) and characterized by low Sodium Adsorption Ratio (SAR) of average of 8.4. In addition, the mean values of the major cations Ca^{2+}, Mg^{2+}, Na^+ and anions SO_4^{2-}, Cl^-, NO_3^- were all within the World Health Organization standard for drinking water. The total bacteria counts ranging from (2/ml - 11 /ml) colony forming units (CFU)/ml. Faecal coliform count ranged from (1/ml to 11/m coliform count/ml, all within the WHO standard for domestic uses. Bacteria isolates include *Escherichia Coli*, *Proteus Vulgaris*, *Pseudomonas Spp*, *Glugella Dysentrae*, *Klebsiella Pneumoniae*, *Vibro Cholera* etc were also analyzed with very low coliform count units.

INTRODUCTION

Water is among the major essential natural resources for the sustenance of life, agriculture and industry. Social and economic progress are based and sustained upon this pre-eminent resource. Availability and easy access to safe and quality water is a fundamental human needs. The demand for water for human consumption, industrial and domestic needs has grown astronomically over the years and the supply by water board is grossly inadequate. Some people have therefore sort of other alternatives of water supply, this sorting to construction of boreholes and the excessive use of surface water (streams). Since these streams and boreholes are for human consumption, there is need for this water to be assessed for quality and to know how extend a particular stream or borehole is good for human, industrial and domestic uses. Though, the boreholes are significantly protected from surface pollutants as the earth media is composed of different surface down to interior layers as a natural filters. Supplies of drinking water should be as pleasant to drinking as circumstances permit, coolness, absence of turbidity and absence of colour and of any disagreeable taste or smell are of the utmost importance in public supplies of drinking water. The construction situation operation and it's distribution system must be such as exclude any possible pollution of the water (WHO, 1987). Water provide energy in form of hydroelectricity and certain countries like Nigeria are nearly 100% dependent on hydro-power for their electricity production. Even for thermal and nuclear power station, substantial amount of cooling water is necessary to dissipate heat. Industry cannot function without water and water is invariably the focal point for many types of reactions and recreations (Lohair & Thanh, 1978).

The study of environmental water pollution in particular has therefore been of considerable importance not only to water analytical chemists but also to engineers, hydrologist, toxicologist and pathologist since most of these determinants pose danger threats to man's life including other living organisms. This, it is very essential to analyze any water pose to human consumption, either to increase the need or reduce to the required dose to avoid endangering the consumer's health, and thus, rendering the water aesthetically suitable. Unlike oil and most other strategic resources, fresh water has no substitute in most of its uses. It is essential for growing food crops, manufacturing goods and safeguarding human health. Therefore, the development of boreholes or surface water (stream) constitute a viable supplement to the earth concrete dam fresh water suitable for human, industrial, agricultural and domestic purposes.

PURPOSE OF THE STUDY

The purpose of this study is to:

1. formulate/revision of water quality standards

2. get informations about the status and water quality trends of the surface and boreholes in the study area in terms of concentration and effect

3. offer appropriate recommendation in terms of the compliance of the prescribed standards

4. have an idea about the suitability of water for the various purposes

5. find out the impact of waste discharged into surface water in the study area

6. have idea about the non point source of pollution in the area

7. get idea about the assimilation capacity of surface water in the study area.

MATERIALS AND METHODS

Descriptive research method was used for this study. The data obtained were based on samples collected from two (2) central surface water from different locations and three (3) boreholes also from different locations as shown in Table 1. for the purpose of this write up, and for easy characterization. The sampling points are given designations BH1-BH3 and ST1-ST2 meaning BH for boreholes and ST for surface water (streams) respectively, presented in table 1. The monitoring was conducted during the rainy season. For all the samples, some physical and chemical parameters were determined at the field using standard field equipment (multiple probe)

Sample collection

Boreholes and surface water were collected in sterile bottles, properly corked to avoid income air into the bottles containing the samples and transported in ice pack to the laboratory within 12 hours from the time of collection. Sampling sites were carefully chosen within Itigidi community in Abi LGA, Cross River State. Nigeria. A total of five (5) samples were analyzed.

Sterilization

Sterilization was done in autoclave. The autoclave is an eletro-thermal device which sterilizes using steam under pressure. The temperature of sterilization is 121°C for 15 mins. Some glass wares were sterile in the oven at 110°C for one 1hour.

Table 1: sample locations including source and designation

S/N.	Community	Location	Source	sample code
1.	Itigidi	Ekokol-Agba.	Surface water	ST1
2.	Itigidi.	Dimdim Eminebol	Surface water	ST2
3.	Itigidi	PHC Levachiel	Borehole.	BH1
4.	Itigidi	Gvt. Pri Sch. Eminebol.	Borehole	BH2
5.	Itigidi.	Eja Tita.	Borehole.	BH3

The Study Area

The study area is Itigidi Community in Abi LGA of Cross River State. Geographically, the Local Government Area is situated between latitude 50 30 and 600 North and longitude 80 35 and 850 East. It occupies a land mass of 662.87Km. The area is in the eastern Nigeria Delta of Nigeria. Two seasons by fluctuation of precipitation predominate in the area namely, wet and dry seasons from April and October and the lowest between November and March. The atre is characterized by humid tropical climate (high temperature, humidity and precipitation). The Itigidi Community is located in the central part of the local government and bounded by the north with Ekureku, south with Bahomono, west with Itigevev/Adadama and the east with Afikpo in Ebonyi State.

Population of the Study Area

The study area Itigidi Community in Abi LGA was one of the oldest community in Abi LGA of Cross River State. The area has a unique characteristics of viable educational pedigree with sound and notable political value. The community is known for her hospitality and diverse social strata like the unique Edele Festival. The area is geographically located in the center of Abi LGA , lact. 5° 52' 58'N and long.8° 01' 17'E. It covers a land mass of 20, 156Km^2 and total population of about 3,737,577 (as extrapolated from 2006 census).

The sampling side

The maximum sampling side varies widely depending on the range of variables to be considered and the analytical methods to be employed. The volume required for individual analysis are summarized in Table 2. (WHO, 1998).

Table 2: sample volumes required for individual physico-chemical parameters

Analysis	**Sample volume (ml)**
Aluminum	30
BOD	1000
Calcium	50
Chloride	100
Iron	50
Magnesium	75
Potassium	100
Sodium	100

KEY:

BOD: Biological Oxygen Demand .

Sampling procedure

Sampling from boreholes

1. The tap outlet was thoroughly cleaned by wiping the outlet with a clean cloth to remove any dirt or attachment that could cause contamination of the water quality.

2. The tap was turned on to maximum and allowed to run for 1 minute and the turned off.

3. It was sterilized for two minutes with a flame from cigarette lighter.

4. The tap was the turned on and the water was allowed to flow at a medium rate for 2 minutes.

5. The bottles were immediately filled with the sample, taken care to prevent entry dust and air.

Sampling from Surface Water

1. The sampling cups were carefully sterilized.

2. The water sample was then filled into the bottles using the sterilized cup.

3. The samples after collection were packed in a cooler containing ice bags

4. The samples were the taken to the for analyses .

Precautions

I made sure that the sampling sites were at least 100m-200m away from each other.

I made sure that my hands were properly cleaned before taking the water samples.

I avoided touching and disturbing the bottom of the water body when taking the samples from the surface water.

I made sure that containers for the sample storage was properly cleaned, corked and labeled to avoid errors.

Bacteriological parameters of water

The microorganisms present in water are determined through series of microbial test such as gram stain test, motility test catalase test, oxidase test etc. This is to enable one identified and characterized the various microorganisms present in water sample. This process of identification and characterization are called **Bacteriological Analysis**

Media Used

For successful conclusion of this work, the following media were used.: Nutrient agar, Endo agar, Eosin methylene blue (EMB) agar, Salmonella shigella agar, Simon's citrate agar, Urea agar, Peptone water, Kligler agar, Iron agar, Mannitol agar and Macconkey agar. All for differential and selective purposes.

Inoculation

Method: The membrane filtration method was used in this work

Materials and Reagents

Water samples, sterilized 100m measuring cylinders, sterilized forceps, membrane filter papers (diameter 0.50um pore size to 0.45. 11um), pressure filtration apparatus comprising upper and lower components, vacuum pump and sterile prepared agar media and alcohol.

Procedure

The components of the filtration unit were sterilized accordingly. The autoclave particularly the upper and lower components of the funnel. A pair of forceps, four 100m measuring cylinders were sterilized along side. The vacuum pump was connected to the special conical flask with a rubber tube. The upper component of the unit was replaced and clamped to make tight. 100m of the sample water was measured in the sterilized measuring cylinder and poured in the vessel of the upper component of the unit. The vacuum pump was powered on to activate filtration by suction pressure through the membrane filter. The pair of forceps was mobbed with alcohol and used to lift the membrane filter from filtration unit on the sterile agar surface. The filter trapped all the microbes present in the water sample.

Incubation

Culture were incubated aerobically at 40°C for 24 hours

Bacteria Growth Enumeration

After 24 hours, plates were pulled out of the incubator and growth estimated to numerically counting the colonies and the number expressed as colony forming unit (CFU) per 100ml of water sample.

Isolation of total Coliform

Membrane filtration technique was used, the agar was dissolved according to specification and autoclave at 121℃ for 15 minutes. It was then dispensed aseptically and allowed to set, about 100ml of the sample was filtered through the membrane filter which had been placed on the filter bed. The filter was removed and placed on agar plate. It was incubated at 37° for 24 hours. The number of pink colonies were enumerated.

Isolation of *Escherichia Coli*

The ***Escherichia Coli*** were made on a separate volume water 100ml each. The water sample was filtered through sterilized membrane filters, the filters were the placed on an absorbent pad saturated with the Macconkey agar, the sterile plate containing the pad and filters were incubated at (44-45)°C for 24 hours, yellow colonies were isolated and counted as ***E Coli.***

Isolation of faecal *streptococci*

Filter with pore size of about 45um was removed aseptically from the membrane filtration apparatus and placed on a culture plate with the blood agar, the plates were labeled and incubated at 37°C for 24 hours. All red colonies were isolated and identified as in table 6.

Colonial Morphology

The colonial morphology include colours, shapes, margin height ie. whether raise or flat. Gram stain was carried out on all isolates.

Gram Stain

The procedure grouped bacteria into gram positive or gram negative. A smear for the isolated colony was made on a glide heat fixed using bursen flame. A few drops of crystal violet solution was added into the smear for one minute and washed off with water for two seconds, gram iodine was immediately applied the washed off with water. Finally, safranin, a counter stain was applied for 30 seconds and washed off with sterile water and dried, the stain smear was observed under the microscope using oil immersion objective. Organisms with violet or purple colour were termed gram positive while those with pink or red colour are gram negative.

Motility test

This tes is based on the fact that bacteria posses flagella and can move. On a clean glass slide, a square of ridge was made with petroleum jelly or Vaseline pomade, a drop of the broth of test organism was placed on clean cover slip. The slide was inverted to enable the jelly contact the edge of the cove slip. The slip get sucked to the jelly on the slide, this was inverted to let the drop of the broth hang on the under side of the cover slip on examination under microscope (x40 objective lens). Non motile will only shake or carried along by current on the medium.

Citrate test

Simon's citration slants were incubated with isolates by stretching the slants surface. Incubation was done at 40°C for 24 hours. Citrate positive slant changed from green colour to bright blue. However, slow citrate utilization were incubated further. 38g of Simon's agar was weighed into 1litre of distilled water. The mixture was boiled to dissolved. Media was sterilized in the autoclave at 121°C for 15mins. Titanium was dispensed into Mecartney bottle for slants.

Methyl Red/Voges Proskauer Test

This test involves the preparation of Peptone water, pipetted into test tube and autoclave at 121℃ for 15mins. It was later removed and allowed to cool for the inoculation of microorganisms. After that, the test tube was incubated for 5 days at 37°C. At the end of inoculation, the culture was divided into half, the first half for methyl red test and the second half for the Voges Proskauer test.

Methyl Red Test

0.5ml or 5 drops of 0.4% methyl red solution was added. A change in colour medium to red or pink indicating methyl red positive ie. acid has been produced by the organisms. If yellow or no colour changed indicates negative reaction.

Voges Proskauer Test

1ml of creative solution was added followed by a drop of sodium hydroxide (NaOH).

Catalase Test

The enzyme catalase is present in certain bacteria and thereby helps in their identification. A drop of hydrogen peroxide (H_2O_2) was placed on a smear of isolated organisms. Production of gas was a clear indication of a positive reaction.

Coagulase Test

Slide method was used. Two drops of plasma were placed on a clean grease free glass slide. A small portion of the test colony was emulsified in the plasma. Formation of coagulates (clumps) is a positive result.

Indole Test

Method: Kovac's method.

The following reagents were used in this test. P-dimethylamino benzaldehyde, iso-amyl alcohol, conc. HCl, Kovac's reagent, brown reagent bottle, Peptone broth.

5.0g of p-dimethylamino benzaldehyde was dissolved in 75ml of amyl alcohol, the 25ml of conc. HCl was added while stirring slowly. The reagent was stored in a brown bottle in the refrigerator. 2ml of 24 hours Peptone broth of test organism, 0.5ml or drops of Kovac's reagent was added and shake gently and observed. A red colouration which indicates a positive result.

Substrate Fermentation

Lactose: Media used was Macconkey agar plate. Test organisms were inoculated and plate incubated at 40°C for 24 hours. Positive lactose fermentation is shown as pink colonies.

Mannitol: Mannitol agar was inoculated with test organisms, incubated as in lactose above, positive mannitol fermenters emerge as yellow colonies.

Glucose: Slant of Kligler Iron agar (KIA) were inoculated with organisms and incubated at 40°C for 24 hours. Pink colour shows alkaline while yellow colour shows acid production from glucose fermentation. No colour changed indicates no glucose fermentation

Blackening at the point of the streak shows hydrogen sulphide (H_2S) production. Negative slants were further incubated to allow late fermentation and the subsequent production of hydrogen sulphide.

Urease Test

Christensen urea agar slants were incubated with test organisms by streaking on the surface of the slants. Incubation was done at 37°C for 24 hours. A change from light orange colour to magenta was positive urease while no colour changed indicates negative reaction.

Eosin Methylene Blue Agar Culture (EMB)

Suspected ***Escherichia Coli*** were streaked on EMB agar plates and then incubated for 24 hours at 44°C. Metallic greenish sheen colouration colonies are indicative of ***E. Coli.***

Oxidase Test

A freshly prepared tetramethyl-p-phenylenediaminedihydrochloride was poured into a clean filter paper, a colony of the isolated organisms was streaked into the filter paper. A positive result was shown by the appearance of deep colouration within 1-5 seconds .

Production of gas during substrate Fermentation

Gas fermentation during substrate Fermentation ion is shown as gas bubbles or air space within the agar slant in the tubes or Macconkey bottles.

Physico-chemical parameters of water samples

The physical and the chemical properties of water are termed physico-chemical properties of water. The physical attributes of the water are determined through means such as multiple probe for colour the colour, P^H and conductivity respectively. However, chemical analysis of water can be achieved in a number of ways, common among which are the following:

Gravimetric Analysis

This involved the weighing of solids obtained sample evaporation, filtration and precipitation using analytical balances that are accurate to 0.0001g. Example are total solids, total dissolved solids and sulphate of above 40ppm.

Volumetric Analysis

This employs titrating volume of samples with known strength of reagents and solutions using indicators reagents. The examples here alkaline, acidity, chloride, hardness and carbon IV oxide.

Colorimetric Analysis

In this method, the determinant is reacted with specific reagents to give coloured products, such colours are stable. The concentration of the determinant are usually very low. The operating principle is that when light passes through a solution a portion of it is absorbed. Beer's law states that the light absorbed increase exponentially with the concentration of the solution. Lambert's law states that light absorbed also increase exponentially with the length of the light path (Outreach Dept.,1997).

The combined laws are represented this

$OD = \log(lo)/l = abc$

Where OD. = Optical density

lo = Intensity of light leaving the solution

l = Intensity of light entering the solution

a = Absorptivity constant

b = Length of light path in solution

c = Concentration of absorbing substance.

Determination of Conductivity

Method: Probe method

Measurement: The electrodes or probe was thoroughly rinse with deionized water and then plugged into the water. The value was recorded in us/cm (micro siemen per centimeter).

Determination of Temperature

The temperature was determined by dipping the mercury in glass thermometer into the sample and the reading taken as the mercury thread rise to a steady point.

Determination of P^H

Method: Probe method

Calibration: The P^H was calibrated with buffer 6.9band 4.01. The probe was then dipped into the P^H buffer 6.9 solution and allowed to adjust to 6.9 after switching the equipment to the P^H scale. The same was repeated with P^H buffer 4.01. Stability was observed on both cases and the reading obtained.

Dissolved Oxygen (DO)

Equipment: Dissolved oxygen meter.

The equipment was placed in such a way that it was not exposed directly to heat radiation from the sun. The switch was turned to the normal percentage saturation position, and the display allowed to show a stable value. The display was then adjusted by turning the small screw on the upper right Conner until the display showed the (r_o). The meter was then ready for measuring both saturation as well as part per million (ppm)mg/l

Measurement: The probe was dipped into the water sample covering about 2/3 of it's length. The switch was again turned to the ppm(mg/l) position, the result was then recorded in mg/l at a stable value of the display.

Biological Oxygen Demand (BOD)

Method: Incubation

The equipment used was dissolved oxygen meter. The sample was brought close to 20°C, the dissolved oxygen sample in the bottle was determined by dissolved oxygen meter. The probe was dipped into the sample to cover the probe to about 2/3 of its length. The switch was turned to the ppm(mg/l) position. This display was allowed to show a stable value and the result was taken and recorded in mg/l. The sample was incubated for 5 days at 20°C and the dissolved oxygen content re-measured.

Calculation:

BOD = (a-b)mg/l

Where, a = Initial dissolved oxygen in the sample

b = Final dissolved oxygen in the sample

Determination of Potassium (K^+)mg/l

Method: Spectrophotometric technique

The reagents used were: Potassium (K-1) reagent pillow, (K-2) reagent pillow and (K-3) reagent pillow.

The K-1 and K-2 reagents pillow were added to the water sample in a 25ml graduated cylinder and swirled to mix. After sometime, when sediment may have occurred, the content of one of K-3 pillow was added to the mixture and agitated for 30 seconds. White precipitate indicating the presence of potassium was observed. A sample bottle was filled to the 25ml mark with the original sample and placed in one bottle holder of the spectrometer and the light shield closed and the values of potassium was read in mg/l.

Determination of Calcium (Ca^{2+})mg/l

Calcium dissolves out of almost rocks and is consequently detected in many waters. Water associated with granite or siliceous sand will contain not less than 10g of calcium per litre. Many waters from limestones areas may contain 30-100mg/l and those associated with gysiferous shade may contain several hundred milligrams per litre. Calcium contributes to the total hardness of water. On heating, calcium salts precipitate to cause boiler scale. Some calcium carbonate is desirable for domestic water because it provides a coating in the pipe which protect them against corrosion.

Method: EDTA titrimetric method.

Principle/ Theory: When EDTA is added to water containing calcium and magnesium ions, it react with the calcium before the magnesium. Calcium can be determined in the presence of magnesium by EDTA titration, the indication used is one that react with calcium only. Murexide indicator gives a colour change when all of the calcium has been complexes by EDTA at a P^H of 12 to 13 (Balance, 1990).

Materials: Porcelain dishes 100ml capacity, burette, pipette, stirring rods, graduated cylinder 50ml

Reagents: Sodium hydroxide (NaOH) 1mol., Murexide indicator. The indicator change from pink to purple at the end-point standard EDTA, titrant 0.01mol.

A colour comparison blank was prepared by placing 50ml of distilled water in a white porcelain dish, sample for filtration was also prepared by placing 50ml of sample in white porcelain dish, 2ml of NaOH solution was added to both the sample and the comparison blank and stirred.0.1 to 0.2mg of murexide indicator mixture (or 1-2 drops of indicator solution) was added to the blank and stirred, then 1 to 2 drops of EDTA, titrant from the burette was also added, the mixture was stirred until the colour turned from red to an orchid purple. The burette reading was recorded and the blank kept for colour reference comparison.

To the sample 0.1 to 0.2(mg) of the indicator was added, a red coloured solution was observed. The sample was then titrated with 0.1 EDTA slowly, constantly stirring until the colour changed from red to faint purple. EDTA was added drop wise until colour matched that of the comparison blank. The burette was then ready and the value of EDTA titrant used determined.

Calculation:

Conc. of $CaCO_3$ in mg/l. = AxBx100/ml of sample

Where, A = vol. of EDTA titrant used for titration or sample (cm^3) from burette.

B = 0.4008mg of Ca/ml of EDTA (Iso, 1990).

In each 100ml of sample, 2ml ammonia buffer solution and 5 drops of Erichrome blank indicator was added and mixed. The wine red solution was titrated with sequestric acid until the last reddish colour disappear from the solution and a blue colour at the end-point was obtained.

Toward the end, sequestric acid was added slowly drop wise. The results were recorded and expressed as $CaCO_3$ in a 100ml of the sample.

Determination of Basic Cation (Na^+ and Mg^{2+})

Method: Gravimetric/Photometric Technique

The analysis for sodium sometimes can be used as an indication of the purity of water for example in surface water condensation, the sodium concentration can be used to indicate water carrying over the boiler system into the surface water body. Sodium determination will indicates the completeness of cation exchange. The sodium concentration of a typical water sample can be estimated by subtracting the sum of cations (Mg^{2+}, K^+, Ca^{2+}) earlier determined from the sum of anions (Cl^-, and SO_4^{2-}) in milli equivalent (mgeq./l) obtained by dividing their concentration in mg/l their respective atomic weight. The corresponding difference of value obtained from the substraction was multiplied by the atomic weight of the sodium obtained. The original value Na^+ in mg/l as for magnesium, titan yellow has been used as reagent for the determination of magnesium.

Determination of Iron (Fe^{2+})

Method: Phenanthroline method

Materials: Colorimetric equipment, spectrophotometer, for use at 510nm, provide a light path of 1cm of longer wavelength. The reagent is 1,10-phenanthroline. Range: 0-3000mg/l (ppm)

A clean sample cell was filled to the 25ml mark, a ferrous iron reagent powder pillow was then added to the sample and swirled to mix. An orange colour was seen indicating the presence of ferrous ion which was allowed to settle for 3mins to fully settled.

To the second bottle, the original sample was filled and made to the 25 mark and placed in the bottle holder (blank sample). When the equipment raed zero, the blank sample bottle without the reagent was inserted into the cell holder. The shield was closed and the value of Fe^{2+} in mg/l read as the total ion from the screen

Determination of Chloride (Cl)mg/l

Method: Silver nitrate method

Materials: Silver nitrate standard solution, 0.1mol potassium chromate indicator, 10%

100ml of the sample was filtered into conical flask, 3 drops of 10% potassium chromate indicator solution was added and stirred. A resulting reddish colour was obtained. The resulting solution was then titrated with silver nitrate soluble with constant stirring until only the slightest perceptible reddish colouration persisted.

Calculation:

$$\text{Chloride as Cl} = \frac{1000(V_1-V_2)\text{mg/l}}{\text{Vol. of sample}}$$

Where, V_1 = volume of silver nitrate required by the sample

V_2 = volume of silver nitrate required by the blank.

RESULTS

Hdrochemical Studies

The results of the physico-chemical parameters are represented in table 3, and that of the bacteriological parameters in table 4 respectively. The bacteriological and the physico-chemical analyses are fully discussed below. The characteristics of the water samples appear to be uniform with some minor variations.

Physico-chemical parameters

The physico-chemical values (turbidity and conductivity) of the area ranges from 0.00 for sample obtained from boreholes at Eminebol, Agba and Levachiel (BH1, BH2 and BH3) to a higher value 21.33, 23. 61 and 29.12 with a mean study value of the area being 24.69

The electrical conductivity values varies from 31.00 us/cm at Ekokol and Eminebol Dimdim 23.10, (ST1 and ST2) with a mean value 27.05 us/cm. The value of the conductivity is sample ST1 was higher than those of other samples, this is due to the impurities and and metal ions present in the sample as compared to other samples. Also, the Sodium Adsorption Ratio (SAR) in each of the sample is calculated using the standard formula

$$\text{SAR} = \mathbf{Na^{+}/\sqrt{1/2\{(Ca2+) + (Mg2+)\}}}$$

Table 3: Physico-chemical Analysis Results of Surface water and Boreholes water samples .

S/N	Parameters	ST1	ST2	BH1	BH2	BH3	Range	Mean	WHO
1	Temperature °C	27	26	25	25	26	2	26	
2.	PH	6.9	6.8	7.2	7.3	7.2	0.5.	7.1	
3.	Turbidity	0.0	0.0	0.0	ND	ND.	ND	ND	
4.	Conductivity us/cm	120	110	118	105	100	20	111	
5.	Dissolved oxygen	4.2	3.8	2.5	1.8	1.5	2.3	2.76	
6.	Ca2+ mg/l	23	18	15	18	13	10	5	
7.	Mg2+ mg/l	7	10	6	12	10	6	9	
8	Alkalinity mg/l	7.2	7.4	7.5	7.3	7.4	0.3	7.4	
9.	Na+ mg/l	72	83	77	66	72	15	59.8	

10	Total hardness	23	20	21	20	23	2	21.4
11.	Colour	ND	ND	ND	ND	ND	ND	_
12.	Fluoride mg/l	ND	ND	ND	ND	_	_	_
13.	Chloride mg/l	3.1	1.6	2.4	ND	ND	1.4	2.4
14.	Nitrate mg/l	11	8	7	6	6	5	8
15.	Iron mg/l	0.02	ND	ND	0.03	0.01	0.02	0.02
16.	Potassium mg/l	0.2	0.1	0.1	0.1	0.2	0.1	0.1
17.	TDS mg/l	74	91	84	65	68	26	76
18.	SAR.	9.2	11	9	6	7	5	8.5

The SAR values are calculated using the formula stated above. Also, the Ca/Na ratio, Na/K ratio, Na/Cl ratio and sodium values are calculated using the formula below.

Sodium value=$Na^+/Na^+ + Ca^{2+}, Mg^{2+}, K^+$

The dash columnin BH3 corresponding to fluoride indicates that fluoride was not detected during the physico-chemical analysis. Though present but but too low to count.(TLTC).

Chloride concentration ranged from 0.00 to 3.1mg/l. These values are generally lowand do not indicate any salt-water intrusion, this is attributed to the concentration effect. Therefore, the water area as fresh based on the chloride concentration.

The major cations include Ca^{2+}, Mg^{2+}, Na^+ and K^+. Potassium concentration varies little. The value ranges from 0.1 to 0.2mg/l. Magnesium varies from 6 to 12mg/l the concentration was below 50mg/l as recommended by WHO (1984). In general, the concentration of Ca, Na, Mg, and K were far below WHO (1984), indicating good quality water. This is because the less the values of the major cations the better the quality of the water.

Bacteriological Parameters

Table 4: Characterization and Identification of Bacteria Isolates

S/N	Col Code	LAC	MANN	CIT	IND	URE	OXID	MR	VP	H_2H	GAS	MOT	CAT	COA	Confirmed microorganisms
1	a	-	-	+	NR	NR	NR	NR	NR	-	-	-	+	NR	***Bacillus Spp***
2	b	+	+	+	-	+	+	+	+	-	+	+	+	NR	***Citrobacterl feundii***
3	c	+	+	+	-	+	+	+	-	-	+	+	+	NR	***Escherichia Coli***
4	d	+	+	-	+	-	+	+	-	-	+	+	+	NR	***Proteus vulgaris***
5	e	+	-	+	+	-	+	+	-	-	+	+	+	NR	***Streptococci Spp***
6	f	-	-	+	-	-	-	+	-	-	-	+	+	NR	***Video Cholera***
7	g	-	-	-	NR	NR	NR	+	NR	-	-	-	+	NR	***Shigella Dusentrae***
8	h	+	-	-	NR	NR	NR	+	NR	-	-	-	+	NR	***Salmonella Spp***
9	I	-	+	-	-	+	+	+	NR	-	-	-	-	NR	***Klebsiella Spp***
10	j	-	-	+	NR	NR	NR	+	-	-	-	-	-	NR	***Corynebacteria***
11	k	-	-	+	NR	NR	NR	+	NR	-	-	-	+	NR	***Micrococcus Spp***
12	l	+	+	+	NR	NR	NR	+	NR	-	-	-	+	NR	***Glugella Dysentrae***
13	m	-	+	+	+	-	-	NR	+	+	+	+	+	NR	***Salmonella Typhi***
14	n	-	+	+	-	-	-	NR	-	-	+	+	+	NR	***Escherichia Coli***
15	o	-	+	+	-	-	-	NR	+	-	+	-	-	NR	***Bacillus Spp***
16	p	+	+	+	-	-	-	NR	-	-	+	-	+	NR	***Shigella Dysentrae***

Key:

Lac - lactose; MANN - mannitol; GLU - glucose; CIT - citrate; IND - indole; - OXID - oxidase; MR - methyl red; VP - Voges Proskauer; H_2S - hydrogen sulphide; MOT - motility; COAG - coagulase; CAT - catalase; NR - no reaction; UREA - urease; (+) positive reaction (-) negative reaction.

The more probable number (MPN) test for coliforms revealed that high coliform counts all the surface water with highest count of 11/ml coliform count unit/100ml were recorded in ST2 and the least we're recorded in all the BH samples as shown in table 5 below.

Table 5: Bacteriological Analysis of surface water and boreholes

S/N.	Sample Code	Sample Location	Total Bacteria Count	Total Coliform Count	Faecal coliform count
1.	ST1	Dimdim-Eminebol	5/ml	5/ml	5/ml
2.	ST2	Ekokol-Agba	7/ml	11/m	11/ml
3.	BH1	PHC Levachiel	1/ml	2/m	3/ml
4.	BH2	Govt Pri Sch, Itigidi	2/m	2/ml	2/ml
5.	BH3	Opp CRSWB Rd	1/ml	1/ml	2/ml

Conclusion

The analyses indicate that the waters are slightly acidic (6.9 to 7.4) in P^H rabge, soft (hardness < 75mg/l) and fresh as conductivity is far less 500us/cm. On the basis of alkali hazard, Fe (<1.5 mg/l), the water is soft and are regarded excellent for drinking, irrigation and most classes of livestock poultry and fisheries cultivation. The mean values for all the parameters analyzed were all within international standard for drinking, domestic and agricultural purposes. The quality evaluation scheme indicates that the water Bodies are generally good exception of SAR which gives poor result after the analyses. Mean value for SAR is 8.4 which is relatively high dose, though, it has no negative effect human health but affect the growth of some species of agricultural plants. Extremely high value of SAR is when the value is greater than 15 and this can greatly impede the growth agricultural crops.

In terms of the bacteria counts, the study revealed that the streams in the area recorded low bacteria counts ranging from 5/ml to 7/ml, this value is considered low because similar research in some other parts of the local government revealed a very high bacteria counts and total faecal coliform count of 72/ml 5.10^4/ml (Enya, V. I, 2006). Therefore, the waters in the area are good for human consumption. The most probable number (MPN) analysis results of coliforms/100ml in the area given clear indication of good quality of the various streams and boreholes. This is concluded that the boreholes waters are of high quality than the stream water as indicated by the results of Physico-chemical and the Bacteriological Analyses. The bacteria isolates in all the boreholes are significantly low which gives them the excellent quality for domestic uses.

Recommendation

Routine water quality assessment should be carried out frequently on yearly basis as of controlling the hygienic safety streams and boreholes supply of water.

Government should construct more boreholes to meet the demand of the people as the population of the study area tend to increase drastically due to the upgrading of Cross River State School of Nursing to Cross River State College of Nursing Itigidi.

Portable drinking water source should be located far from latrine to stop disease causing microorganisms to penetrate into the source, water supply from contaminated source should be boiled and filtered before drinking. Filtration should be carried out after pre treatment to remove sediment which may give taste, colour and odour to the water.

The P^H of the waters be monitored to avoid corrosion of the pipes. This can be done either by the addition of lime or chlorine as the case may be.

Unwanted materials should be recycled more often instead of being dumped into water Bodies.

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