

Full Length Research Paper

Physical, chemical and bacterial analysis of drinking water: Kakua Chiefdom, BO district, Sierra Leone

Yahaya Kudush Kawa^{1,2*}, John Paul Kaisam³, J. P. Moiwo¹ and Victoria Kabia¹

¹Department of Chemistry, Njala University, Sierra Leone.

²College of Chemistry, Northeast Normal University, Changchun, China.

³Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China.

Received 27 August, 2015; Accepted 11 January, 2016

Water makes the difference between living and non-living things, base on this there is a strong need to look at the chemistry, to make sure that it is free from contamination because of chemical reaction that take place in the living cell. In the case of this study, it is critical to determine the quality of the water supplied, because of the chemical reaction. This study analyzes 10 representative well water systems for 18 quality parameters in Kakua Chiefdom of Bo District, Sierra Leone. The study note among others, well-water total dissolved solids (TDS), turbidity, electrical conductivity (EC), coliform and nitrate (NO_3^-), in the region that are fairly high. The incidence of coliform in well waters is highest in April and those iron (Fe_2^+) and nitrate in May. The DIPA street well is amongst the most contaminated and TDS, Non-faecal and fluoride (F) have the highest scores in a three-category plot along wells. Correlation analysis among the water chemistry shows an interesting results; ranging strong positive ($R=1.0$) to strongly negative ($R=-1.0$).

Key words: Physico-chemical, parameter chemical parameters, bacteriological parameters, water molecule.

INTRODUCTION

Sierra Leone is located on the west coast of Africa between latitudes 6.91 to 10.08°N and longitudes 10.21 to 13.32°W (Figure 1, inset plate). It is bordered on the west by the Atlantic Ocean, on the north and northeast by Guinea and on the southeast by Liberia (Figure 1). Sierra Leone has a population of 5.5 million people (Squire, 2001), with a total area of 71 740 km², 71 620 km² (99.8%) of which is land and 120 km² (0.2%) water

(Barnett et al., 2000).

Sierra Leone has a tropical monsoon climate with two distinct seasons; the wet and dry seasons. While night time temperatures in the dry season can be as low as 16°C (NRDS, 2009), the annual average temperature is 26°C. Tropical rainfall is the dominant precipitation, ranging from 5000 mm in the coastal regions to 2000 mm in the hinterlands. Dense networks of tributaries carrying

*Corresponding author. E-mail: yahaya_kawa@yahoo.com. ykawa@njala.edu.sl. Tel: +23279544698.



Figure 1. Map showing administrative district shesad.

abundant water flows throughout the year (USAID, 2012) feed the seven main rivers of Sierra Leone (Figure 1).

The land cover mainly includes lowland deciduous forests, inland valley swamps, coastal mangrove swamps, bolilands, and wooded savannah and the main cultivated crops are coffee, cocoa, oil palm, rice,

cassava, groundnut, coconut, citrus, maize and cashew (USAID, 2012). Rain fed agriculture is the main mode of livelihood, directly employing 75% of the population (Barnett et al., 2000). Sierra Leone is divided into 149 chiefdoms, 12 districts, 3 provinces and 1 western area. Bo is a district in the southern province of sierra Leone

with 15 chiefdoms, total area of 1400 km² and population of 463 668 people. This study was conducted in Kakua Chiefdom (Figure 1, right plate), one of the 15 chiefdoms in Bo District.

World Health Organization (WHO) and its member states has its objectives to all people, in respect to their stages in progress and their social and economic circumstances have right to have access to enough supply of safe drinking water. At the beginning of 2000, about 1.1 billion people in the world were without access to improved supply of clean water. Africa has the lowest water supply coverage with only 62.0% of the population having access to improved water supply. The continent contains 28.0% of world's population without access to improved water supply. Ethiopia is one of the ten African countries, which have less than 50.0% water supply coverage, with only 24.0% of the population having access to improved water supply. In Ethiopia the situation is much worse in rural areas where coverage is only 13.0% compared with 77.0% in urban areas. Water is considered one of the most important and sensitive issues in the Middle East, where increasing water deficiency and deterioration of the available water are imminent (Al-Khatib et al., 2003).

Most of the middle-eastern countries, including Palestine, are characterized by arid to semi-arid climatic conditions and have very limited water resources. The majority of fresh water supplies in these countries come from scarce groundwater resources. Future population growth in these countries and its associated water demands is expected to place severe pressure on the limited groundwater reserves (Nasserdin et al., 2009).

The risk of microbiological contamination of drinking water during collection and storage in the home has long been recognized (Van Derslice and Briscoe, 1995; Lye, 2002; Thomas et al., 2003; Gerba and Smith, 2005). Factors such as site characteristics, interval duration, and ultra violet ultraviolet (UV) intensity would all affect the survival of microorganisms on the catchment surface and their viability in the run-off (Evans et al., 2006). Septic systems have been noted as one of the largest sources of pollution in the suburbs (along with construction erosion) through failing systems and subsurface movement of pollutants. Water pollution induced by storm runoff from different roofing materials is considered a non point source (Chang et al., 2004).

The parameters (pH, TDS, TH, alkalinity, free available chlorine, sulfate and ammonia-N) could influence drinking water flavor, while the turbidity and coliform group were measured due to esthetic and health concerns, respectively (Lou et al., 2007). Many consumers will link the presence of offensive tastes or odors with the possibility of a health risk though an unpleasant taste in water does not necessarily indicate that the water is unsafe to drink (Lou et al., 2007).

Variation of roof runoff quality seems to reflect differences in roofing materials, age and management, the surrounding environment, season, storm duration and intensity, and air quality conditions of the region (Chang et al., 2004). This is the first explanation about analysis of drinking water in the Kakua Chiefdom in Bo District Southern Sierra Leone West Africa, which deals with environmental Chemistry to the study knowledge.

In this study, the environment will be looked as consisting of five spheres - the hydrosphere, atmosphere, geosphere, biosphere and astrosphere. Although often not acknowledged as one of the environmental spheres, the astrosphere, consisting of the things humans construct, use, and do in the environment, is very important to consider as one of these five spheres. By so doing, the study can begin the essential process of using our human activities to preserve and enhance the earth environment upon which all-living organisms and we depend. Water composes one of the five "spheres" in which environmental chemistry is discussed. This research introduces the environmental chemistry of water.

Properties of water as a unique substance

Water has a number of unique properties that are essential to life, and that determine its environmental chemical behavior. Many of these properties are due to water's polar molecular structure and its ability to form hydrogen bonds. The most important special characteristics are shown in Table 1.

MATERIALS AND METHODS

Characteristics and description of sample collection points

Because of the limited time of study, ten (10) different points were collected out of the total of fifty (50) water sources in the Kakua Chiefdom that is, Bo Town. These sampling points were done by considering the various uses of the sources being put to; their location in the community, relative magnitude and direction are shown in Table 2.

Instrumentation and uses

Conductivity meter is the instrument used to determine electrical conductivity, salinity, temperature and total dissolved solids (TDS). The CO150 conductivity meter is a valued priced, full featured portable meter, which can be used for a wide variety of application in the field or the laboratory. Water quality acid base and other samples can be easily analyze for conductivity with the available conductivity probe. This meter feature a microprocess or design which is complicated and time-consuming calibration and measurement procedure for a wide variety of application. Hydrometer is an instrument made up of metal with a round plate and a curve handle with black/blue sponge. It is calibrated in meter

Table 1. The main characteristics of water as a universal solvent.

Property	Effects and Significance
Excellent solvent	Transport of nutrients and waste products, making biological processes possible in an aqueous medium
Highest dielectric constant of any common liquid	High solubility of ionic substances and their ionization in solution
Higher surface tension than any other liquid	Controlling factor in physiology; governs drop and surface phenomena
Transparent to visible and longer-wavelength fraction of ultraviolet light	Colorless, allowing light required for photosynthesis- to reach considerable depths in bodies of water
Maximum density as a liquid at 4°C	Ice floats; vertical circulation restricted in stratified bodies of water
Higher heat of evaporation than any other material	Determines transfer of heat and water molecules between the atmosphere and bodies of water
Higher latent heat of fusion than any other liquid except ammonia	Temperature stabilized at the freezing point of water
Higher heat capacity than any other liquid except ammonia	Stabilization of temperatures of organisms and geographical regions

Table 2. Details of the characteristics of water wells used in sample collection in Kakua Chiefdom, Bo District, Sierra Leone.

Well site (Code)	Use	Impact	Depth (m)	Safety
St. Andrews (SAS)	Multi-use	High	37.4	Covered and fenced
SALWACO Bo (SBO)	Domestic	High	18.6	Covered and unfenced
Cheshire home (CHE)	Domestic	High	58.1	Covered and fenced
J-Quarters (JQS)	Domestic	High	10.3	Covered and fenced
Kebbie town (KTN)	Domestic	High	13.7	Covered and fenced
New York (NYK)	Domestic	Moderate	8.4	Covered and fenced
Sewa river plant (SRP)	Multi-use	High	59.2	Covered and fenced
Water street (WST)	Domestic	Moderate	7.5	Covered and unfenced
Diepha street (DST)	Domestic	Moderate	8.9	Covered and fenced
Sewa road (SRD)	Domestic	High	11.2	Covered and unfenced

with a tape rule at the end of the tape, there is a two (2) meter long metal attached to it, it uses two medium cells battery with 1.5v. As the battery is fixed, it shows a red light. When put into the well, as the metal touches the water at the surface it alarms and you drop it at the base of the well; it makes a second alarm from there you can take your readings, that is from the initial depth, subtract from the final depth which will give your final answer. For you to know the depth of the well, that is, initial depth – final depth = 0.63-0.3 = 0.33m

pH meter pH [mv] temperature meter was used to determine the pH and temperature of the water samples. This meter features a custom digital Liquid-crystal display (LCD) display, which simultaneously shows temperature and pH measurement results. This meter has all the features of a simple pH meter plus a mill Volt Mode 1p69 (waterproof design, electrode holder ergonomic design and ultra buffer recognition).

Oxfarm delagua portable water testing kits was used to carry out bacteriological (faecal and non-feacal) analysis. The kit contains the following: incubator, turbidity, methanol dispenser and other necessary field materials. Hachdigital titration (Model 16900) Hach digital titrator is a new concept in trimetric analysis. It is a precision

dispensing device fitted with compact cartridges that contain concentrated titrants. Accurate titrations are made without the buck fragility of conventional burette. A main drive in the digital titration controls a plunger, which forces the solution from a titration cartridge in a carefully regulated flow. The titration body is constructed of precision model heavy duty chemical and impact resistance acetyl plastic. Accuracy is rated at $\pm\%$ or better for a titration of more than 100 digits. For less than 100 digits, the accuracy is ± 1 . Pack test ion selection water inspection test kits (WAK COD) was used to determine the level of chloride. The kit contains several tubes containing very strong oxidizing agent (KMnO_4), with a standard colour chart with measuring range of 0 to 100 mg/L (ppm) and a desiccant. Found also in the kit is the instruction manual. This kit was used to determine chemical oxygen demand (COD) of the water sample.

Transmittance photometer (Palintest 5000) instrument was used to determine the level of phosphate (PO_4)³⁻. This photometer like the DR2010 spectrophotometer is a microprocessor controlled single beam photometer design for volumetric testing in the laboratory and in the field. The wavelength range of 410 to 640 nm

is selected on the photometer and result is shown on percentage transmittance (%T). Unlike the spectrophotometer that uses power pillows, the palintest tablet and results obtained is correlated with a chart for each ion determined.

Potable data logging (HACHDR 2010) spectrometer HACH model DR 2010 spectrophotometer is a microprocessor controlled, single beam for data logging spectrophotometer designed for colorimetric testing in the laboratory or in the field. The instrument is recalibrated for over 120 different colorimetric testing of water quality and has been factory-installed to streamline testing procedures within its wavelength range of 400 to 900 nm; the DR 2010 provides a result in concentration unit, percentage transmittance (%T) and absorbance (ABS) units. This instrument was used to determine the level of sulphate (SO_4^{2-}), iron (Fe^{2+}) and nitrate (NO_3^-). Refrigerator (Zero model) was used to maintain a temperature of 4°C required to store samples for chemical analysis. Pressure cookers and stoves were used to sterilize sample kits and culture medium. The following items were used in the preparation of the culture medium at the Ministry of Energy and Power, Water Division Laboratory, Tower Hill.

1. Membrane lauryl sulphate broth.
2. Distilled water.
3. Polypropylene N Bottles.
4. Measuring Cylinder.
5. Pressure cooker and stove

Sampling procedures

For water wells with pump was operated on for about 20 min, by allowing some water to run through in order to clear any substance in the water column. After this exercise, the out-let pipe is sterilized using an alcohol flaming. The pump was operated for further two minutes and the sample was taken in the following stream of water. For well without hand pumps, a weighed bottle or shallow sampling device was used. A stone of suitable size sterilized and attached to the sampling bottle with a piece of string. 20 m length of clean string was rolled around a stick and tied onto the bottle string. The sample bottle was lowered, weighed down by the stone into the well. It was immersed completely in the water and lowered to the bottom of the well, once it is filled the string was rewind round the stick to bring the bottle up. The bottle was then Stoppard and given a field code.

Preparation and preservation of sample analysis

The samples collected for chemical analysis were filtered immediately after collection using 0.7µm membrane filter. The filter removes algae, bacteria and particulate matter that contaminate or rapidly absorb elements from water. The samples collected in the field were protected from the direct sunrays to avoid further reaction, and were therefore stored in special container, which were partially dark. Also each sample was protected from extractable contamination by sealing the sample bottle tightly with clean plastic cover. All physical parameters together with the chemical oxygen demand (COD) were performed in the field, as samples were collected. For chemical analysis, the sample bottles were completely filled with samples since the presence of air may chemically biologically alter the samples especially for the Fe^{2+} determination. Three parameters were used; physico-chemical and bacteriological parameter; temperature, pH, turbidity, electrical conductivity, TDS are physico-parameter; chloride (Cl^-), sulphate

(SO_4^{2-}), nitrate (NO_3^-), phosphate (PO_4^{3-}), chemical oxygen demand (COD)-chemical parameter; bacteriological faecal coli form counts and non-faecal coli form counts.

RESULTS AND DISCUSSION

The results of the analysis of the quality of well water used for various purposes (but mainly for drinking) in Kakua Chiefdom in Bo District, Sierra Leone, are sufficiently summarized in the plots given in Figure 2 and Figure 3. The discussions in the next sections done in relation to that analysis give further in-depth insight of the reactions as influenced by the environmental (physical, chemical and biological) conditions in the study area. Such discussion is necessary to inform policy/decision makers on the risks posed by the water supply system in the country and develop the most efficient measures to mitigate or eliminate these risks.

Temperature

Most individuals find water at temperatures of 10 to 15°C most palatable. Ground waters and waters from mountainous areas are normally within this range.

Surface waters are, of course, subject to the effect of ambient temperatures and can be very warm during dry season. The temperature of water affects the efficiency of treatment units. For example, from the period when the sample was collected, the range of temperature is from 27.97 to 28.19°C in Table 2 with high temperatures, the viscosity decreases. This, in turn, fall the efficiency of settling of the solids that the water may contain because of the resistance that the high viscosity offers to the downward motion of the particles as they settle. Pressure drops also increase in the operation of filtration units, again, because of the resistance that the higher viscosity offers.

pH determination

The pH of natural waters on land is controlled mainly by the bicarbonate-carbonate system. Most of the CO_2 absorbed into the ocean is in the form of HCO_3^- (93%) and CO_3^{2-} (6%). The pH of the upper regions of the sea is controlled by the carbonate as well as the borate systems. In the lower regions of the sea, pH appears to be controlled by the precipitation and solution of various minerals. The bicarbonate alkalinity of natural waters has the following typical ranges: rainwater 0 to 2.5 ppm (mg/L), river and groundwater 6 to 600 ppm, and seawater 140 to 159 ppm. pH is a measure of the hydrogen ion (H^+) concentration. Solutions range from

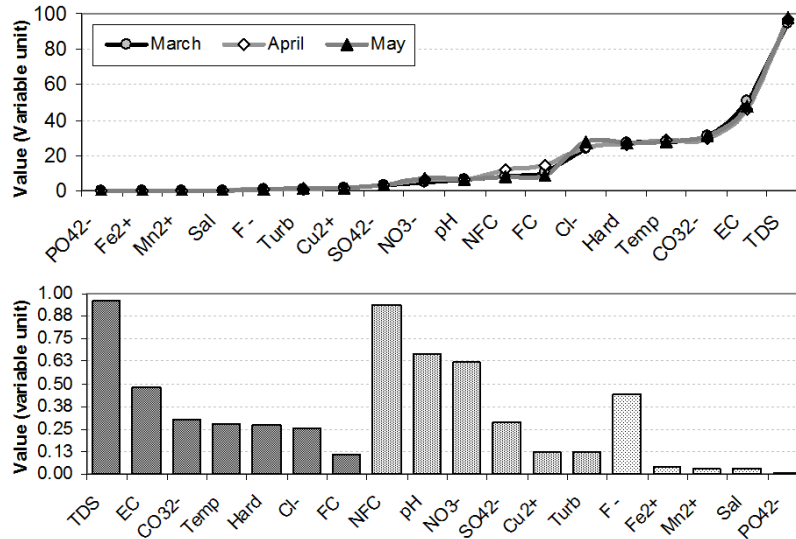


Figure 2. The top-plate is the trend in measured well-water quality variables for the months of March to May averaged spatially for the 10 wells across the study area. The bottom plot is the trend in measured well-water quality variables averaged temporally for the months of March through May and spatially for the 10 wells across the Kakua Chiefdom study area. For the actual variable values in the bottom-plate, the first seven variables (TDS to FC) are multiplied by 1.0×10^2 , the second six (NFC to Turb) by 1.0×10 , and the last five (F- to PO42-) by 1.0×10^2 . Note that the definitions and units of the coded variables on the X-axis are as defined in Table 2 and Table 3.

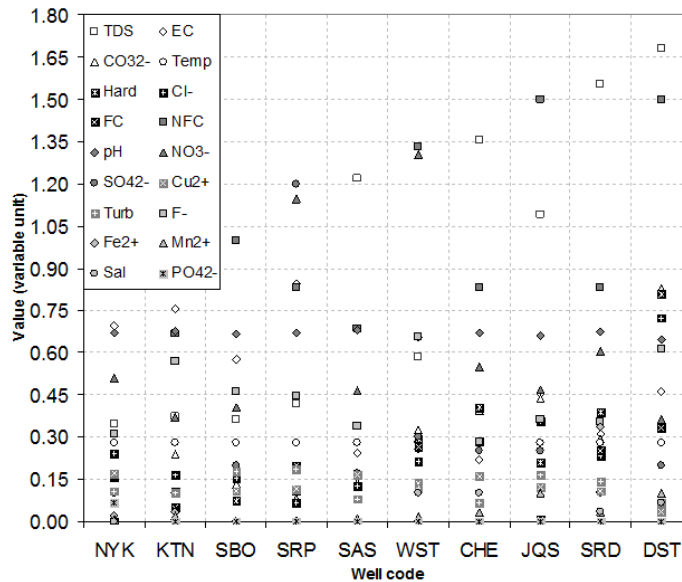


Figure 3. Plot of the trends in measured well-water quality variables averaged for the months of March through May in the Kakua Chiefdom study. For the actual values of the variables on the plot, the first seven variables (TDS to FC) are multiplied by 1.0×10^2 , the second six (NFC to Turb) by 1.0×10 , and the last five (F- to PO42-) by 1.0×10^2 . Note that the well codes on the X-axis and the units of the variables are as defined in Table 2 and Table 3.

Table 3. Well-by-well mean values of measured well-water variables in the Kakua Chiefdom study area, Bo District, Sierra Leone.

Well-site/Variable	Unit	SRD	SRP	DST	KTN	NYK	SAS	WST	CHE	JQS	SBO	AVG
Total dissolved solid (TDS)	ppm	155.67	41.80	233.33	37.30	34.70	122.00	58.53	135.67	109.03	36.27	96.43
Electrical conductivity (EC)	$\mu\text{S/cm}$	31.10	84.63	46.10	75.63	69.63	24.40	26.00	21.87	45.43	57.50	48.23
Carbonate (CO_3^{2-})	mg/100 ml	29.33	8.00	83.00	23.67	15.67	14.00	32.67	39.33	43.67	13.33	30.27
Temperature (Temp)	$^{\circ}\text{C}$	27.97	27.80	27.83	27.90	28.13	28.00	27.90	27.93	27.80	28.03	27.93
Hardness (Hard)	mg/100 ml	38.67	10.67	80.67	10.67	16.00	12.67	29.33	40.67	21.00	7.33	26.77
Chloride (Cl^-)	mg/100 ml	23.33	6.67	72.33	16.33	24.00	12.67	21.33	28.33	35.67	15.33	25.60
Faecal coliform (FC)	u/100 ml	25.00	20.00	33.33	5.00	0.00	0.17	26.67	0.00	0.67	0.00	11.08
Non-faecal coliform (NFC)	u/100 ml	8.33	8.33	15.00	6.67	1.67	6.83	13.33	8.33	15.00	10.00	9.35
pH	-	6.73	6.70	6.47	6.77	6.70	6.80	6.53	6.70	6.60	6.67	6.67
Nitrate (NO_3^-)	mg/100 ml	6.03	11.47	3.63	3.70	5.10	4.63	13.03	5.50	4.70	4.07	6.19
Sulphate (SO_4^{2-})	mg/100 ml	1.00	12.00	2.00	1.00	1.00	1.70	3.00	2.50	2.50	2.00	2.87
Copper (Cu^{2+})	mg/100 ml	1.09	1.17	0.36	1.03	1.72	1.65	1.37	1.60	1.22	1.08	1.23
Turbidity (Turb)	mg/100 ml	1.43	1.87	0.67	1.00	1.07	0.80	1.20	0.67	1.63	1.80	1.21
Fluoride (F^-)	mg/100 ml	0.36	0.45	0.61	0.57	0.31	0.34	0.66	0.28	0.36	0.46	0.44
Iron (Fe^{2+})	mg/100 ml	0.34	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.04
Manganese (Mn^{2+})	mg/100 ml	0.04	0.00	0.10	0.02	0.01	0.01	0.02	0.03	0.10	0.00	0.03
Salinity (Sal)	mg/100 ml	0.03	0.00	0.07	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.03
Phosphate (PO_4^{2-})	mg/100 ml	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.01

The values are averages over March, April and May 2010, and AVG denotes average and the rest of the well codes are as defined in Table 2

very acidic (having a high concentration of H^+ ions) to very basic (having a high concentration of OH^- ions). The pH scale ranges from zero to 14, with 7 being the neutral value and Table 2 pH ranges from 6.73 to 6.67 which is recommended by WHO. The pH of water is important to the chemical reactions that take place within water, and pH values that are not high or low which cannot inhibit the growth of microorganisms. With high and low pH values, high pH values are considered basic and low pH values are considered acidic. Stated in another way, low pH values indicate a high level of H^+ concentration, while high pH values indicate a low H^+ concentration. Because of this inverse logarithmic relationship, there is a ten-fold difference in H^+ concentration. Natural water varies in pH depending on its source. Pure water has a neutral pH, with an equal number H^+ and OH^- .

Turbidity determination (NTU)

Water clarity is one of the first characteristics people notice (Table 3). Turbidity in water is caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. The greater the amount of total suspended solids in the water, the murkier it appears and the higher the measured turbidity. Thus, in plain English, turbidity is a measure of the light-transmitting properties of water. Natural water that is very clear (low turbidity) allows you to see images at

considerable depths, while high turbidity water appears cloudy. Keep in mind that water of low turbidity is not necessarily without dissolved solids. Dissolved solids do not cause light to be scattered or absorbed, making the water look clear. High turbidity causes problems for the components that cause high turbidity that can cause taste and odor problems, and will reduce the effectiveness of disinfection.

Electrical conductivity determination

The reading was allowed to stabilize, after stabilization meter displayed "ready" indicated at the top right of the display. The reading was then noted. The probe was removed and rinsed with de-ionized water before repeating the experiment. The same procedure was done for the remaining samples. The result from Table 3, Sewa River plant has high electrical conductivity (EC) values of $84.63 \mu\text{S/cm}$ and Kebie Town is the second highest with $75.63 \mu\text{S/cm}$.

Total dissolved solids determination

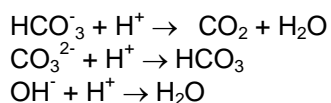
Gases can also be dissolved in water. Oxygen, carbon dioxide, hydrogen sulfide, and nitrogen are examples of gases that dissolve in water. Gases dissolved in water are important. For example, carbon dioxide is important

because of the role it plays in pH and alkalinity. Carbon dioxide is released into the water by microorganisms and consumed by aquatic plants. However, dissolved oxygen (DO) in water is of most important. DO is not only important to most aquatic organisms, but it is also an important indicator of water quality. Like terrestrial life, aquatic organisms need oxygen to live. As water moves past their breathing apparatus, microscopic bubbles of oxygen gas in the water, DO, are transferred from the water to their blood. Like any other gas diffusion process, the transfer is efficient only above certain concentrations. In other words, oxygen can be present in the water, but at too low a concentration to sustain aquatic life. Oxygen also is needed by virtually all algae and macrophytes, and for many chemical reactions that are important to water body functioning. From the mean result in Table 3, DST has 233.33 ppm, which is very high than the other.

ALKALINITY AND ACIDITY

Alkalinity

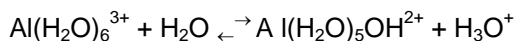
The capacity of water to accept H^+ ions (protons) is called alkalinity. Alkalinity is important in water treatment, and in the chemistry and biology of natural waters. From Table 3 it shows that, water is not alkaline non-basic, but neutral from the pH values. This must be known to calculate the quantities of chemicals to be added in treating the water. Due to the low alkaline and basicity of water often has a low pH and generally contains low levels of dissolved solids. These characteristics may be good for water to be used in boilers, food processing, and municipal water systems in Bo town. Alkalinity is not serving as a pH buffer and reservoir for inorganic carbon, thus helping to determine the ability of water to support algal growth and other aquatic life. Biologists use it as a measure of water fertility. Generally, the basic species responsible for alkalinity in water are bicarbonate ion, carbonate ion and hydroxide ion:



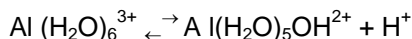
Other, usually minor, contributors to alkalinity are ammonia and the conjugate bases of phosphoric, silicic, boric, and organic acids. It is important to distinguish between high basicity, manifested by an elevated pH, and high alkalinity, the capacity to accept H^+ .

Acidity as applied to natural water systems is the capacity of the water to neutralize OH^- . Acidic water is not frequently encountered, except in cases of severe pollution. Acidity generally results from the presence of weak acids such as $H_2PO_4^-$, CO_2 , H_2SO_4 , proteins, fatty

acids, and acidic metal ions, particularly Fe^{3+} . Acidity is more difficult to determine than is alkalinity. One reason for the difficulty in determining acidity is that two of the major contributors are CO_2 and H_2SO_4 , both volatile solutes that are readily lost from the sample from the table mart is (3) which show that the above chemical is low which make the acidity values insignificant. The acquisition and preservation of representative samples of water to be analyzed for these gases is difficult. The term *free mineral acid* is applied to strong acids such as H_2SO_4 and HCl in water. Pollutant acid mine water contains an appreciable concentration of free mineral acid. Whereas total acidity is determined by titration with base to the phenolphthalein end point (pH 8.2, where both strong and weak acids are neutralized), free mineral acid is determined by titration with base to the methyl orange endpoint (pH 4.3, where only strong acids are neutralized). The acidic character of some hydrated metal ions may contribute to acidity as shown by the following example:



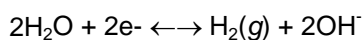
For brevity in this research, the hydronium ion, H_3O^+ , is abbreviated simply as H^+ and H^+ -accepting water is omitted so that the above equation becomes



Some industrial wastes, for example pickling liquor used to remove corrosion from Steel, contain acidic metal ions and often some excess strong acid. For such wastes, the determination of acidity is important in calculating the amount of lime, or other chemicals, that must be added to neutralize the acid (Table 3).

OXIDATION-REDUCTION

Oxidation-reduction (redox) reactions in water involve the transfer of electrons between chemical species. In natural water, bacteria carry out wastewater, and soil, most significant oxidation-reduction reactions, so they are considered in this section as well. The relative oxidation-reduction tendencies of a chemical system depend upon the activity of the electron, e^- . When the electron activity is relatively high, chemical species (even including water) tend to accept electrons and are reduced.



When the electron activity is relatively low, the medium is oxidizing, and chemical species such as H_2O may be oxidized, losing electrons:

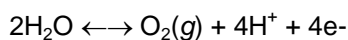
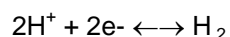


Table 4. Correlation matrix for the 18 water-quality variables analyzed in this study.

R	PO ₄ ²⁻	Sal	Mn ²⁺	Fe ²⁺	F ⁻	Turb	Cu ²⁺	SO ₄ ²⁻	NO ₃ ⁻	pH	NFC	FC	Cl ⁻	Hard	Temp	CO ₃ ²⁻	EC
Sal	-0.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn ²⁺	0.73	-0.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe ²⁺	0.50	-0.87	-0.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F ⁻	-0.99	0.92	-0.01	-1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
Turb	0.83	-1.00	-0.70	0.96	0.80	-	-	-	-	-	-	-	-	-	-	-	-
Cu ²⁺	0.63	-0.16	1.00	1.00	-0.47	-0.17	-	-	-	-	-	-	-	-	-	-	-
SO ₄ ²⁻	-0.43	0.82	0.88	1.00	0.75	0.48	1.00	-	-	-	-	-	-	-	-	-	-
NO ₃ ⁻	0.95	-0.98	-0.41	1.00	0.55	0.42	0.99	-	-	-	-	-	-	-	-	-	-
pH	0.92	-0.99	-0.54	1.00	0.38	0.98	0.74	-0.21	0.86	-	-	-	-	-	-	-	-
NFC	0.50	0.00	0.99	0.98	0.30	0.62	0.75	-0.20	0.35	0.58	-	-	-	-	-	-	-
FC	0.19	0.33	0.96	0.96	0.44	0.30	0.97	1.00	0.00	0.17	1.00	-	-	-	-	-	-
Cl ⁻	0.72	-0.97	-0.78	1.00	0.33	-0.42	0.84	1.00	1.00	0.79	-0.68	-1.00	-	-	-	-	-
Hard	-0.08	-0.43	-0.95	1.00	0.34	1.00	0.75	-0.20	-0.13	0.01	0.99	-0.29	-0.80	-	-	-	-
Temp	0.60	-0.12	1.00	1.00	0.31	-0.89	0.73	1.00	-0.12	-0.18	0.96	0.90	-0.31	-0.96	-	-	-
CO ₃ ²⁻	-0.37	-0.15	-0.98	1.00	0.27	-0.95	0.37	1.00	0.72	0.87	0.41	-0.66	0.87	0.57	0.95	-	-
EC	-0.94	0.64	-0.92	1.00	0.35	0.52	1.00	0.48	0.89	0.98	1.00	-0.53	0.28	0.44	0.87	0.06	-
TDS	0.97	-0.96	-0.31	1.00	-0.99	0.05	0.89	0.84	-0.21	1.00	0.98	0.97	0.90	0.66	-0.88	-0.69	-0.83

The acronyms and units are as defined in Table 3.

The relative tendency toward oxidation or reduction is based upon the electrode potential, E, which is relatively more positive in an oxidizing medium and negative in a reducing medium. It is defined in terms of the half reaction (Table 4).



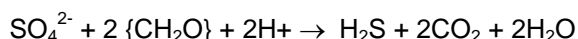
Chloride determination

The actual concentration of the chloride was obtained by multiplying digit required by digit multiplier; also corresponding to the sample volume and the titration cartridge selected. Table 3 shows how the figures were obtained during titration where the chlorine is a halogen that cannot react with the heavy metal in the water.

Sulphate determination (0 to 70 mg/L SO₄²⁻)

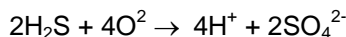
Sulphate content in Table 3 is very low, because sulphur cannot exhibit its distinct property as allotrope, and it lacks one component phase equilibrium. The sulfur cycle involves interconversions among a number of sulfur species, including inorganic soluble sulfates, insoluble sulfates, soluble sulfide, gaseous hydrogen sulfide, and insoluble sulfides; biologically bound sulfur; and sulfur in synthetic organic compounds. The major microbial mediated processes in this cycle are the following:

Sulfate reduction to sulfide by bacteria such as *Desulfovibrio*, which utilizes sulfate as an electron acceptor in the oxidation of organic matter:



The odiferous and toxic H₂S product may cause serious problems with water quality.

Sulfide oxidation by bacteria such as *Thiobacillus*:



Oxidation of sulfur in a low oxidation state to sulfate ion produces sulfuric acid, a strong acid. Some of the bacteria that mediate this reaction, such as *Thiobacillus thiooxidans* are remarkably acid tolerant. Acid-tolerant sulfur-oxidizing bacteria produce and thrive in acidic waters, such as acid mine water, which can be very damaging to the environment.

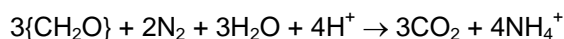
Nitrate HR (0-30.0 mg/L)

Some of the most important microorganism-mediated and human activities chemical reactions in aquatic and soil environments are those involving nitrogen compounds. They are key constituents of the nitrogen cycle, which take place in the atmosphere, a cycle that describes the dynamic processes through which nitrogen is interchanged among the atmosphere, organic matter, and

inorganic compounds. The range values in Table 2 are 6.03 to 6.67 mg/100 ml which can lead to the key microbial mediated processes in the nitrogen cycle.

Nitrogen fixation

The binding of atmospheric nitrogen in a chemically combined form:



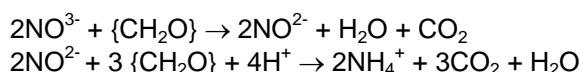
Biological nitrogen fixation is a key biochemical process in the environment and is essential for plant growth in the absence of synthetic fertilizers.

Nitrification

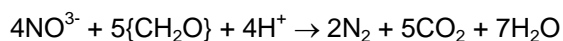
The conversion of N (-III) to N (V) is catalyzed by *Nitrosomonas* and *Nitrobacter*.



Nitrification is important in nature because plants absorb nitrogen primarily as nitrate ion, which is produced by nitrification. When fertilizers are applied in the form of ammonium salts or anhydrous ammonia, a microbial transformation to nitrate enables maximum assimilation of nitrogen by the plants. Nitrate reduction is a system by which nitrogen in chemical compounds is reduced by microbial action to lower oxidation states in the absence of free oxygen:



Denitrification, which produces N_2 gas from chemically fixed nitrogen:



Denitrification is the mechanism by which fixed nitrogen is returned to the atmosphere and is useful in advanced water treatment for the removal of nutrient nitrogen. Loss of nitrogen to the atmosphere may also occur through the formation of N_2O and NO by bacterial action on nitrate and nitrite catalyzed by several types of bacteria.

Phosphate determination HR (PO_4^{3-})

The phosphorus cycle involves natural and pollutant sources of phosphorus including biological, organic, and inorganic phosphorus. Biological phosphorus is a key constituent of cellular DNA. Organic phosphorus occurs

in organophosphate insecticides. The major inorganic phosphorus species are soluble $\text{H}_2\text{PO}_4^{4-}$ and HPO_4^{2-} and insoluble $\text{Ca}_5(\text{OH})(\text{PO}_4)_3$. Soil and aquatic microbial processes are very important in the phosphorus cycle. Of particular importance is the fact that phosphorus is the most common limiting nutrient in water, particularly for the growth of algae. Bacteria are even more effective than algae in taking up phosphate from water, accumulating it as excess cellular phosphorus that can be released to support additional bacterial growth, if the supply of phosphorus becomes limiting. Microorganisms that are died release phosphorus that can support the growth of additional organisms. Biodegradation of phosphorus compounds is important in the environment for two reasons. The first of these is that it is a mineralization process that releases inorganic phosphorus from the organic form. This process provides an important source of nutrient orthophosphate required for the growth of plants and algae. Second, biodegradation deactivates highly toxic organophosphate compounds, such as the organophosphate insecticides.

Copper determination (COPPERCOL)

Clinical, epidemiological, and toxicological studies have demonstrated some heavy metal such as lead, copper iron etc, Exposure can adversely affect human health and most of them are radioactive material. The three systems in the human body most sensitive to some of them are the blood-forming system, the nervous system, and the renal system. In children, blood levels from 0.8 to 1.0 g/L can inhibit enzymatic actions. In addition, in children, this lead can alter physical and mental development, interferes with growing, decrease attention span and hearing, and interferes with the synthesis. In older men and women, lead can increase blood pressure. Lead is emitted into the atmosphere as Pb , PbO , PbO_2 , PbSO_4 , PbS , $\text{Pb}(\text{CH}_3)_4$, $\text{Pb}(\text{C}_2\text{H}_5)_4$, and lead halides. In drinking water, it can be emitted from pipe solders. The source of copper in drinking water is the plumbing used to convey water in the house distribution system. In small amounts, it is not detrimental to health, but it will impart an undesirable taste to the water. In appropriate concentrations, copper can cause stomach and intestinal distress. It also causes Wilson's disease. Certain types of PVC (polyvinyl chloride) pipes, called CPVC (chlorinated polyvinyl chloride), can replace copper for household plumbing. In Table 2 copper values ranges from 1.09 to 1.23 mg/100 ml which cannot affect the life of the people.

Ammonia determination

Ammonia is a primary breakdown product of nitrogen

containing organic matter in aquatic environments. Because a great deal of organic matter and waste is introduced into the hydrologic cycle by natural and anthropogenic processes, ammonia can be found in aquatic environments, especially those exposed to large amounts of human or domestic animal wastes. Ammonia is also of great importance in understanding the global cycling of several key elements, including nitrogen and carbon. Ammonia is one of the compounds uniquely critical to life that when not present in adequate amounts in aquatic environments can be associated with negative biological effects and when in excess can result in adverse ecological and toxic effects. When insufficient ammonia is available to plants, which assimilate ammonia to grow, they may experience metabolic problems due to nutrient limitations. Conversely, excess ammonia is commonly associated with eutrophic conditions in water bodies and toxicity to some organisms. Further, nitrous oxide (N₂O) a molecule involved in the environmental cycling of ammonia is considered a potential 'greenhouse gas' which can also destroy stratospheric ozone. Because of these adverse effects, ammonia is frequently considered a pollutant in aquatic systems.

Iron and manganese

Iron (Fe) and manganese (Mn) are objectionable in water supplies because they impart brownish colors to laundered goods. Fe also affects the taste of beverages such as tea and coffee. Mn flavors tea and coffee with a medicinal taste. The range value for (Fe) and (Mn) is 0.34-0.04, and 1.09-1.23 mg/100 ml respectively.

Total hardness determination (ppm) 20 ml

1 m NaOH solution was added to 50 ml of water sample to produce pH of 12 or 13. The solution was stirred and an appreciable amount of murexide indicator was added to the solution. This was immediately titrated with 0.01 m ethylene diamine tetra-acetic acid (EDTA) solution with continuous shaking. Colour change from red to blue showed the end, and the volume of EDTA titrant used was recorded. This was repeated for the blank and was therefore stored in special containers that were partially dark. In addition, each sample was protected from excreta contamination by sealing the sample bottles tightly with clean plastic cover. The samples were then taken to the laboratory at the Ministry of Energy and Power, Water Division at Tower Hill for physical, chemical and bacteriological analysis. At the laboratory, split sampling was done, various parameters of the analysis (that is, physical, chemical and bacteriological [biological] analyses) to make allowance for appropriate preservation

method. The sample for chemical analysis were generally acidified with 2 ml of 10% HNO₃, the samples were then taken in the refrigerator (zero models) at 4°C. All chemical analysis was done within 48 h when the samples for bacteriological analysis were analyzed within 5 h. All the physical parameters w together with the chemical oxygen demand (COD) were performed in the field as samples were collected.

For chemical analysis, the samples bottles were completely filled with the samples since the presence of air may chemically, biologically alter the samples especially for Fe²⁺ determination. In addition, the pH of 2 was aimed for Fe²⁺ by 1 ml concentrated hydrochloric acid per 100 ml of samples, before storage to avoid any oxidation reaction. Samples were collected and analyzed once every month for the three months under investigation (March to May 2009); each of these:

Fluorides: The absence of fluorides in drinking water encourages dental caries or tooth decay; excessive concentrations of the chemical produce mottling of the teeth or dental fluorosis. Thus, managers and operators of water treatment plants must be careful that the exact concentrations of the fluorides are administered to the drinking water. Optimum concentrations of 0.7 to 1.2 mg/L are normally recommended, although the actual amount in specific circumstances depends upon the air temperature, since air temperature influences the amount of water that people drink. In addition, the use of fluorides in drinking water is still controversial. Some people are against its use, while some are in favor of it. In the study research, the fluoride values in Table 2 range from 0.34 to 0.44 mg/100 ml, which might prevent tooth decay.

Salinity: The presence of salinity in drinking water can affect persons suffering from heart, kidney, or circulatory ailments. It may elevate blood pressures of susceptible individuals. Sodium is plentiful in the common table salt that people use to flavor food to their taste. It is a large constituent of sea water; hence, in water supplies contaminated by the sea as in the case of Antipolo mentioned earlier, this element would be plentiful. The salinity content in the sample is insignificant from Table 2 it ranges from 0.03 to 0.03 mg/100 ml.

Bicarbonate alkalinity: If the initial pH of a sample is less than 7.0 in Table 2, then there is bicarbonate alkalinity. Alternatively, even though the amount of pH in Table 2 is 6.73 the acidity is low so the Bicarbonate is not alkaline. It is in the range value that is recommended by WHO which is 29.33 to 30.27 mg/100 ml.

Carbonate alkalinity: There were interference changes in pH during alkalinity titration, which make the pH 6.73 to 6.67 in Table 2. If only CO₃²⁻ ions are present, the

amount of acid necessary to lower the pH below 6.73 is one-half the total acid necessary to lower the pH below 6.67. The first abrupt pH change at 6.73 represents the conversion of carbonate to HCO_3^- (that is, half of the carbonate has been neutralized), and the second abrupt pH change at 6.67 represents neutralization of the HCO_3^- created from carbonate. If only CO_3^{2-} ions. carbonate rocks, mainly aragonite and calcite, constitute about 11% of the total sediments of the earth's crust. Bicarbonate salts are relatively soluble in water, but calcium carbonate is not. Freshwater does not sustain extreme super saturation of calcium carbonate. In most cases, the phase precipitated is calcite—the polymorph of calcium carbonate that has the lowest solubility product. Carbonate solubility in seawater is governed essentially by the same parameters, but kinetically the precipitation of calcium carbonate is complicated by high concentrations of Mg^{2+} and the actions of marine organisms.

Bacteriological analysis bacteria: Are single-celled prokaryotic microorganisms shaped as rods (bacillus), spheres (coccus), or spirals (vibrios, spirilla, spirochetes) that are uniquely important in environmental chemistry. Characteristics of most bacteria include a semi rigid cell wall, motility with flagella for those capable of movement, unicellular nature (although clusters of cloned bacterial cells are common), and multiplication by binary fission in which each of two daughter cells is genetically identical to the parent cell. Bacteria obtain the energy and raw materials needed for their metabolic processes and reproduction by mediating chemical reactions. Nature provides a large numbers of such reactions and bacterial species have evolved that utilize many of them. Because of their participation in such reactions, bacteria are involved in many biogeochemical processes and elemental transitions and cycles in water and soil. The metabolic activity of bacteria is greatly influenced by their small size, which is of the order of a micrometer in magnitude. Their surface-to-volume ratio is very large, so that the inside of a bacterial cell is highly accessible to a chemical substance in the surrounding medium. Thus, for the same reason that a finely divided Catalyst is more efficient than a more coarsely divided one, bacteria may bring about very rapid chemical reactions compared with those mediated by larger organisms. The study research on bacteria is base faecal coliform (FC) and non-faecal coliform (FC), from Table 2 the range values are 25.00 to 11.08 and 8.33 to 9.35 $\mu/100$ ml. From chemistry point of view, those values may not influence the oxidation and reduction.

Conclusion

The available information on the presence of physio-

chemical and bacteriological in water samples is spotty, many studies lack specific information on the type of water sample (blowholes, river, or tap water), where, when, and why samples were collected. However, taken as a whole, the studies indicate that the presence of physiochemical in water samples should be low at concentrations in the tenths to single mg/100 ml range. Chemical analysis in water concentrations near landfills, agricultural sites, chard coal regions, or locations are nitrogen-and phosphorus -enriched rock can have elevated levels, typically of carbonate. Higher nitrogen and phosphorus carbonate in water concentrations are limited by the low solubility of most mineral species.

Water quality can be a geologic or anthropogenic function, both of which could influence well-water compositions in the study area. About 20% of the well-tested wells have high TDS concentrations. Another 44% of the turbidity is above 1 mg/100 ml. Also 16 of the well have faecal coliform counts above 20 $\mu/100$ MI. While the SRP has the highest sulphate concentration (SO_4^{2-}), WTS well has the highest nitrate concentration (NO_3^-). The pH<7.0 indicated a tendency of acidity.

There are also low irons (Fe^{2+}) values in the well. pH value treated to WHO standard can even cause some damage in the human system due to it acidity.

Conflicts of interest

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors would like to thank The Sierra Leone Government Scholarship (SLG) and the China Scholarship Council (CSC) for supporting this study. They also are thankful to the Chemistry Department of Njala University for inspiring and designing the study and to SALWACO for allowing the use of the laboratory.

REFERENCES

- Al-Khatib I, Kamal S, Taha B, Al Hamad J, Jaber H (2003). Water-health relationships in developing countries: A case study in Tulkarem district in Palestine. *Int. J. Environ. Health Res.* 13:199-206.
- Barnett AA, Read N, Scurlock J, Low C, Norris H, Shapley R (2000). Ecology of rodent communities in agricultural habitats in eastern Sierra Leone: Cocoa groves as forest refugia. *Trop. Ecol.* 41(2):127-142.
- Chang M, McBroom M, Beasley R (2004). Roofing as a source of nonpoint water pollution. *J. Environ. Manage.* 73:307-315.
- Evans C, Coombes P, Dunstan R (2006). Wind, rain and bacteria: The effect of weather on the microbial composition of roof-harvested rainwater. *Water Res.* 40:37-44.

- Gerba CP, Smith JE (2005). Sources of pathogenic microorganisms and their fate during land application of wastes. *J. Environ. Qual.* 34:42-48.
- Lou J, Lee W, Han J (2007). Influence of alkalinity, hardness and dissolved solids on drinking water taste: A case study of consumer satisfaction. *J. Environ. Manage.* 82:1-12.
- Lye D (2002). Health risks associated with consumption of untreated water from household roof catchment systems. *J. Am. Water Resour. Assoc.* 38(5):1301–1306.
- Nasserdin K, Mimi Z, Bevan B, Elian B (2009). Environmental management of the stone cutting industry. *J. Environ. Manage.* 90:466-470.
- NRDS (2009). Sierra Leone national rice development strategy, 31pp.
- Squire CB (2001). Sierra Leone's biodiversity and the civil war: A case study prepared for the biodiversity support program. Washington, D.C.
- Thomas F, Bastable C, Bastable A (2003). Faecal contamination of drinking water during collection and household storage: the need to extend protection to the point of use. *J. Water Health* 1(3):109–115.
- USAID (2012). USAID projects in Sierra Leone.
- Van Derslice J, Briscoe J (1995). Environmental interventions in developing countries, interactions and their implications. *Am. J. Epidemiol.* 141:135-144.