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RESEARCH ARTICLE

WATER QUALITY ASSESSMENT FOR DRINKING AND SANITATION PURPOSES IN SECONDARY SCHOOLS IN PORT HARCOURT METROPOLIS, RIVERS STATE, NIGERIA

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ABSTRACT

Water quality assessment research will go on despite the numerous research previously carried out because water quality is not constant and as exploration activities are being carried out around the world, the quality of water depreciates. The school environment represents an important setting and needs to be monitored as the students' social habits and behaviors are learned at school. Every child has the right to be in a school that offers safe drinking water, healthy sanitation and hygiene education. There is therefore dire need to monitor drinking water quality provided by the school, for potability and sanitation regularly. A total of 40 drinking water samples were collected from 40 different secondary schools (27 day schools and 13 boarding schools), randomly selected within the Port Harcourt Metropolis, and analyzed using standard analytical techniques. To achieve the aim of this research work, an already delineated map of Port Harcourt Metropolis, into 13 zones, by the Survey Department was used. Physicochemical and microbiological parameters were determined to ascertain how safe the water is for direct consumption. Descriptive statistical analysis using Microsoft Excel 2013 Version was adopted to determine parameter concentration trends across the study area. Some of the results obtained are at variance with the Standard Organisation of Nigeria (SON) and World Health Organisation (WHO) standards for potable water. The pH values ranged from 3.78 – 7.72 with a mean value of 5.75. About 40% of the samples met WHO and SON minimum acceptable limit of 6.5 – 8.5. The reported pH range for 60% of the water samples showed that the drinking water in some secondary schools is acidic and well below the stipulated range of 6.5 – 8.5 for drinking purposes. The implication is that drinking water in most secondary schools in Port Harcourt Metropolis is acidic. All other physico-chemical parameters fall within WHO and SON standard for drinking water except for Magnesium. 67% of the samples had elevated values that ranged from 0.27 – 3.38mg/l, above (up to 12 times) the allowable limit stipulated by WHO and SON. All heavy metals present in the water samples were within the WHO and SON limits, making the water virtually free from dangers to the human body posed by the presence of heavy metals in water. The water samples were also free from total coliform bacteria and faecal coliform bacteria. However, the results showed the presence of total heterotrophic bacteria to a harmful quantity (well above 10cfu/ml which is the allowable limit by SON) in 30% of the water samples. This suggests that drinking water in 30% of the schools is not fit for human consumption. The study recommends installation of treatment plants in every day and boarding secondary schools. This is to facilitate the treatment of drinking water, for acidity and bacteria, before consumption by the students. The acidity can also be treated by introducing baking soda (sodium bicarbonate) in measured amounts into the water before drinking, while the bacteria can be removed by chlorination. Regular and periodic monitoring of the water quality in secondary schools, by designated authorities, is also urgently recommended.

KEYWORDS

Physiochemical, Conductivity, Salinity, Turbidity, Ph

1. INTRODUCTION

Water is the elixir of life, without water there is no existence (Effiong, 2017). It is an absolute necessity for life on earth. Water is the major component of all living beings and it is the major constituent of human cells (Wikipedia, 2016). It is involved in every bodily function from circulation and digestion to the control of body temperature and the excretion of waste products. Water is, after oxygen, invaluable and vital to the existence of all living things. It is used by all plants and animals in order to provide essential minerals for growth and nourishment. Water in its natural state is colorless, tasteless and odorless. It makes up to about 60% of human body mass. 60% of the weight in men is made up of water, while that of women is 55%. Infants are about 70% to 80% water while the elderly are around 45% (Jones and Bartlett, 2012). Water covers about 75% of the total earth's surface area. It appears naturally in all three common states of matter (liquid, gas and solid) on Earth. It makes up coastal water bodies (sea, estuaries and oceans) and freshwater bodies (ponds, lakes, rivers, streams and groundwater). Approximately 97.2% of

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it is saline while 2.8% is fresh ("Water Fact sheet", 2014). Water is not only a crucial environmental factor to all forms of life. It also has a significant role to play in socio-economic development of man and his state of well-being.

The benefits of water extend to developmental sectors such as education, health, agriculture, food production, industrial, energy and other socio-economic activities. Water having acceptable quality in its physical, chemical and bacteriological parameters, so that it can be used for drinking and cooking, is referred to as potable (WHO, 2004). It has been treated, purified or filtered and meets all standards for drinking water (Effiong, 2017). Therefore, water is termed 'potable' when it does not pose any significant health risk over a long time of consumption and has all qualities to serve as drinking water. Potable or safe drinking water is not completely pure as it contains some traces of salts such as calcium, magnesium, carbonates, bicarbonates and others. The monitoring organizations under the supervision of the Joint Monitoring Programme (JMP) defined "safe drinking water" as water from "improved water sources," which includes boreholes, household connections, rainwater collection points, public standpipes/taps, protected hand-dug wells and springs.

The standards for safe drinking water are set for the different quality parameters and are different for different countries. The standard by WHO is not exactly the same for the USA, Nigeria, Canada, Russia, India, Kenya, Ethiopia, and so on. It is recommended by medical experts that adults consume 8-10 glasses of water daily. People adhere to this recommendation religiously but majority do not take into cognizance the quality of water they consume. The water ingested daily can either improve or deter good health if its quality is not taken into consideration. Groundwater resource is the most important resource available to mankind. It exists below the surface of the ground in the spaces between particles of rock or soil, or in the crevices and cracks in rocks, usually within 100 meters of the surface of the Earth (WHO, 2004). It plays a substantial role in water supply, in ecosystem functioning and human well-being. Worldwide, 2.5 billion people depend solely on groundwater resources to satisfy their basic daily water needs, and hundreds of millions of farmers rely on groundwater to sustain their livelihoods and contribute to the food security of so many others (WHO, 2004). According to a report from WHO, groundwater provides drinking water to at least 50% of the global population and accounts for 43% of all water used for irrigation, and also sustains the base flows of rivers and important aquatic ecosystems (WHO, 2004).

Water is a liquid without colour, smell or taste. It is composed of oxygen in its pure state and hydrogen. Providing students with access to safe, free drinking water in the school is one of strategies that schools can use to create an enabling environment that supports good health and sound learning. Potable drinking water can contribute to good health, and schools are in a unique position to promote healthy dietary behaviors, including drinking water (Adams et al., 2009). More than 90% of children and adolescents are enrolled in schools, and students typically spend, at least, 6 hours at school each day (National Centre for Education Statistics, 2011). Ensuring that pupils have access to safe, free drinking water throughout the school environment gives them a healthy alternative to sugar sweetened beverages before, during and after school (Muckelbauer et al., 2009). Since water is an essential nutrient that is vital to life, poor hydration can harm physical and mental performance. Healthy and calorie free water is the perfect hydrating beverage and an ideal alternative to sugary drinks, such as soda (Wang et al., 2009). Access to safe drinking water helps to increase students' overall water consumption, maintain hydration and reduce energy intake, if substituted for sugar-sweetened beverages (Kaushik et al., 2007). Also, adequate hydration may improve cognitive function among children and adolescents, which is important for learning (Centre for Disease Control and Prevention, 2014).

2. Area of Study

This study was carried out in Port Harcourt Metropolis, Rivers State. The study area covers 260sq.Km. As at the year 2020, population was of 2,667,435 persons (National Bureau of Statistics, 2021). The area is located in the south-south region of Nigeria or otherwise known as Niger Delta Region. It is located between Latitudes $4^0$45'E - $4^0$60'E and Longitudes $6^0$50'E - $8^0$00'E according to Wokocha and Omenihu, 2015 as shown in Figure 1. Water samples were collected from 40 secondary schools distributed across Port Harcourt Metropolis in Rivers State.

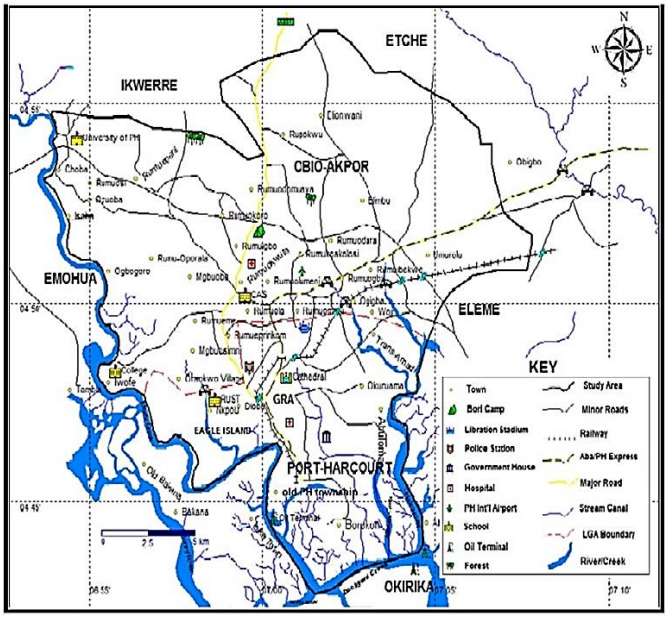

Figure 1: Map of Port Harcourt Metropolis (Source: Adapted from Google Earth, (2020).

3. Methodology

3.1 Sampling Locations

A total of 40 drinking water samples were collected from 40 different secondary schools (27-day schools and 13 boarding schools), randomly selected within the Port Harcourt Metropolis, in Rivers State. To achieve the aim of this research work, an already delineated map of Port Harcourt Metropolis, into 13 zones, by the Survey Department was used (Figure 2). The zones are:

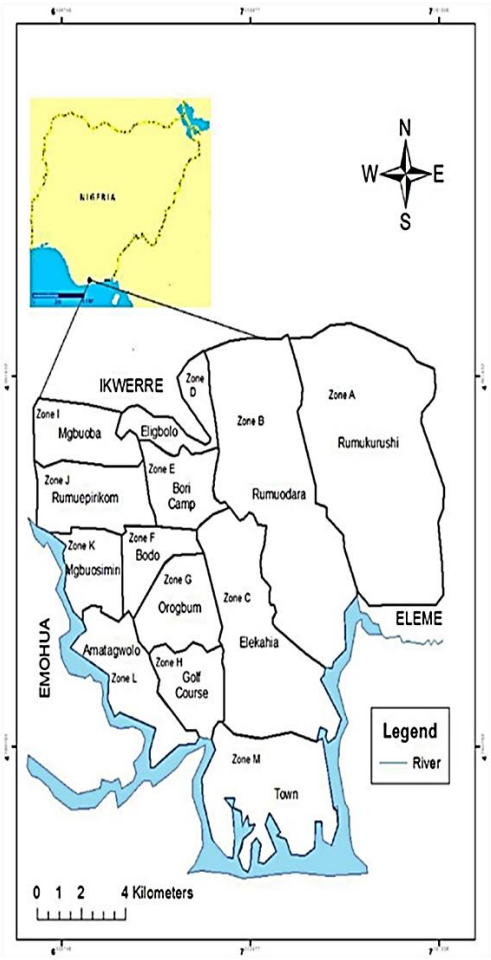

Figure 3: Map of Port Harcourt metropolis showing 13 zones (Source: Survey Department Port Harcourt, 2007)

3.1.1 Rumukwurushi (Zone A; Woji/Rumuibekwe/Elimgbu)

(i) Word of Faith Group of schools, Woji. Day.

(ii) Opendoor International School, Woji. Day.

(iii) Faith International School, Woji. Day.

3.1.2 Rumuodara (Zone B; Rukpokwu/Rumuodomaya)

(i) Vondorix International School, Rukpokwu. Boarding.

(ii) Hallel College, Rukpowu. Boarding.

(iii) Wisdom Gate International College, Rukpokwu. Boarding.

3.1.3 Elekahia (Zone C; Rumuomasi/Transamadi)

(i) Graceland International School, Stadium Road. Boarding.

(ii) Tantua High School, Elekahia. Boarding.

(iii) Teko Education Centre, Rumuomasi. Day.

3.1.4 Rumuokwuta (Zone D; Rumuokwuta/Ozuoba)

(i) Jephthah Comprehensive Secondary School, Ozuoba. Boarding.

(ii) Royal Girls Academy, Ozuoba. Boarding.

(iii) Model Girls Secondary school, Rumuokwuta. Day.

3.1.5 Eligbolo (Zone E; Aluu/Rumuokoro)

(i) Federal Government College, Rumuokoro. Boarding.

(ii) Model Girls Junior Secondary School, Mbodo Aluu. Day.

(iii) Jesuit Memorial College, Mbodo Aluu. Boarding.

3.1.6 Bodo (Zone F; GRA)

(i) Olivet Heights International School, Gra Phase2. Day

(ii) Norwegian International School, GRA Phase3. Boarding.

(iii) Pri-Queen Academy, GRA Extension. Day.

3.1.7 Ogbunabali (Zone G; Abuloma/woji/GRA)

(i) Community Junior Secondary School, Rumurolu. Day.

(ii) God's Favour Group of Schools, Ozuboko.

(iii) Catoky International Secondary School. GRA Extension. Day.

3.1.8 Golf Course (Zone H; Abuloma)

(i) Olives Secondary School, Abuloma. Day.

(ii) Federal Government Girls College, Abuloma. Boarding.

(iii) State Secondary School, Amadi Ama. Day.

3.1.9 Mgbuoba (Zone I)

(i) Cenad High School. Mgbuoba. Day.

(ii) Bloombreed High School. Mgbuoba. Boarding.

(iii) University Demonstration Secondary School, Choba. Day.

3.1.10 Rumuepirikom (Zone J; Elioparanwo/mgbuoba)

(i) Community Secondary School, Rumuepirikom. Day.

(ii) The Nobles Oxford Academy, Elioparanwo. Day.

(iii) Victory International High School, Elioparanwo. Day.

3.1.11 Mgbuosimiri (Zone K; Rumuolumeni/Rumueme)

(i) De Masters International School, Rumuolumeni. Day.

(ii) Model Girls Secondary School, Rumueme. Day.

(iii) Community Secondary School, Nkpor. Day.

3.1.12 Amatagwolo (Zone L; RSU/Eagle Island/Mile 4)

(i) Alpha Academy Eagle Island. Day.

(ii) International Secondary School, RSU. Day.

(iii) Istan Comprehensive High School, Mile 4. Day.

3.1.13 Town (Zone M; Borikiri)

(i) Government Comprehensive Secondary School, Borikiri. Boarding.

(ii) Nigerian Navy Secondary School, Borikiri. Boarding.

(iii) Methodist Girls High School, Harbour Road. Day.

(iv) Emarid College. Harbour Road. Day.

Zones A to M are made up of the 40 schools under study, representing all secondary schools in Port Harcourt Metropolis. An average of 3 schools was randomly assessed from each of the zones.

3.2 Materials and Equipment

Materials used for the data collection and laboratory analysis include the following:

1) Sterilized, properly labeled, one liter (1L) white plastic sample Jerry cans (for physic-chemical analysis).

2) Sterilized glass laboratory bottles (for microbiological analysis and heavy metals)

3) A Global Positioning System (GPS) tool (to measure the coordinates of the boreholes to be sampled)

4) Iced-pack coolers (for carrying samples back to the laboratory, in accordance with procedure, guidelines and standards).

5) Field notebook and pen.

6) Extech in-situ Equipment.

7) Atomic Absorption Spectrophotometer (AAS) for the analysis of heavy metals.

8) Laminar flowhood, autoclave, water bath, incubator, hot plate, weighing balance, microwave and vortex mixer (for microbial analysis).

3.3 Field Methods

Standard field methods were applied in the sample collection at the site and in-situ analysis carried out according to standard procedures and practices.

3.4 Collection of Samples

The water samples were collected from borehole tank stands, from 40 different secondary schools, randomly selected from the thirteen zones, using small white jerry cans of one liter capacity, and sterilized glass bottles. These bottles were rinsed with the appropriate solvent to avoid contamination by any physical, chemical or microbial means. The collected borehole water samples were then labeled immediately on the field using appropriate codes and transferred into sterile ice-packed coolers. To ensure the efficacy of the physical parameters; Temperature, P^H, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity and Turbidity readings were measured, in-situ, using the Extech DO700 meter and Extech Turbidity meter TB400. The samples were then taken to the laboratory, where they were stored in the refrigerator for microbial and physicochemical analysis.

3.6 Sample Preservation and Storage

Ice-packed coolers were used to store and preserve the water samples collected in accordance with Standard Guidelines. Samples for metal analysis were collected in plastic containers, as certain cations such as Zinc (Zn), Manganese (Mn), Cadmium (Cd), Copper (Cu), Iron (Fe), Sodium (Na), Potassium (K) and Lead (Pb) are subject to loss by adsorption or ion-exchange with walls of glass containers. The containers for metals were acidified with Nitric acid to a pH below 2.0, to prevent any physiochemical reaction (Ubong and Gobo, 2001). This was also preserved the water sample before analysis (adding 1ml of HNO_3 to 1 liter of sample).

3.7 Laboratory Procedure

The laboratory procedures, considered to be sufficiently accurate and most acceptable for general use in water analysis have been described in several publications and the most widely known, and used, (WHO, 2011; SON, 2007). Water samples randomly collected from the 40 secondary schools in Port Harcourt Metropolis were taken to the Institute of Pollution Studies Laboratory at the Rivers State University, Nkpolu-

Oroworukwo, Port Harcourt, for analysis. The water samples were analyzed for the routine water chemistry constituents (chemical parameters) that are indicative of general water quality; Hardness, Alkalinity, Bicarbonate, Calcium, Magnesium, Chloride, Phosphate, Nitrate, Sulphate etc. and the Microbial Parameters such as the Total Heterotrophic Bacteria (THB), Total Coliform Bacteria (TCB) and Faecal Coliform Bacteria (FCB). The water samples were analyzed also for the following heavy metals and their concentrations: Sodium (Na), Potassium (K), Zinc (Zn), Lead (Pb), Cadmium (Cd), Copper (Cu), Manganese (Mn) and Iron (Fe).

4. Results and Discussion

4.1 On-site Data

The on–site data are presented in Table 1 which shows the borehole codes (Sta1 – Sta40), the 40 secondary schools, their school type (Boarding and Day), locations (from the 13 zones in Port Harcourt Metropolis) and coordinates. 27-day schools and 13 boarding schools were investigated.

4.2 Physicochemical Parameters Results

The physicochemical and heavy metal parameter results are presented in Tables 2.

4.2.1 P^H

The mean P^H values for the water samples from all the schools ranged from 3.78 – 7.72 with a mean value of 5.75. Water sample at Sta32, from Jesuit Memorial College, Rumuagholu, Mbodo Aluu, recorded the highest P^H value of 7.72, while that of Emarid College, Harbour Road (Sta4), recorded the least P^H value of 3.78.

4.2.2 Temperature

The mean Temperature of the water samples ranged from 29.1°C – 30.6°C with a mean of 29.9°C. Sta15 water sample from Community Secondary School, Rumuepirikom recorded the highest mean temperature of 30.6°C, while University Demonstration Secondary School, Uniport, Choba (Sta38), recorded the least mean Temperature of 29.1°C.

4.2.3 Electrical Conductivity

The mean Electrical Conductivity (EC) of the water samples ranged from 38.3µS/cm – 378.7µS/cm with mean value of 208.5µS/cm. Emarid College, Harbour Road (Sta4) recorded the highest electrical conductivity of 378.7µS/cm while the lowest was observed in Sta10 (Federal Government Girls College, Abuloma) with a value of 38.3µS/cm.

4.2.4 Turbidity

The mean turbidity value for the water samples ranged from 0.2NTU – 1.1NTU, with mean value of 0.7NTU. Sta35 (Istan Comprehensive High School, Mile 4) recorded the highest turbidity of 1.1NTU while Sta31 (Wisdom Gate International College, Rukpokwu) recorded the lowest with a value of 0.2NTU.

4.2.5 Salinity

The salinity for the water samples from all the schools ranged from 0.018 – 0.202mg/l with a mean value of 0.11mg/l. Water samples from Emarid College, Harbour Road (Sta4) recorded the highest, with Salinity of 0.202mg/l, while Federal Government Girls College, Abuloma (Sta10) and Jephtah Comprehensive Secondary School, East West Road (Sta17) recorded the lowest, with Salinity value of 0.018mg/l.

4.2.6 Total Dissolved Solids

The mean total dissolved solids concentration in the water samples from all the schools ranged from 26.7mg/l – 263.0mg/l with a mean value of 144.9mg/l. Water sample Sta4 (Emarid College, Harbour Road) recorded the highest concentration, with TDS value of 263.0mg/l, while Sta17 (Jephthah Comprehensive Secondary School, East West Road) recorded the least concentration, with TDS of 26.7mg/l.

4.2.7 Phosphate

The mean phosphate values of the water samples ranged from 0mg/l – 0.39mg/l with a mean value of 0.2mg/l). Federal Government Girls College, Abuloma (Sta10) had the highest phosphate concentration with a value of 0.39mg/l, while Model Girls Secondary School, Rumueme, Hallel College, Rukpokwu, Teko Education Centre, Rumuomasi, International Secondary School, RiSU, and Victory International High School, Elioparanwo (Sta14, 30, 33, 34 and 40 respectively) had 0.0mg/l phosphate content.

4.2.8 Nitrate

The mean Nitrate concentration in the water samples ranged from 0.02mg/l – 3.00mg/l with a mean value of 1.51mg/l. Sta8 water sample from Woji Town of Faith group of Schools, Woji recorded the highest nitrate concentration of 3.00mg/l, while Sta38 water sample (University Demonstration Secondary School, Uniport) recorded the least nitrate concentration of 0.02mg/l.

4.2.9 Sulphate

The sulphate concentration of the water samples ranged from <1.0mg/l – 17.2mg/l with a mean value of 8.6mg/l. Sta4 recorded the highest sulphate concentration of 17.2mg/l, while Sta1, Sta5, Sta7-20, Sta22-27 and Sta29-40 recorded the least concentration of less than 1.0mg/l (<1.0mg/l).

4.2.10 Chloride

The chloride content of the water samples ranged from <1.0mg/l – 24.0mg/l with a mean value of 12.0mg/l. Sta4 recorded the highest chloride content of 24.0mg/l while the lowest was observed in Sta9, 31, 32, 38 with a value of less than 1.0mg/l (<1.0mg/l).

4.2.11 Alkalinity

The alkalinity of the water samples ranged from 0mg/l – 48.7mg/l with a mean value of 24.0mg/l. Sta37 (Bloombreed High School, Mgbuoba) recorded the highest alkalinity of 48.7mg/l while the lowest were seen in Sta 4 and Sta6, where alkalinity was not detected (ND).

4.2.12 Total Hardness

Total hardness of the water samples ranged from 0.2mg/l – 39.2mg/l with a mean value of 19.7mg/l. The Nobles Oxford Academy, Elioparanwo (Sta 19) recorded the highest Total Hardness of 39.2mg/l while the lowest was observed in Sta 38, where the Total Hardness was 0.2mg/l.

4.2.13 Magnesium

Magnesium in the water samples ranged from 0.05mg/l – 3.38mg/l with a mean value of 1.72mg/l. Sta 19 recorded the highest magnesium content with a concentration of 3.38mg/l while the lowest was observed in Sta17, where magnesium was 0.05mg/l.

4.2.14 Calcium

The calcium present in the water samples ranged from <0.20 – 11.83mg/l with a mean value of 5.92mg/l. Sta 37 recorded the highest calcium content of 11.83mg/l while the lowest with <0.20mg/l was observed in Sta 21, Sta 31, Sta 38 and Sta 40.

4.3 Heavy Metals Parameters Results

The results of the heavy metals analyses are presented in Table 3.

4.3.1 Iron (Fe)

The iron content in the water samples ranged from <0.005 – 0.043mg/l with a mean value of 0.022mg/l. The highest iron content was recorded in Sta 28 (Vondorix International Schools, Rukpokwu) with a value of 0.043mg/l, while the lowest was in Sta 1-3, Sta 9, Sta 11-12, Sta 14, Sta 17-18, Sta 20, Sta 22-25, Sta 32 and Sta 34 with values less than 0.005mg/l respectively.

4.3.2 Sodium (Na)

The sodium content in the water samples ranged from 0.730 – 59.371mg/l with a mean value of 30.051mg/l. The highest sodium content was recorded in Sta 4 with a value of 59.371mg/l, while the lowest was observed in Sta 38 with value 0.730mg/l.

4.3.3 Potassium (K)

The potassium content in the water samples ranged from <0.001 – 14.314mg/l with a mean value of 7.16mg/l. The highest potassium content was recorded in Sta 4 with a value of 14.314mg/l.

4.3.4 Manganese (Mn)

The Manganese content in the water samples ranged from 0.001mg/l – 0.607mg/l with a mean value of 0.304mg/l. The highest Manganese content was recorded in Model Girls Junior Secondary School, Mbodo Aluu

(Sta 29) with a value of 0.607mg/l, while the lowest was observed in Olives Secondary School, Abuloma (Sta 9), with a value of 0.001mg/l.

4.3.5 Copper (Cu)

The Copper content in the water samples ranged from <0.001mg/l – 0.063mg/l with a mean value of 0.032mg/l. The highest Copper content was recorded in Sta 38 with a value of 0.063mg/l, while the lowest was observed in Sta 1-4, Sta 6-7, Sta 9-14, Sta 16 and Sta 19, with a value of less than 0.001mg/l.

4.3.6 Lead (Pb)

The Lead content in the water samples ranged from <0.010mg/l – 0.423mg/l with a mean value of 0.217mg/l. The highest Copper content was recorded in Sta 13 with a value of 0.423mg/l, while the lowest was observed in Sta 1-2, Sta 15-16, Sta 28-29 and Sta 37-39 with a value of less than 0.010mg/l.

4.3.7 Cadmium (Cd)

The Cadmium content in the water samples ranged from 0.000mg/l – 0.026mg/l with a mean value of 0.013mg/l (World Health Organization, 2011). The highest Copper content was recorded in Sta 40 with a value of 0.026mg/l, while the lowest was observed in Sta 14, and Sta 37, with a value of 0.000mg/l.

4.3.8 Zinc (Zn)

The Zinc content in the water samples ranged from <0.001mg/l – 0.040mg/l with a mean value of 0.021mg/l (WHO, 2011; SON, 2007). The highest Zinc content was recorded in Sta 1 (Government Comprehensive Secondary School, Borokiri) with a value of 0.040mg/l, while the lowest were less than 0.001mg/l in Sta 3-4, Sta 6-24 and Sta 26-40.

Table 1: On-site Data of Borehole Water Samples from Secondary Schools in Port Harcourt Metropolis, September 2021.

School Ownership	School	Location	Sample Code	Coordinates	School Type	Colour	Smell
1.Private	Opendoor International School	Woji	Sta5	N04 51' 37.0", E007 01' 48.8"	Day	Colourless	None
2.Private	Faith International School	Woji	Sta6	N04 51' 37.0", E007 01' 48.8"	Day	Colourless	None
3.Government	Community Junior Secondary School	Woji	Sta7	N04 51' 37.0", E007 01' 48.8"	Day	Colourless	None
4.Private	Word of Faith group of Schools	Woji	Sta8	N04 51' 37.0", E007 01' 48.8"	Day	Colourless	None
5.Private	Vondorix International School	Rukpokwu	Sta28	N04 51' 12.2", E007 04' 88.4"	Boarding	Colourless	None
6.Government	Model Girls Junior Secondary School	Mbodo Aluu	Sta29	N04 51' 12.2", E007 04' 88.4"	Day	Colourless	None
7.Private	Hallel College	Rukpokwu	Sta30	N04 51' 12.2", E007 04' 88.4"	Boarding	Colourless	None
8.Private	Wisdom Gate International College	Rukpokwu	Sta31	N04 51' 12.2", E007 04' 88.4"	Boarding	Colourless	None
9.Private	Jesuit Memorial College	Mbodo Aluu	Sta32	N04 51' 12.2", E007 04' 88.4"	Boarding	Colourless	None
10.Private	Teko Education Centre	Rumuomasi	Sta33	N04 50' 07.4", E007 01' 31.4"	Day	Colourless	None
11.Private	Graceland International School	Elekahia	Sta25	N04 50' 07.4", E007 01' 31.4"	Boarding	Colourless	None
12.Private	Tantua High School	Elekahia	Sta26	N04 50' 07.4", E007 01' 31.4"	Boarding	Colourless	None
13.Private	Olives Secondary School	Abuloma	Sta9	N04 51' 33.8", E007 01' 13.4"	Day	Colourless	None
14.Government	Fed. Govt. Girls College	Abuloma	Sta10	N04 51' 33.8", E007 01' 13.4"	Boarding	Colourless	None
15.Private	God's Favour Group of Schools	Ozuboko	Sta11	N04 51' 33.8", E007 01' 13.4"	Day	Colourless	None
16.Government	State Secondary School	Amadi-Ama	Sta12	N04 51' 33.8", E007 01' 13.4"	Day	Colourless	None
17.Private	Norwegian International School	GRA Phase 3	Sta22	N06 52' 46.4", E004 42' 33.9"	Boarding	Colourless	None
18.Private	Pri-Queen Academy	GRA	Sta23	N06 52' 46.4", E004 42' 33.9"	Day	Colourless	None
19.Private	Catoky International Secondary School	Extension GRA	Sta24	N06 52' 46.4", E004 42' 33.9"	Day	Colourless	None
20.Private	Olivet Heights International School	Extension	Sta27	N06 98' 55.0", E004 84' 95.0"	Day	Colourless	None
21.Private	Alpha Academy	GRA Phase 2	Sta13	N04 78' 94.1" E007 00' 00.7"	Day	Colourless	None
22.Private	International Secondary School	Eagle Island	Sta34	N04 79' 23.0" E006 98' 25.0"	Day	Colourless	None
23.Private	De Master's International School	RiSU, Nkpolu	Sta39	N04 47' 47.5", E006 55' 42.6"	Day	Colourless	None
24.Private	Victory High School	Rumuolumeni	Sta40	N04 47' 47.5", E006 55' 42.6"	Day	Colourless	None
25.Government	Community Secondary School	Rumuolumeni Nkpor	Sta20	N04 47' 47.5", E006 55' 42.6"	Day	Colourless	None
26.Private	Jephthah Comprehensive Secondary School	Ozuoba	Sta17	N04 52' 18.9", E006 55' 58.5"	Boarding	Colourless	None
27.Government	Federal Government College	Rumuokoro	Sta21	N04 52' 47.2", E006 56' 26.8"	Boarding	Colourless	None
28.Government	Model Girls Secondary School	Rumuokwuta	Sta16	N04 52' 47.2", E006 56' 26.8"	Day	Colourless	None
29.Private	Royal Girls Academy	Ozuoba	Sta18	N04 52' 18.9", E006 55' 58.5"	Boarding	Colourless	None
30.Private	Cenad High School	Mgbuoba	Sta36	N04 52' 18.9", E006 55' 58.5"	Day	Colourless	None
31.Private	Bloombreed High School	Mgbuoba	Sta37	N04 52' 18.9", E006 55' 58.5"	Boarding	Colourless	None
32.Government	University Demonstration Secondary School	Choba	Sta38	N04 52' 18.9", E006 55' 58.5"	Day	Colourless	None
33.Government	Community Secondary School	Rumuepirikom	Sta15	N04 50' 49.7", E006 55' 42.6"	Day	Colourless	None
34.Private	The Nobles Oxford Academy	Elioparanwo	Sta19	N04 50' 49.7", E006 55' 42.6"	Day	Colourless	None
35.Government	Model Girls Secondary School	Rumueme	Sta14	N06 52' 46.4", E004 42' 33.9"	Day	Colourless	None
36.Private	Istan Comprehensive High School	Rumueme	Sta35	N06 52' 46.4", E004 42' 33.9"	Day	Colourless	None
37.Government	Government Comprehensive Secondary School	Borikiri	Sta1	N04 44' 56.0" E007 02' 06.0"	Boarding	Colourless	None
38.Navy	Nigerian Navy Secondary School	Borikiri	Sta2	N04 44' 56.0" E007 02' 06.0"	Boarding	Colourless	None
39.Church	Methodist Girls High School	Harbour Road	Sta3	N04 79' 89.4" E006 99' 95.3"	Day	Colourless	None
40.Private	Emarid College	Harbour Road	Sta4	N04 79' 89.4" E006 99' 95.3"	Day	Colourless	None

Table 2: Physiochemical Parameters of Borehole Water Quality Analysis from Secondary Schools in Port Harcourt Metropolis, September 2021.

Parameters/ Sample codes	PH	Temperature °C	Electrical Conductivity µS/cm	Salinity ‰	Turbidity NTU	Total Dissolved Solids mg/l	NO3- mg/l	PO4-3 mg/l	SO4-2 mg/l	Cl- mg/l	Alkalinity. mg/l	Hardness mg/l	Ca2+ mg/l
Sta 1	6.67	29.4	230.7	0.111	0.9	164.7	1.90	0.02	<1.0	11.4	8.7	13.4	5.07
Sta 2	5.41	29.6	194.3	0.091	0.5	135.3	2.24	0.08	4.1	16.3	8.7	20.4	5.38
Sta 3	4.08	29.5	266.3	0.125	0.3	185.7	2.24	0.10	4.5	12.8	26.0	11.5	3.12
Sta 4	3.78	29.4	378.7	0.202	0.5	263.0	2.82	0.12	17.2	24.0	0.0	35.7	9.83
Sta 5	4.66	29.6	210.3	0.100	0.3	146.7	2.69	0.12	<1.0	9.5	6.0	19.4	5.61
Sta 6	3.87	29.7	322.7	0.152	0.3	225.0	2.86	0.09	3.5	15.2	0.0	6.0	0.81
Sta 7	6.62	29.7	92.7	0.043	0.5	64.3	1.95	0.13	<1.0	5.3	9.3	5.0	0.13
Sta 8	4.52	29.8	199.3	0.093	0.3	139.7	3.00	0.29	<1.0	9.3	33.3	15.3	3.79
Sta 9	6.87	30.4	47.0	0.022	0.3	32.7	0.47	0.22	<1.0	0.4	10.0	1.6	0.43
Sta 10	6.85	30.3	38.3	0.018	0.2	27.3	0.56	0.39	<1.0	1.0	8.0	1.2	0.27
Sta 11	5.94	30.4	92.7	0.043	0.3	65.3	2.39	0.02	<1.0	3.3	6.0	2.0	0.26
Sta 12	4.59	30.4	155.7	0.074	0.2	109	2.85	0.12	<1.0	6.8	5.3	14.8	4.32
Sta 13	4.62	30.4	237.0	0.111	0.3	165.3	2.61	0.02	<1.0	20.7	6.0	8.4	1.09
Sta 14	4.39	30.4	289.3	0.136	0.3	202.7	2.89	0.00	<1.0	23.5	7.3	5.2	0.42
Sta 15	4.63	30.6	177.0	0.083	0.2	123.7	2.66	0.01	<1.0	9.6	6.7	5.8	1.25
Sta 16	4.73	30.5	150.0	0.077	0.3	114	0.82	0.01	<1.0	6.5	8.0	5.9	1.46
Sta 17	5.63	30.4	38.0	0.018	0.3	26.7	0.56	0.03	<1.0	1.4	9.3	0.8	0.22
Sta 18	5.47	30.4	48.0	0.023	0.3	34	0.59	0.03	<1.0	1.1	10.7	0.9	0.09
Sta 19	7.23	30.4	325.3	0.153	0.4	226.7	0.91	0.04	<1.0	17.9	23.3	39.2	10.12
Sta 20	7.18	30.5	112.0	0.052	0.3	77.7	0.75	0.02	<1.0	6.6	10.7	5.6	1.47
Sta 21	7.07	30.3	163.3	0.077	0.3	115	0.52	0.03	1.7	11.4	8.7	0.7	<0.02
Sta 22	5.27	29.5	132.3	0.062	0.7	93	0.50	0.04	<1.0	10.4	8.0	3.8	0.51
Sta 23	5.59	29.5	98.7	0.046	0.3	66.7	0.72	0.03	<1.0	4.9	6.7	2.6	0.60
Sta 24	6.24	29.5	53.7	0.025	0.4	37.7	0.61	0.05	<1.0	1.6	6.7	1.2	0.33
Sta 25	7.24	29.7	60.0	0.029	0.4	42	0.16	0.03	<1.0	1.0	20.0	1.0	0.20
Sta 26	4.87	29.8	133.3	0.064	0.2	93.3	0.64	0.04	<1.0	7.1	8.0	3.0	0.38
Sta 27	4.51	30.0	229.7	0.108	0.3	161	0.79	0.06	<1.0	9.9	5.3	8.3	1.75
Sta 28	5.28	29.7	123.7	0.059	0.3	87.7	0.57	0.01	1.0	5.1	10.7	1.4	0.02
Sta 29	5.01	29.6	161.7	0.078	0.4	114	0.73	0.03	0.5	7.7	10.7	5.9	0.02
Sta 30	5.50	29.6	107.0	0.050	0.2	74.7	0.75	0.00	0.3	3.5	6.7	1.2	0.23
Sta 31	6.60	29.3	68.0	0.033	0.2	48	0.58	0.01	<1.0	0.8	8.0	0.8	<0.02
Sta 32	7.72	29.2	103.7	0.048	0.3	73.3	0.05	0.01	<1.0	<1.0	30.7	22.8	4.22
Sta 33	5.54	29.7	87.7	0.058	0.3	64.3	0.64	0.00	0.2	4.8	8.0	0.8	0.04
Sta 34	4.33	30.2	336.0	0.160	0.4	236	1.04	0.00	<1.0	22.6	4.0	12.2	2.64
Sta 35	6.07	29.2	74.3	0.035	1.1	53	0.38	0.02	<1.0	1.1	8.0	3.8	1.19
Sta 36	6.95	29.2	75.7	0.038	0.3	55.3	0.16	0.01	<1.0	1.0	11.3	4.2	0.51
Sta 37	7.71	30.0	155.0	0.074	0.3	108.3	0.65	0.07	<1.0	2.3	48.7	30.8	11.83
Sta 38	7.27	29.1	58.7	0.029	0.3	41.7	0.02	0.22	0.4	<1.0	8.0	0.2	<0.02
Sta 39	6.68	30.2	181.7	0.086	0.3	126.3	0.85	0.04	<1.0	10.1	8.0	6.5	1.34
Sta 40	5.60	30.0	154.0	0.084	0.4	99.7	0.69	0.00	<1.0	10.2	7.3	1.8	<0.02

Table 3: Heavy Metal Parameters of Borehole Water Samples from Schools in Port Harcourt Metropolis.

	Mg	Cd	Cu	K	Fe	Mn	Pb	Na	Zn
Sample codes	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
Sta 1	0.19	<0.001	<0.001	0.421	<0.005	0.013	<0.010	29.731	0.040
Sta 2	1.68	0.004	<0.001	3.207	<0.005	0.038	<0.010	32.530	0.022
Sta 3	0.91	0.009	<0.001	7.232	<0.005	0.105	0.186	22.277	<0.001
Sta 4	2.70	0.009	<0.001	14.314	0.008	0.101	0.183	59.371	<0.001
Sta 5	1.32	0.010	0.045	2.952	0.032	0.231	0.191	29.887	0.155
Sta 6	0.96	<0.001	<0.001	6.304	0.039	0.201	0.100	42.062	<0.001
Sta 7	1.14	0.002	<0.001	0.736	0.018	0.035	0.067	8.927	<0.001
Sta 8	1.41	0.001	0.010	4.678	0.004	0.219	0.024	26.191	<0.001
Sta 9	0.13	0.005	<0.001	0.691	<0.005	0.001	0.024	1.259	<0.001
Sta 10	0.13	<0.001	<0.001	0.377	0.012	0.021	0.021	1.312	<0.001
Sta 11	0.33	0.010	<0.001	1.958	<0.005	0.042	0.014	9.123	<0.001
Sta 12	0.97	<0.001	<0.001	1.685	<0.005	0.183	0.141	16.825	<0.001
Sta 13	1.38	0.002	<0.001	0.819	0.013	0.126	0.423	46.944	<0.001
Sta 14	1.01	0.000	<0.001	6.636	<0.005	0.106	0.021	56.466	<0.001
Sta 15	0.65	0.008	0.013	0.460	0.010	0.072	<0.010	27.598	<0.001
Sta 16	0.54	0.010	<0.001	1.735	0.014	0.048	<0.010	10.105	<0.001
Sta 17	0.05	0.008	0.026	<0.001	<0.005	0.026	0.069	3.403	<0.001
Sta 18	0.17	0.001	0.012	<0.001	<0.005	0.028	0.057	4.518	<0.001
Sta 19	3.38	<0.001	<0.001	3.201	0.018	0.516	0.043	47.610	<0.001
Sta 20	0.46	0.003	0.020	0.237	<0.005	0.025	0.138	9.720	<0.001
Sta 21	0.16	0.008	0.003	1.324	0.011	0.094	0.124	26.503	<0.001
Sta 22	0.62	0.003	0.018	3.056	<0.005	0.058	0.026	23.079	<0.001
Sta 23	0.27	0.004	0.026	1.806	<0.005	0.066	0.107	9.960	<0.001
Sta 24	0.10	<0.001	0.032	0.588	<0.005	0.031	0.184	4.818	<0.001
Sta 25	0.11	0.002	0.038	0.124	<0.005	0.028	0.115	6.756	0.034
Sta 26	0.49	0.007	0.029	1.412	0.014	0.088	0.155	9.686	<0.001
Sta 27	0.94	0.012	0.026	6.618	0.016	0.164	0.210	28.516	0.000
Sta 28	0.34	0.011	0.018	1.044	0.043	0.083	<0.010	23.452	<0.001
Sta 29	1.42	0.003	0.016	4.030	0.011	0.607	<0.010	21.006	<0.001
Sta 30	0.15	0.008	0.031	0.071	0.011	0.047	0.057	9.163	<0.001
Sta 31	0.19	0.007	0.031	0.712	0.013	0.048	0.045	2.843	<0.001
Sta 32	2.97	0.006	0.018	<0.001	<0.005	0.024	0.088	1.037	<0.001
Sta 33	0.17	0.004	0.034	1.368	0.017	0.039	0.041	8.802	<0.001
Sta 34	1.36	0.006	0.031	3.439	<0.005	0.288	0.134	57.082	<0.001
Sta 35	0.21	0.008	0.016	0.029	0.018	0.051	0.117	3.128	<0.001
Sta 36	0.71	0.005	0.018	<0.001	0.008	0.050	0.074	3.946	<0.001
Sta 37	0.31	0.000	0.022	0.088	0.004	0.055	<0.010	7.061	<0.001
Sta 38	0.06	0.003	0.063	<0.001	0.011	0.034	<0.010	0.730	<0.001
Sta 39	0.77	0.016	0.025	1.041	0.010	0.069	<0.010	30.084	<0.001
Sta 40	0.43	0.026	0.028	0.594	0.022	0.066	0.110	25.579	<0.001

5. Conclusion

The assessment of drinking water from schools in Port Harcourt Metropolis of Rivers State showed variation in quality. Twenty-nine (26) parameters where determined in each of the forty (40) water samples, from 40 secondary schools, within the thirteen (13) zones in Port Harcourt Metropolis. The results showed that about 85% of the parameters studied in each of the water samples met the satisfactory limit for safe drinking water. These parameters include temperature, electrical conductivity, salinity, turbidity, TDS, hardness, phosphate, sulphate, nitrate, chloride, calcium, manganese, lead, zinc, iron, cadmium, copper, sodium, potassium. About 15% (pH, alkalinity and magnesium) had a non-uniform result with some percentages meeting the allowable limit while some were below the standard for drinking water stipulated by standards. Magnesium (Mg^{2+}) was not detected in about 33% of the water samples. They therefore met the 0.20 mg/l limit by SON. 67% had elevated values that ranged from 0.27 – 3.38mg/l, above (up to 12 times) the allowable limit. The Research also showed that 70% of the boreholes had Total Heterotrophic Bacteria within the guideline maximum limit of 10cfu/ml by the World Health Organization. 30% of the water samples, however, were contaminated with THB which is greater than the national and international guideline limits and unacceptable. The findings also showed that alkalinity values of all the samples ranged from 0 – 48.7mg/l. The low alkalinity indicate the acidic nature of water samples in the study locations. Finally, the research findings further showed that only 40% of the samples met WHO and SON minimum acceptable limit of 6.5 – 8.5. The reported pH range for 60% of the water samples showed that the drinking water in some secondary schools is acidic and well below the stipulated range of 6.5 – 8.5. This result shows that the drinking water in most secondary schools in Port Harcourt Metropolis pose a hazardous threat to the health of the students. Therefore, the quality of drinking water from most boarding and day

secondary schools in Port Harcourt Metropolis is undesirable, unhealthy and impermissible for drinking purposes. Quality control measures need to be put in place in the schools, and both physicochemical and microbiological treatment of drinking water carried out before further use.

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