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# Physicochemical and Mineral Properties of Drinking Water from Rural Settlements of Owo Local Government Area of Ondo State, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author OFF designed the study and managed the analyses of the study. Author OIA performed the statistical analysis, wrote the protocols and the first draft of the manuscript while author TB managed the literature searches. All authors read and approved the final manuscript.*

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## ABSTRACT

The major sources of drinking water of the residents of rural settlements in Owo Local Government area are either uncovered wells or streams which are also used as latrines and dumpsites. This coupled with the acute poverty and abysmal sanitary practices of persons living across these settlements spurred scientific interests into the assessment of the safety of the drinking water available to these settlements. Hence, physicochemical and mineral properties of major water sources across these rural settlements were assessed to highlight possible associated health risk factors of the sources of drinking water across 10 rural settlements in Owo Local Government Area (L.G.A.) of Ondo State, Nigeria. Investigations were carried out to assess the total dissolved solvents, water hardness, hydrogen ion concentration (pH), temperature, electric conductivity, sodium ion concentration, potassium ion concentration, magnesium ion concentration, iron ion concentration and chloride ion concentration of water samples from surface (streams) and ground water (wells) sources according to specified WHO standards. The overall safety indexes of different drinking water sources (streams and wells) were also compared for the 10 rural settlements. The

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results indicated varying levels of mineral toxicities for all the drinking water samples obtained across the settlements which pose grave potential health risks. Therefore, government intervention such as provision of pipe-borne water, construction of adequate sewage disposal facilities and proper sanitary surveillance by settlements by local health officials are strongly recommended across these rural settlements.

*Keywords: Drinking water; minerals; toxicities; overall safety index; rural settlements; Owo L.G.A.*

## 1. INTRODUCTION

Drinking water quality is a worldwide concern and has great impact on human health [1]. The safety of drinking water is shown in terms of its physical, chemical (mineral) and bacteriological parameters [1,2]. In developing countries such as Nigeria, most of the rural settlements are poor with lack of access to potable water supplies and hence rely mainly on rivers, streams, wells as water sources for their daily needs [1-3]. Water from these sources are used directly by the inhabitants for drinking; these water sources are however prone to mineral contamination and devoid of quality treatments before drinking [2, 3]. Consequently, a significant proportion of residents in rural settlements of Nigeria are exposed to water-borne diseases, mineral toxicities and other related growth complications [3,4].

Water provides essential elements, but when polluted with excess minerals and chemical solvents it becomes an undesirable substance that is injurious to human health [4-6]. Contamination of drinking water may arise from introduction of chemical compounds into the water supply systems through leaks, cross contamination or direct contamination by human activities around water bodies [3-6]. Many problems are associated with excess chemical and mineral dissolved components of drinking water, chiefly is their ability to accumulate in the body and cause adverse health effects after prolonged period of time [5-7].

The sources of drinking water of the residents of the rural settlements in Owo Local Government area are either uncovered wells or streams which are also used as latrines and dumpsites [1,7,8]. This is as a result of lack of governmental aids to provide good sources of potable water and proper waste disposal systems across these settlements [1,8]. This coupled with the acute poverty; marginalization and very low standard of living of persons living across these settlements have spurred scientific interests into the assessment of the safety of the potable water available to these settlements [8]. Hence, a good knowledge of the physicochemical and mineral qualities of water is necessary so as to guide its suitability for use. This study was therefore carried out to assess the mineral and physicochemical qualities and to highlight the associated possible health risk factors of the sources of potable water across 10 rural settlements in Owo Local Government Area of Ondo State, Nigeria.

## 2. METHODOLOGY

### 2.1 Study Area Description

Owo Local Government Area (L.G.A) is found in Ondo State, Nigeria with coordinates $7^{o}$11N 5°35E / 7.183°N 5.583°E [8]. It is located 150 km north of Akure, Ondo State capital with an estimated population of 425,700 persons. The 10 rural settlements under study focus for the research are: Alupe (A), Ago- Ebira (B), Ijebu (C), Ipele (D), Ipenme (E), Ode Oriya (F,) Utelu (G), Ohore (H), Ilale (I) and Isu Ada (J) settlements respectively.

### 2.2 Study and Sampling Design

A descriptive analytic study was used to examine the physicochemical and mineral qualities of drinking water from ground and surface water sources in the 10 settlements listed above [9, 10]. Water samples from wells and streams that served as major potable water source in these settlements were collected via simple random sampling methods [10].

### 2.3 Sample Collection

A total of 20 water samples were collected from both ground water and surface water sources across 10 rural settlements of Owo L.G.A. in December, 2016. Out of these, a total of 10 well water samples and 10 stream water samples were collected from different locations across the rural settlements using a simple random sampling technique [9,10]. Ethical approval was obtained from the local health management authorities before samples were obtained. The samples were collected into labeled sterile universal bottles (250ml) and stored in ice packs

before physicochemical and mineral analysis were carried out according to specified WHO standards [11,12]. All the samples collected were analyzed in the laboratory within 6hr of sample collection.

### 2.4 Sample Preparation and Standardization

The methods described in [9,10] were adopted for water sample preparation and standardization in which specified volumes of each stock were taken under standard conditions and different analysis were done on the sample stocks from the different settlements. Thereafter, the samples were analyzed for total dissolved solvents, water hardness, hydrogen ion concentration (pH), temperature, electrical conductivity, sodium ion concentration, potassium ion concentration, magnesium ion concentration, iron ion concentration and chloride ion concentration respectively; compared with the standard WHO compendiums for physicochemical and mineral safety threshold levels for drinking water [11-12].

### 2.5 Determination of Physicochemical and Mineral Properties of Standardized Samples

The analysis of the standardized water samples for temperature, pH, electrical conductivity, total dissolved solvents and water hardness were carried out following standard guidelines by adopting the methods described in [13-15]. Consequently, the sodium ion concentration, potassium ion concentration, magnesium ion concentration, iron ion concentration and chloride ion concentration of the water samples were carried out according to standard specifications as described in [11,12,16].

### 2.6 Data Analysis

Analyzed sample treatments were replicated thrice; data means obtained were subjected to a 2-way analysis of variance and treatment means were separated using Duncan's New Multiple Range test at P ≤0.05 level of significance [1,9,10,13-16].

## 3. RESULTS

The water hardness, total dissolved solids and concentrations of sodium, chloride, magnesium, potassium and iron ions were all in their standard units (mg/L), electrical conductivity in µS/cm, temperature in $^{o}$C and pH in mol/dm$^{3}$ expressed as means of replicated treatments subjected to statistical analysis using Duncan's New Multiple Range test at P≤ 0.05 level of significance as shown in Tables 1-5 [11-15]. The analyzed data were compared with the W.H.O mineral and physicochemical standards set for drinking water. The safety set standards for physicochemical and mineral properties of drinking water include: Total water hardness at (≤100 mg/L) [11,15], Total dissolved solids (≤100 mg/L) [12,13], pH (≤6.50-8.50 for surface water (stream) [11,12] and ≤6.0- 8.50 for ground water (well) [9-11], Temperature (≤25°C- 27°C) [12], Electrical conductivity (≤50 µS/cm) [11,12], Mineral concentrations: chloride ion (≤200 mg/L) [12-14], sodium ion (≤20 mg/L) [9-13], potassium ion (≤25 mg/L) [10,11], magnesium ion (≤30 mg/L) [11,15] and iron ion (≤0.30 mg/L) [12,14] respectively.

The overall safety index of the various stream and well water samples were represented separately in Tables 6 and 7; compared with the standard set for the different parameters examined. Furthermore, the overall safety indexes of the stream water samples across the 10 settlements were found to be generally lower than those of well water samples. Also, a comparative study of Tables 6 and 7 will reveal that the overall safety indexes of all samples (well and stream) from settlements A and F were extremely low; as samples from settlements C, D, G-J had slightly safe indexes but yet still remain unsafe for drinking, while samples from settlements B and E were moderately safe and may serve the purpose of drinking.

## 4. DISCUSSION

It was observed from this study that, the drinking water samples across all the 10 settlements were averagely polluted resulting in either physicochemical imbalances or mineral toxicities of drinking water from the rural settlements as reflected in the results. This is mainly due to abysmal sanitary practices and continuous pollution from animal and anthropogenic sources across these settlements as drinking water sources also serve other purposes such as bathing, waste disposal and faecal dumps sites giving a lucid justification of the results observed; this also agrees with other recent findings in [9, 10,13,14]. The levels of the total dissolved solids, water hardness, concentration of mineral elements and electrical conductivities of samples across these settlements indicated high mineral and electrolyte toxicities; a common attribute of unsafe drinking water sources described in the recent research findings of [1,2,5,6,10,13,15].

**Table 1. Total concentration of water hardness and total dissolved solvents of samples across 10 rural settlements**

| S.T. | Water hardness of samples across the rural settlements (Mg/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 580.50±7.20$^{f}$ | 116.30±2.50$^{b}$ | 386.57±5.72$^{e}$ | 390.10±5.00$^{e}$ | 210.50±2.00$^{c}$ | 306.50±2.50$^{d}$ | 432.20±6.50$^{e}$ | 256.33±3.00$^{c}$ | 60.50±3.22$^{a}$ | 182.70±4.20$^{b}$ |
| W | 88.20±4.30$^{c}$ | 94.50±2.00$^{c}$ | 148.55±3.00$^{d}$ | 18.10±2.00$^{a}$ | 100.50±1.50$^{d}$ | 112.48±3.40$^{d}$ | 206.13±15.00$^{e}$ | 110.50±3.50$^{d}$ | 56.0±1.50$^{b}$ | 82.50±3.00$^{b}$ |
| **S.T.** | **Total dissolved solids of samples across the rural settlements (Mg/L)** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 76.80±1.80$^{c}$ | 48.40±2.40$^{a}$ | 81.80±2.50$^{c}$ | 72.80±3.20$^{c}$ | 64.80±2.40$^{b}$ | 44.20±2.50$^{a}$ | 85.80±1.20$^{d}$ | 97.60±2.30$^{d}$ | 36.80±1.52$^{a}$ | 47.20±2.45$^{a}$ |
| W | 72.70±1.35$^{d}$ | 43.80±1.45$^{b}$ | 61.80±1.52$^{c}$ | 49.50±1.55$^{b}$ | 30.02±1.34$^{a}$ | 41.80±2.48$^{b}$ | 57.30±2.71$^{b}$ | 40.10±1.78$^{a}$ | 36.80±2.90$^{a}$ | 39.80±1.67$^{a}$ |

*Keys: S.T. - sample types, W- well, S- stream, A- Alupe, B- Ago-Ebira, C- Ijebu, D- Ipele, E- Ipenme, F- Ode Oriya, G- Utelu, H- Ohore, I- Ilale and J- Isu- Ada, Standard index for Total water hardness is set at (≤100 mg/L) while that of Total dissolved solids is at (≤100 mg/L); values with the same letter as superscript have no significant difference at p≤0.05 level of significance*

**Table 2. Temperature and pH of water samples across 10 rural settlements**

| S.T. | Temperature of samples across the rural settlements (°C) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 26.10±1.20$^{a}$ | 25.80±1.50$^{a}$ | 26.50±1.70$^{a}$ | 27.20±1.00$^{b}$ | 25.00±2.00$^{a}$ | 25.00±1.50$^{a}$ | 26.00±2.50$^{a}$ | 26.00±1.00$^{a}$ | 26.30±1.22$^{a}$ | 27.00±1.20$^{b}$ |
| W | 27.10±1.30$^{c}$ | 26.00±1.00$^{b}$ | 26.00±1.50$^{b}$ | 28.50±1.00$^{c}$ | 26.00±1.50$^{b}$ | 26.00±1.40$^{b}$ | 26.40±2.00$^{b}$ | 26.00±1.00$^{b}$ | 26.89±1.30$^{b}$ | 25.90±1.00$^{a}$ |
| **S.T.** | **pH of samples across the rural settlements (Mol/dm$^3$)** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 8.25±1.30$^{c}$ | 7.97±1.40$^{c}$ | 7.02±1.64$^{b}$ | 8.19±0.50$^{c}$ | 7.50±1.34$^{b}$ | 6.31±1.20$^{a}$ | 7.96±1.00$^{c}$ | 6.61±1.30$^{a}$ | 6.80±1.00$^{a}$ | 7.21±1.40$^{b}$ |
| W | 8.11±1.05$^{d}$ | 7.81±1.85$^{c}$ | 6.98±1.24$^{b}$ | 8.08±1.02$^{d}$ | 6.80±1.14$^{b}$ | 6.20±1.45$^{a}$ | 8.03±1.51$^{d}$ | 6.50±1.28$^{a}$ | 6.50±1.49$^{a}$ | 7.06±1.33$^{b}$ |

*Keys: S.T. - sample types, W- well, S- stream, A- Alupe, B- Ago-Ebira, C- Ijebu, D- Ipele, E- Ipenme, F- Ode Oriya, G- Utelu, H- Ohore, I- Ilale and J- Isu- Ada, the standard index set for pH is at (≤6.50-8.50 for surface water (stream) and ≤6.0- 8.50 for ground water (well) while that of Temperature is (≤25°C- 27°C); values with the same letter as superscript have no significant difference at p≤0.05 level of significance*

**Table 3. Electrical conductivity and chloride ion concentration of water samples**

| S.T. | Electrical conductivity of samples across the rural settlements (µS/cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 37.20±2.50$^{b}$ | 26.90±1.00$^{a}$ | 32.20±1.80$^{b}$ | 98.70±4.00$^{e}$ | 92.10±5.20$^{e}$ | 74.00±1.00$^{d}$ | 50.01±4.50$^{c}$ | 86.00±2.00$^{d}$ | 67.10±2.22$^{c}$ | 82.10±3.25$^{d}$ |
| W | 21.80±0.70$^{a}$ | 20.10±0.30$^{a}$ | 31.10±1.22$^{b}$ | 45.80±3.00$^{c}$ | 67.20±3.33$^{d}$ | 44.30±4.40$^{c}$ | 49.80±2.33$^{c}$ | 67.10±3.50$^{d}$ | 65.00±1.67$^{d}$ | 77.90±1.84$^{e}$ |
| **S.T.** | **Chloride ion concentration of samples across the rural settlements (Mg/L)** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 216.50±3.50$^{d}$ | 187.67±3.40$^{c}$ | 151.00±4.14$^{c}$ | 105.33±1.33$^{b}$ | 178.24±2.67$^{c}$ | 219.25±1.55$^{d}$ | 251.13±1.67$^{e}$ | 196.00±1.00$^{c}$ | 106.75±2.00$^{b}$ | 88.00±1.00$^{a}$ |
| W | 193.25±1.45$^{e}$ | 179.35±2.35$^{d}$ | 60.28±1.74$^{a}$ | 87.50±1.50$^{b}$ | 155.21±2.33$^{d}$ | 201.46±3.46$^{e}$ | 113.23±1.33$^{c}$ | 168.35±1.85$^{d}$ | 84.67±1.23$^{b}$ | 82.53±1.43$^{b}$ |

*Keys: S.T. - sample types, W- well, S- stream, A- Alupe, B- Ago-Ebira, C- Ijebu, D- Ipele, E- Ipenme, F- Ode Oriya, G- Utelu, H- Ohore, I- Ilale and J- Isu- Ada, the standard index for Electrical conductivity is set at (≤50 µS/cm), while that of chloride ion is at (≤200 mg/L), values with the same letter as superscript have no significant difference at p≤0.05 level of significance*

**Table 4. Sodium and potassium ion concentration in water samples**

| S.T. | Sodium ion concentration of samples across the rural settlements (Mg/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 30.02±1.20$^{d}$ | 28.60±1.21$^{d}$ | 20.80±2.14$^{c}$ | 36.20±2.34$^{e}$ | 20.90±1.20$^{c}$ | 21.20±1.56$^{c}$ | 19.60±1.20$^{b}$ | 11.80±1.00$^{a}$ | 21.80±1.29$^{c}$ | 17.60±1.25$^{b}$ |
| W | 23.40±1.60$^{c}$ | 21.10±0.85$^{c}$ | 19.70±1.48$^{b}$ | 22.10±2.15$^{c}$ | 20.80±1.40$^{b}$ | 19.90±0.95$^{b}$ | 12.70±1.00$^{a}$ | 9.20±1.50$^{a}$ | 20.90±1.76$^{b}$ | 18.70±0.56$^{b}$ |
| **S.T.** | **Potassium ion concentration of samples across the rural settlements (Mg/L)** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 48.10±1.54$^{f}$ | 38.70±1.40$^{e}$ | 30.20±2.16$^{d}$ | 21.10±0.46$^{b}$ | 17.90±1.37$^{a}$ | 21.20±1.26$^{b}$ | 26.20±1.29$^{c}$ | 21.80±1.28$^{b}$ | 48.00±2.00$^{f}$ | 32.70±1.46$^{d}$ |
| W | 39.20±1.38$^{d}$ | 28.80±1.29$^{c}$ | 28.10±1.61$^{c}$ | 10.10±2.12$^{a}$ | 9.50±1.55$^{a}$ | 20.10±1.33$^{b}$ | 16.50±0.50$^{b}$ | 10.20±1.56$^{a}$ | 46.50±1.58$^{d}$ | 29.25±1.75$^{c}$ |

*Keys: S.T. - sample types, W- well, S- stream, A- Alupe, B- Ago-Ebira, C- Ijebu, D- Ipele, E- Ipenme, F- Ode Oriya, G- Utelu, H- Ohore, I- Ilale and J- Isu- Ada, the standard index set for sodium ion (≤20 mg/L) while that of potassium ion (≤25 mg/L); values with the same letter as superscript have no significant difference at p≤0.05 level of significance*

**Table 5. Magnesium and iron ion concentration in water samples**

| S.T. | Magnesium ion concentration of samples across the rural settlements (Mg/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 40.10±2.40$^{e}$ | 22.05±1.25$^{c}$ | 37.10±1.24$^{e}$ | 35.60±1.86$^{e}$ | 13.10±1.33$^{a}$ | 27.20±1.89$^{d}$ | 28.90±1.57$^{d}$ | 30.60±1.37$^{d}$ | 18.90±1.10$^{b}$ | 23.50±1.65$^{c}$ |
| W | 11.50±0.50$^{c}$ | 13.70±1.54$^{d}$ | 2.00±1.00$^{a}$ | 1.89±1.21$^{a}$ | 2.50±1.00$^{a}$ | 5.60±1.46$^{b}$ | 11.40±1.64$^{c}$ | 7.70±1.25$^{b}$ | 6.50±0.50$^{b}$ | 7.29±1.56$^{b}$ |
| **S.T.** | **Iron ion concentration of samples across the rural settlements (Mg/L)** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| S | 0.90±0.04$^{d}$ | 0.30±0.01$^{b}$ | 1.10±0.26$^{d}$ | 0.05±0.01$^{a}$ | 0.10±0.07$^{a}$ | 0.60±0.06$^{c}$ | 0.90±0.19$^{d}$ | 0.30±0.08$^{b}$ | 0.40±0.12$^{c}$ | 0.42±0.04$^{c}$ |
| W | 0.70±0.38$^{d}$ | 0.04±0.01$^{a}$ | 0.29±0.11$^{c}$ | 0.02±0.01$^{a}$ | 0.05±0.01$^{a}$ | 0.20±0.03$^{b}$ | 0.16±0.02$^{b}$ | 0.15±0.07$^{b}$ | 0.20±0.08$^{b}$ | 0.12±0.05$^{b}$ |

*Keys: S.T. - sample types, W- well, S- stream, A- Alupe, B- Ago-Ebira, C- Ijebu, D- Ipele, E- Ipenme, F- Ode Oriya, G- Utelu, H- Ohore, I- Ilale and J- Isu- Ada, the standard set for magnesium ion is (≤30 mg/L) while that of iron ion is set at (≤0.30 mg/L); values with the same letter as superscript have no significant difference at p≤0.05 level of significance*

**Table 6. Overall safety index of stream water samples across the 10 rural settlements**

| Rural settlements | Safety criteria assessment used for stream water samples | | | | | | | | | | Ov. S. I. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| A | -ve | +ve | +ve | +ve | +ve | -ve | -ve | -ve | -ve | -ve | 4/10 |
| B | -ve | +ve | +ve | +ve | +ve | +ve | -ve | -ve | +ve | -ve | 6/10 |
| C | -ve | +ve | +ve | +ve | +ve | +ve | +ve | -ve | -ve | -ve | 6/10 |
| D | -ve | +ve | -ve | +ve | -ve | +ve | -ve | +ve | -ve | -ve | 4/10 |
| E | -ve | +ve | +ve | +ve | -ve | +ve | +ve | +ve | +ve | +ve | 8/10 |
| F | -ve | +ve | +ve | -ve | -ve | -ve | -ve | +ve | +ve | -ve | 4/10 |
| G | -ve | +ve | +ve | +ve | -ve | -ve | +ve | -ve | +ve | -ve | 5/10 |
| H | -ve | -ve | +ve | -ve | -ve | +ve | +ve | +ve | -ve | +ve | 5/10 |
| I | +ve | +ve | +ve | +ve | -ve | +ve | -ve | -ve | +ve | -ve | 6/10 |
| J | -ve | +ve | -ve | +ve | -ve | +ve | +ve | -ve | +ve | -ve | 5/10 |

*Keys: 1- Water hardness, 2- Total dissolved solids, 3- Temperature, 4- $_P$H, 5- Electrical conductivity, 6- Chloride ion concentration, 7- Sodium ion concentration, 8- Potassium ion concentration, 9- Magnesium ion concentration, 10- Iron ion concentration, A- Alupe, B- Ago-Ebira, C- Ijebu, D- Ipele, E- Ipenme, F- Ode Oriya, G- Utelu, H- Ohore, I- Ilale and J- Isu- Ada, Ov. S. I. – Overall safety index of sample sources, -ve- Greater than specified standard (unsafe), +ve- lower than specified standard (safe). The standards set for each safety criteria are: Total water hardness at (≤100 mg/L), Total dissolved solids (≤100 mg/L), pH (≤6.50-8.50 for surface water (stream) and ≤6.0- 8.50 for ground water (well), Temperature (≤25°C- 27°C), Electrical conductivity (≤50 µS/cm), Mineral concentrations: chloride ion (≤200 mg/L), sodium ion (≤20 mg/L), potassium ion (≤25 mg/L), magnesium ion (≤30 mg/L) and iron ion (≤0.30 mg/L) respectively*

**Table 7. Overall safety index of well water samples across the 10 rural settlements**

| Rural settlements | Safety criteria assessment used for well water samples | | | | | | | | | | Ov. S. I. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| A | +ve | +ve | -ve | +ve | +ve | +ve | -ve | -ve | +ve | -ve | 6/10 |
| B | +ve | +ve | +ve | +ve | +ve | +ve | +ve | -ve | +ve | +ve | 9/10 |
| C | -ve | +ve | +ve | +ve | +ve | +ve | +ve | -ve | +ve | -ve | 7/10 |
| D | +ve | +ve | -ve | +ve | +ve | +ve | -ve | +ve | +ve | +ve | 8/10 |
| E | -ve | +ve | -ve | +ve | -ve | +ve | -ve | +ve | +ve | +ve | 6/10 |
| F | -ve | +ve | -ve | +ve | +ve | -ve | +ve | +ve | +ve | +ve | 7/10 |
| G | -ve | +ve | -ve | +ve | -ve | +ve | +ve | +ve | +ve | +ve | 7/10 |
| H | -ve | +ve | -ve | +ve | -ve | +ve | +ve | +ve | +ve | +ve | 7/10 |
| I | +ve | +ve | -ve | +ve | -ve | +ve | -ve | -ve | +ve | +ve | 6/10 |
| J | -ve | +ve | +ve | +ve | -ve | +ve | +ve | -ve | +ve | +ve | 7/10 |

*Keys: 1- Water hardness, 2- Total dissolved solids, 3- Temperature, 4- $_P$H, 5- Electrical conductivity, 6- Chloride ion concentration, 7- Sodium ion concentration, 8- Potassium ion concentration, 9- Magnesium ion concentration, 10- Iron ion concentration, A- Alupe, B- Ago-Ebira, C- Ijebu, D- Ipele, E- Ipenme, F- Ode Oriya, G- Utelu, H- Ohore, I- Ilale and J- Isu- Ada, Ov. S. I. – Overall safety index of sample sources, -ve- Greater than specified standard (unsafe), +ve- lower than specified standard (safe). The standards set for each safety criteria are: Total water hardness at (≤100 mg/L), Total dissolved solids (≤100 mg/L), pH (≤6.50-8.50 for surface water (stream) and ≤6.0- 8.50 for ground water (well), Temperature (≤25°C- 27°C), Electrical conductivity (≤50 µS/cm), Mineral concentrations: chloride ion (≤200 mg/L), sodium ion (≤20 mg/L), potassium ion (≤25mg/L), magnesium ion (≤30 mg/L) and iron ion (≤0.30 mg/L) respectively*

Subsequently, the oral interviews conducted by authors with inhabitants of these settlements revealed that all the settlements lacked access to either pipe-borne water and/or water storage facilities; most importantly, the inhabitants are reluctant to recognize any potential harm in the use of stream water and uncovered well water for their drinking and other domestic purposes. Bioethical concerns however still exists in many African rural cultural beliefs that flowing water sources (streams) or wells cannot be contaminated as similar bioethical concerns were also encountered in the reports of [1,15,17,18].

Local health demography of these rural settlements obtained from local health authorities suggests frequent relapse of gastro-intestinal infections and mineral deficiencies, this research study accurately justifies why this was so; agreeing with the findings of [1,2,17,18]. The

standard of living in these settlements are generally low with high poverty rates, it was obvious that adequate health care facilities and basic social amenities were not in place, hence, the use of water bodies as vehicles for waste disposal had become a norm and such is the case of many rural settlements across developing African countries [1,9,10,17,18].

## 5. CONCLUSION

The findings of this research have demonstrated the poor quality of drinking water across the 10 settlements in the study area, revealed the potential health risks associated with mineral imbalance of the major sources of water in the settlements and provided insights into the relationship between poor sanitary practices of these inhabitants and the continual pollution of major drinking water sources in these settlements. Therefore, Government aid is swiftly recommended for these settlements as the findings of this research proved potential dangers of mineral toxicities across these rural settlements. Moreso, access to pipe-borne water and construction of adequate sewage facilities and waste disposal facilities by Local Government Authorities is urgently needed. Proper health education and strict sanitary surveillance should be ensured across these settlements by local health officials for adequate environmental biosaftey.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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