An Evaluation of the Physicochemical Characteristics of the Hand-Dug Shallow Water Wells in Awka Metropolis, Anambra State, Nigeria

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INTRODUCTION
The quality of water is a vital concern for mankind since it is directly linked with human welfare. Since it is a dynamic system containing living as well as non-living organic, soluble as well as insoluble substances, its quality is likely to change day by day and from source to source. Only one percent of water is available on land for drinking, agriculture, domestic power generation, industrial consumption, transportation and waste disposal [1].

Potable water is one that is free from pathogens, low in compounds that are acutely toxic and have grave long-term effects on human health. It is the primary need of every human
being. The provision of potable water to rural and urban population is necessary to prevent health hazards [2]. A primary concern of people living in developing countries is that of obtaining clean drinking water. 

In African, millions of people in the semi-urban communities and rural areas are dependent on ground water. Consequently, the realization of the potential health hazards that may result from the contamination of drinking water from any source is therefore of primary importance because of the danger and risk of water-borne diseases [3]. The problems of ground water quality are much more acute in areas which are densely populated, thickly industrialized, and have shallow ground water tables.

The rapid growth of urban areas has further affected ground water quality due to over exploitation of resources and improper waste disposal practices [4]. The use of shallow ground water sources for drinking and other domestic purposes is a common feature of many low income communities in developing countries [5]. Due to the depth and structure of shallow wells, contamination with organic and inorganic compounds is a major concern [6]. Contamination with chemical elements such as lead, cadmium, chromium, fluoride, arsenic, copper and magnesium can occur in such water, with consequent adverse health effects leading to avoidable economic and human losses.

The unreliable water supply within Awka metropolis has forced residents to increasingly depend on shallow wells as the source of water for drinking and domestic use. Although these shallow wells are covered, many of them are located close to household drainage systems and septic tanks and are therefore susceptible to contamination. A good knowledge of the physicochemical properties of water meant for drinking and domestic purposes is crucial to avert a possible health hazard, therefore in this study, the physiochemical characteristics of some hand-dug shallow water wells in Awka metropolis were evaluated.

METHODS
COLLECTION OF SAMPLES
Water samples from fifteen hand-dug shallow wells in Okpuno Awka, Ifite Awka, Okperi Awka, Umuogbu Awka, Ogbengwu Awka, Umuokpu Awka, Umunagu Awka, Sugarline Amansea, Ngo Amansea, Omeluora Close Amansea, Okoye Close Amansea, Orji Avenue Amansea, Akurulo Avenue Amansea, Obi Avenue Amansea and Kenneth Close Amansea were evaluated physicochemically during the dry and wet seasons.

Two-litre plastic containers with screw caps were used to collect the samples. The containers were initially washed with detergent and thereafter rinsed with sterile distilled water. The containers were also rinsed with the water samples at the point of collection. The samples were transported to the Biotechnology Research Centre of Nnamdi Azikwe University Awka where they were analyzed within twenty-four hours of collection.

PHYSICOCHEMICAL ANALYSIS
The physicochemical characteristics evaluated were temperature, pH, electrical conductivity, total dissolved solids, total suspended solids, total solids, wells depth, total acidity, total alkalinity, total hardness, total chloride, calcium hardness, magnesium hardness, sulphate, iron, lead, cadmium and arsenic. The evaluation was carried out using standard analytical methods [7].
DETERMINATION OF TEMPERATURE
The temperature was determined using a centigrade thermometer. The thermometer was immersed into a beaker containing the sample and the temperature value was recorded when the reading stabilized.

MEASUREMENT OF pH
The pH was measured with a pH meter (JENWAY) that was standardized with pH buffers. The electrode of the meter was inserted into the sample contained in a beaker and the value was read when the reading stabilized.

MEASUREMENT OF TOTAL DISSOLVED SOLIDS
One hundred millilitres of a water sample were passed through a dried whatman filter paper of known weight. The filter paper was fitted into a funnel placed in a 100ml conical flask. The wet filter paper was removed, dried in an oven at 105°C for 20 seconds and allowed to cool after which it was reweighed.
Total dissolved solids (mg/l) = \[
\frac{(A-B) \times 1000}{\text{Volume of sample}}
\]
A= weight of filter paper + dissolved solids
B= Weight of filter paper

MEASUREMENT OF TOTAL SUSPENDED SOLIDS
One hundred milliliters of a water sample were introduced into a dried conical flask of known weight and evaporated to dryness in a hot air oven at 105°C. The flask was allowed to cool and reweighed thereafter.
Total suspended solids (mg/l) = \[
\frac{(A-B) \times 1000}{\text{Volume of sample}}
\]
A= weight of conical paper + suspended particles
B= Weight of conical flask

MEASUREMENT OF TOTAL SOLIDS
The total solids were calculated from the total dissolved solids and total suspended solids.
Total dissolved solids + total suspended solids = total solids

MEASUREMENT OF THE DEPTH OF THE WELLS
The depth was measured with a measuring tape.

MEASUREMENT OF ELECTRICAL CONDUCTIVITY
It was determined using a conductivity meter (Aquapro). The electrode of the meter was inserted into a beaker containing the water sample and the value was read when the reading stabilized.

MEASUREMENT OF TOTAL ACIDITY
One hundred milliliters of a water sample were introduced into a 250ml conical flask and a drop of a mixed solution of bromothymol blue and phenolphthalein was added. The mixture was titrated with barium hydroxide solution till a red colour was observed. The volume of the barium hydroxide used was recorded as the total acidity of the water sample.

MEASUREMENT OF TOTAL ALKALINITY
One hundred milliliters of a water sample were introduced into a 250ml conical flask. Two drops of bromocresol green solution were added and the mixture was titrated with 0.02N sulphuric acid till a yellow colour was observed. The volume of the sulphuric acid used was recorded as the total alkalinity of the sample.
MEASUREMENT OF TOTAL HARDNESS
One hundred milliliters of a water sample were introduced into a 250ml conical flask. 1ml of pH buffer 10 solution, 2ml of sulphuric acid and 0.2ml of Eriochrome Black T indicator were added to the sample and the mixture was titrated with ethylene diamine tetra acetic acid (EDTA) till a blue colour was observed. The volume of the EDTA used was recorded as the total hardness of the sample.

MEASUREMENT OF TOTAL CHLORIDE
One hundred milliliters of a water sample were introduced into a 250ml conical flask and 1ml of potassium dichromate solution was added to it. The mixture was titrated with silver nitrate solution till a reddish brown colour was observed. The volume of silver nitrate used was recorded as the total chloride in the sample.

MEASUREMENT OF CALCIUM HARDNESS
One hundred milliliters of a water sample were introduced into a conical flask and 0.5ml of a mixed solution of murexide and sodium chloride were added. 1ml of sodium hydroxide solution was also added and the mixture was titrated with ethylene diamine tetra acetic acid (EDTA) till a purple colour was observed. The volume of the EDTA used was recorded as the value of the calcium hardness of the water sample.

MEASUREMENT OF MAGNESIUM HARDNESS
Magnesium hardness was determined from the total hardness and calcium hardness.

\[
\text{Magnesium hardness} = \text{Total hardness} - \text{calcium hardness.}
\]

MEASUREMENT OF SULPHATE
One hundred milliliters of a water sample was filtered and 10ml of barium nitrate were added to the filtered sample. The mixture was passed through a filter paper of known weight. The filter paper was thereafter dried in the oven at 105°C for 30 seconds and reweighed. The sulphate was calculated from the formula

\[
\text{Sulphate} = \frac{(A-B) \times 1000}{\text{Volume of sample}}
\]

A= weight of filter paper + suspended particles
B= Weight of filter

MEASUREMENT OF HEAVY METALS
The heavy metals (iron, lead, cadmium and arsenic) were determined by atomic absorption spectrometry. One hundred milliliters of a filtered water sample were introduced into a 250ml conical flask and digested with concentrated nitric acid. The digested sample was filtered into a sample bottle and aspirated into the oxyacetylene flame. The absorbance of the aspirated sample was read using the atomic absorption spectrophotometer.

DATA ANALYSIS
The data were subjected to correlation analysis to determine the level of significance between the physicochemical parameters using SPSS 8.0 package.

RESULTS
The physical characteristics of the hand-dug shallow water wells during the dry season are shown in Table 1. The temperature ranged from 27-28°C, pH, 4.1-5.5; electrical conductivity, 10-910 us/cm; total dissolved solids, 0.01-0.79mg/l; total suspended solids, 0.04-1.62mg/l; total solids, 0.02-0.35mg/l; total solids, 0.08-0.87mg/l and wells depth, 10-14m.
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Table 1. Physical Characteristics of the Hand-Dug Shallow Water Wells during the dry season

| Sample | Well location   | Temp (°C) | pH | Electrical conductivity (us/cm) | Total dissolved solids (mg/l) | Total suspended solids (mg/l) | Total solids (mg/l) | Wells Depth (m) |
|--------|-----------------|-----------|----|--------------------------------|-----------------------------|-----------------------------|-------------------|----------------|
| 1      | Okpuno Awka     | 27        | 5.2| 18                             | 0.16                        | 0.35                        | 0.51              | 13             |
| 2      | Ifite Awka      | 28        | 4.5| 120                            | 0.09                        | 0.05                        | 0.14              | 11             |
| 3      | Okperi Awka     | 27        | 4.3| 140                            | 0.79                        | 0.02                        | 0.81              | 14             |
| 4      | Umuogbu Awka    | 28        | 4.4| 280                            | 0.32                        | 0.03                        | 0.35              | 10             |
| 5      | Ogbengwu Awka   | 28        | 4.4| 800                            | 0.17                        | 0.05                        | 0.22              | 14             |
| 6      | Umuokpu Awka    | 28        | 4.2| 910                            | 0.67                        | 0.05                        | 0.87              | 12             |
| 7      | Umunagu Awka    | 28        | 4.3| 350                            | 0.42                        | 0.06                        | 0.48              | 13             |
| 8      | Sugarline Amansea | 28     | 5.5| 50                             | 0.06                        | 0.10                        | 0.16              | 11             |
| 9      | Ngo Amansea     | 27        | 4.1| 350                            | 0.01                        | 0.07                        | 0.08              | 10             |
| 10     | Omeluora Close Amansea | 28 | 4.3 | 250 | 0.25 | 0.03 | 0.29 | 12 |
| 11     | Okoye Close Amansea | 28 | 5.0 | 180 | 0.50 | 0.14 | 0.64 | 14 |
| 12     | Orji Avenue Amansea | 27 | 4.5 | 560 | 0.17 | 0.10 | 0.27 | 13 |
| 13     | Akurulo Avenue Amansea | 28 | 4.6 | 10 | 0.05 | 0.16 | 0.26 | 12 |
| 14     | Obi Avenue Amansea | 28 | 4.5 | 10 | 0.10 | 0.18 | 0.18 | 14 |
| 15     | Kenneth Close Amansea | 28 | 4.2 | 150 | 0.03 | 0.10 | 0.10 | 13 |
|        | WHO Standard    | 25-40     | 6.5| 1000                           | 500                         | NS                          | 500               | NS             |

NS=No standard

The physical characteristics of the hand-dug shallow water wells during the wet season are presented in Table 2. The temperature was 28-29°C; pH, 5.0-7.3, electrical conductivity, 15-1042us/cm; total dissolved solids, 0.09-19.91mg/l; total suspended solids, 0.31-20.09mg/l and wells depth, 5-10m.

Table 2. Physical Characteristics of the Hand-Dug Shallow Water Wells during the wet season

| Sample | Well location   | Temp (°C) | pH | Electrical Conductivity (us/cm) | Total dissolved solids (mg/l) | Total suspended solids (mg/l) | Total solids (mg/l) | Wells Depth (m) |
|--------|-----------------|-----------|----|--------------------------------|-----------------------------|-----------------------------|-------------------|----------------|
| 1      | Okpuno Awka     | 28        | 6.0| 20                             | 19.91                       | 0.38                        | 20.09             | 10             |
| 2      | Ifite Awka      | 29        | 5.6| 132                            | 0.34                        | 0.61                        | 0.95              | 7              |
| 3      | Okperi Awka     | 29        | 6.7| 169                            | 0.80                        | 0.04                        | 0.83              | 9              |
| 4      | Umuogbu Awka    | 29        | 5.5| 344                            | 0.35                        | 0.59                        | 0.94              | 7              |
The chemical characteristics of the hand-dug shallow water wells during the dry season are presented in Table 3. The total acidity was 1.5-61.3mg/L; total hardness, 16-68mg/L; total chloride, 11.62-320.69mg/L; calcium hardness, 1.40-29.46mg/L; magnesium hardness, 0.00-11.27mg/L, sulphate, 0.000-0.007mg/L and total alkalinity, 4-34mg/L.

| Sample | Well location         | Total acidity (mg/L) | Total hardness (mg/L) | Total chloride (mg/L) | Calcium hardness (mg/L) | Magnesium hardness (mg/L) | Sulphate (mg/L) | Total alkalinity (mg/L) |
|--------|-----------------------|----------------------|-----------------------|-----------------------|-------------------------|--------------------------|------------------|------------------------|
| 1      | Okpuno Awka           | 3.5                  | 40                    | 78.35                 | 4.81                    | 8.55                     | 0.000            | 20                     |
| 2      | Ifite Awka            | 48.8                 | 30                    | 122.08                | 1.60                    | 6.90                     | 0.000            | 28                     |
| 3      | Okperi Awka           | 17.5                 | 60                    | 204.08                | 13.63                   | 11.27                    | 0.001            | 22                     |
| 4      | Umuogbu Awka          | 20.0                 | 24                    | 134.84                | 5.61                    | 4.47                     | 0.002            | 34                     |
| 5      | Ogbengwu Awka         | 42.5                 | 36                    | 320.69                | 29.46                   | 0.00                     | 0.002            | 30                     |
| 6      | Umuokpu Awka          | 48.8                 | 68                    | 251.45                | 14.83                   | 9.51                     | 0.007            | 8                      |
| 7      | Umanagu Awka          | 61.3                 | 30                    | 205.90                | 8.82                    | 5.15                     | 0.004            | 4                      |
| 8      | Sugarline Amansea     | 1.5                  | 16                    | 12.75                 | 3.61                    | 2.72                     | 0.000            | 6                      |
| 9      | Ngo Amansea           | 40.0                 | 32                    | 47.38                 | 5.61                    | 6.41                     | 0.000            | 7                      |
| 10     | Omeluora Close Amansea| 12.5                 | 22                    | 40.09                 | 10.42                   | 2.81                     | 0.000            | 5                      |
| 11     | Okoye Close Amansea   | 17.5                 | 20                    | 56.49                 | 6.41                    | 3.30                     | 0.001            | 9                      |
| 12     | Orji Avenue Amansea   | 17.5                 | 20                    | 18.22                 | 6.41                    | 3.11                     | 0.000            | 12                     |
| 13     | Akurulo Avenue Amansea| 112.5                | 32                    | 11.62                 | 1.40                    | 6.41                     | 0.003            | 8                      |

NS= No standard
The chemical characteristics of the hand-dug shallow water wells during the wet season are shown in Table 4. The total acidity was 31.3-86.3mg/l; total alkalinity, 12-106mg/l; total hardness, 37-320mg/l; total chloride, 52.84-763.47mg/l; calcium hardness, 4.81-52.91mg/l; magnesium hardness, 8.65-70.60mg/l and sulphate, 0.000-0.100mg/l.

Table 4. Chemical Characteristics of the Hand-Dug Shallow Water Wells during in the wet season

| Sample | Well location       | Total acidity (mg/L) | Total Alkalinity (mg/L) | Total hardness (mg/L) | Total chloride (mg/L) | Calcium hardness (mg/L) | Magnesium hardness (mg/L) | Sulphate (mg/L) |
|--------|---------------------|----------------------|-------------------------|-----------------------|-----------------------|--------------------------|---------------------------|------------------|
| 1      | Okpuno Awka         | 60.0                 | 40                      | 84                    | 194.06                | 5.01                     | 19.19                     | 0.015            |
| 2      | Ifite Awka          | 65.5                 | 28                      | 107                   | 179.94                | 6.61                     | 24.39                     | 0.000            |
| 3      | Okperi Awka         | 86.3                 | 64                      | 184                   | 763.47                | 23.05                    | 39.11                     | 0.000            |
| 4      | Umuogbu Awka        | 42.5                 | 42                      | 104                   | 230.50                | 6.41                     | 23.71                     | 0.014            |
| 5      | Ogbengwu Awka       | 62.5                 | 54                      | 320                   | 490.15                | 52.91                    | 70.60                     | 0.015            |
| 6      | Umuokpu Awka        | 82.5                 | 12                      | 154                   | 540.26                | 28.86                    | 33.82                     | 0.008            |
| 7      | Umanagha Awka       | 65.0                 | 20                      | 232                   | 330.72                | 11.42                    | 53.60                     | 0.009            |
| 8      | Sugarline Amansea   | 50.0                 | 42                      | 47                    | 180.39                | 4.81                     | 10.54                     | 0.008            |
| 9      | Ngo Amansea         | 72.0                 | 56                      | 222                   | 235.05                | 11.02                    | 51.27                     | 0.100            |
| 10     | Omeluro Close Amansea | 21.0               | 32                      | 276                   | 162.17                | 18.84                    | 62.49                     | 0.006            |
| 11     | Okoye Close Amansea | 72.5                 | 106                     | 134                   | 221.39                | 17.23                    | 28.37                     | 0.010            |
| 12     | Orji Avenue Amansea | 50.0                 | 50                      | 70                    | 52.84                 | 7.21                     | 15.45                     | 0.023            |
| 13     | Akarulo Avenue Amansea | 31.3              | 24                      | 37                    | 71.06                 | 5.61                     | 8.65                      | 0.010            |
| 14     | Obi Avenue Amansea  | 40.0                 | 16                      | 67                    | 116.60                | 8.02                     | 15.94                     | 0.012            |
| 15     | Kenneth Close Amansea | 66.3              | 80                      | 102                   | 116.62                | 13.83                    | 21.43                     | 0.000            |
| WHO Standard |                  | 0.3                 | 250                     | 150                   | 250                   | 75                       | 50                        | 500              |

NS= No standard

The heavy metals characteristics of the hand-dug shallow water wells during the dry season are shown in Table 5. The iron content was 0.02-0.29mg/l; lead, 0.00-0.09mg/l; cadmium, 0.01-0.33mg/l and arsenic, 0.01-0.10mg/l.
### Table 5. Heavy Metals Characteristics of the Hand-Dug Shallow Water Wells during the dry season

| Sample | Well Location       | Iron (mg/L) | Lead (mg/L) | Cadmium (mg/L) | Arsenic (mg/L) |
|--------|---------------------|-------------|-------------|----------------|---------------|
| 1      | Okpuno Awka         | 0.02        | 0.09        | 0.14           | 0.04          |
| 2      | Ifite Awka          | 0.05        | 0.05        | 0.24           | 0.07          |
| 3      | Okperi Awka         | 0.03        | 0.03        | 0.19           | 0.08          |
| 4      | Umuogbu Awka        | 0.02        | 0.04        | 0.26           | 0.01          |
| 5      | Ogbengwu Awka       | 0.07        | 0.00        | 0.23           | 0.07          |
| 6      | Umuokpa Awka        | 0.05        | 0.06        | 0.01           | 0.03          |
| 7      | Umunagu Awka        | 0.03        | 0.02        | 0.23           | 0.08          |
| 8      | Sugarline Amansea   | 0.08        | 0.05        | 0.10           | 0.10          |
| 9      | Ngo Amansea         | 0.08        | 0.07        | 0.33           | 0.03          |
| 10     | Omeluora Close Amansea | 0.07     | 0.05        | 0.02           | 0.02          |
| 11     | Okoye Close Amansea | 0.29        | 0.07        | 0.17           | 0.05          |
| 13     | Orji Avenue Amansea | 0.03        | 0.05        | 0.24           | 0.07          |
| 14     | Akurulo Avenue Amansea | 0.11      | 0.07        | 0.09           | 0.04          |
| 14     | Obi Avenue Amansea  | 0.03        | 0.05        | 0.20           | 0.02          |
| 15     | Kenneth Close Amansea | 0.02     | 0.04        | 0.19           | 0.02          |
|        | WHO Standard        | 0.3         | 0.01        | 0.03           | 0.01          |

The heavy metals characteristics of the hand-dug shallow water wells during the wet season are presented in Table 6. Iron ranged from 0.38 to 6.92 mg/l; lead, 3.33-13.33mg/l; cadmium, 2.50-37.50mg/l and arsenic, 3.10-39.82mg/l.

### Table 6. Heavy Metals Characteristics of the Hand-Dug Shallow Water Wells during the wet season

| Sample | Well Location       | Iron (mg/L) | Lead (mg/L) | Cadmium (mg/L) | Arsenic (mg/L) |
|--------|---------------------|-------------|-------------|----------------|---------------|
| 1      | Okpuno Awka         | 0.38        | 3.33        | 22.50          | 32.41         |
| 2      | Ifite Awka          | 5.00        | 11.11       | 20.00          | 5.17          |
| 3      | Okperi Awka         | 5.38        | 11.00       | 32.50          | 3.10          |
| 4      | Umuogbu Awka        | 0.77        | 11.08       | 27.50          | 25.51         |
| 5      | Ogbengwu Awka       | 1.54        | 7.22        | 30.00          | 5.15          |
| 6      | Umuokpa Awka        | 3.46        | 10.58       | 5.00           | 10.34         |
| 7      | Umunagu Awka        | 2.69        | 10.00       | 2.50           | 8.62          |
| 8      | Sugarline Amansea   | 0.39        | 13.33       | 35.00          | 5.10          |
| 9      | Ngo Amansea         | 4.61        | 10.55       | 32.50          | 39.82         |
| 10     | Omeluora Close Amansea | 4.23     | 10.00       | 35.20          | 24.48         |
| 11     | Okoye Close Amansea | 3.07        | 11.66       | 10.00          | 23.44         |
| 13     | Orji Avenue Amansea | 1.15        | 13.30       | 32.40          | 22.41         |
| 14     | Akurulo Avenue Amansea | 6.92      | 9.44        | 37.20          | 10.30         |
| 14     | Obi Avenue Amansea  | 3.46        | 6.11        | 34.00          | 18.62         |
| 15     | Kenneth Close Amansea | 6.18     | 7.77        | 37.50          | 26.51         |
|        | WHO Standard        | 0.3         | 0.01        | 0.03           | 0.01          |

### DISCUSSION

The physicochemical characteristics of the water samples varied with the seasons. The temperature range was higher during the wet than dry season (Tables 1 and 2). The temperature values for both seasons were within the World Health Organization (WHO) Standard of 25-40°C. The temperature values may be attributed to the fact that the samples were collected early in the morning. Okonko et al [8] obtained a temperature of 28-30°C for the water wells located at Abeokuta, Ogun State and Ojota, Lagos State. The temperature of any water body affects the rate of proliferation of microorganisms [9] and controls the rate of all chemical reactions.
All the water samples were acidic during the dry season (Table 1) but during the wet season, they were slightly acidic to alkaline (Table 2). The pH values obtained during the dry season may be attributed to the contamination of the water wells by acidic leachates from the soil. However, more water was available to dilute the leachates during the wet season. Olusiji et al [10] however reported that the pH level of some hand-dug wells in Ekiti State ranged from 6.0-7.3 indicating that the water was slightly acidic to alkaline. The average pH values obtained in this work for both seasons did not comply with the WHO permissible limit of 6.5-8.5. pH is important in determining the corrosive nature of water. The lower the pH value, the higher the corrosive nature of water [11]. pH values ranging from 3.0 to 10.5 could favour the growth of both indicator and pathogenic microorganisms [12].

Electrical conductivity is a measure of the water capacity to convey electrical current. It also shows the amount of dissolved salts in the water body. The average conductivity values for both seasons were within the WHO limit of 1000 us/cm (Tables 1 and 2). The result agreed with that of Olusiji et al [10] who reported an electrical conductivity range of 20-750 us/cm for the water samples they examined. High electrical conductivity values may be attributed to the dissolution of the soil organic and inorganic materials by infiltrating water.

The total dissolved solids indicate the salinity behavior of ground water substances and temperature [13]. In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates, magnesium, organic matter, salts and other particles. The average values for both seasons were within the WHO limit of 500mg/l (Tables 1 and 2). The result agreed with the reports of Sachinkumar and Patil [14] on the physicochemical characterization of water from forest covered gavase wet land of Kolhapur district, Maharashtra (India) and Manjare et al [15] who studied the monthly changes in the physical and chemical parameters in Tamadalge water tank in Kolhapur and reported that the total dissolved solids were within the WHO permissible limit thereby indicating that the tank was not polluted. Water with total dissolved solids above the recommended limit contains high level of ions which can lead to gastrointestinal irritations and staining of fabrics.

All the water wells sampled during both seasons recorded low levels of total suspended solids. This result conformed to the finding of Mahananda et al [16] who carried out an investigation on the ground water as well as the surface water quality, nutrient status and physicochemical characteristics of Bargarh district of Orissa, India and reported that the total suspended solids of the ground water ranged from 31.39-61.36mg/l. Well water with high level of total suspended solids could be dangerous to human health when the water is consumed without filtration and it is aesthetically unsatisfactory. It is also capable of shielding pathogenic microorganisms.

Total solids are the sum of the total dissolved solids and total suspended solids. The values for both seasons were within the WHO stipulated standard of 500mg/l (Tables 1 and 2). The wells were deeper during the dry season than during the wet season (Tables 1 and 2). This may be due to the fact that during the wet season, debris and sand can enter the wells by wind and water actions when they are not properly covered, thereby reducing their depth. Generally, all the wells were shallow in depth thereby making them susceptible to surface infiltration by leachates.

The total acidity of the water samples for both seasons were above the WHO standard of 0.3mg/l (Tables 3 and 4). The results agreed with the work of Taiwo et al [17] that reported high acidity value of 1.00mg/l for the water samples they examined. Total alkalinity is due to the presence of bicarbonates, carbonates and hydroxides of calcium, sodium and
potassium. It is a measure of the capacity of the water samples to neutralize strong acids. The total alkalinity values for all the samples evaluated during both seasons were within the WHO permissible limit. This result agreed with the work of Manjare et al [15] that recorded the monthly changes in the physical and chemical parameters of water samples in India and reported that all the parameters including total alkalinity were within the WHO permissible limits.

Hardness is the property of water which prevents it from lather formation with soap and increases its boiling point. It is usually due to the presence of multivalent ions emanating from minerals dissolved in water. The total hardness of the samples for both seasons were within the WHO permissible limit of 50mg/l (Tables 3 and 4). The result is in conformity with the work of Rokade and Ganeshwade [18] that reported that the high fluctuations in the physicochemical parameters indicated the intensity of pollution. Hard water is not suitable for domestic, industrial and agricultural uses. No health effects have been associated with hardness in drinking water. Dzik [19] has however reported an inverse relationship between water hardness and cardiovascular diseases.

Calcium and magnesium are directly related to hardness. The calcium hardness values during both seasons were within the WHO permissible limit of 75mg/l (Tables 3 and 4). Calcium is abundant in the earth crust and can also be released as a weathering product of feldspars, hence its presence in water. The values for magnesium hardness during both seasons were within the WHO standard of 50mg/l (Tables 3 and 4). Magnesium in water can come from the leaching of minerals such as clay and biotite. Olusiji et al [10] however reported a calcium hardness range of 4.8mg/l -139.5mg/l and magnesium hardness of 3.4-25.9mg/l for the water samples they examined. All except two samples met the WHO permissible limit of 250mg/l. (Tables 3 and 4) for chloride. This result is similar to the finding of Saravanakumar and Ranjith Kumar [20] who studied different parameters and observed that there were slight fluctuations in the physicochemical parameters among the water samples they examined. Chloride in the groundwater may have resulted from natural and anthropogenic sources such as industrial effluents, septic tank effluents and the use of inorganic fertilizers for agricultural purposes. Chloride is not harmful to humans at low concentration but alters the taste of water at concentration above 500mg/l [21]. High chloride concentration serves as an indicator of pollution by sewage.

Sulphate is a non-toxic anion present in natural water. The values for the Sulphates during both seasons were within the WHO limit of 250mg/l (Tables 3 and 4). The low level of sulphates may be attributed to the possible microbial reduction of sulphate ions. This result is at variance with that of Olusiji et al [10] on the potability status of twenty hand-dug wells in Ekiti State. They recorded a sulphate range of 3.0mg/l-6.2mg/l. Ailments such as dehydration and gastrointestinal irritation have been linked with sulphate concentration above 500mg/l [22]. The sources of iron in water include magnetite and biotite. The values for iron during both seasons were above the WHO permissible limit of 0.3mg/l (Tables 5 and 6 ). This result is in conformity with the work of Adeyemo et al [23], who reported that the iron level of 3.00mg/l that was obtained from investigating the water quality and sanitary conditions in a major abattoir in Ibadan exceeded the WHO recommended standard of 0.3mg/l. Iron at a high concentration can cause transfusional siderosis in the spleen, disturbance in liver functions and diabetes mellitus [24].
The values for lead during both seasons were above the WHO recommended standard of 0.01mg/l (Tables 5 and 6). This result agreed with that of Adeyemo et al [23] that reported a lead concentration of 0.09mg/l in water in a major abattoir in Ibadan, Nigeria. High level of lead in water can lead to cancer, interference in vitamin D metabolism, adverse effects in mental development in infants and toxicity to the central and peripheral nervous systems.

The values for cadmium during both seasons were above the WHO permissible limit of 0.03mg/l (Tables 5 and 6). High level of cadmium in water could be toxic to the kidney. The arsenic concentrations during both seasons were above the recommended limit of 0.01mg/l (Tables 5 and 6). Arsenic is toxic to humans even at low concentration. Arsenic in the shallow hand-dug wells may have originated from agricultural practices since the inhabitants of the study area are mostly arable farmers or from natural arsenic bearing rock as reported by Smedley and Kinniburgh [25].

The values for the temperature, electrical conductivity, calcium hardness and total chloride during both seasons were significant at 5% significance level using t-distribution while the values for the pH, total dissolved solids, total suspended solids, total solids, wells depth, total acidity, total alkalinity, total hardness, sulphate, iron, lead, cadmium and arsenic during both seasons were insignificant at 5% significance level using t-distribution.

All the shallow water wells assessed in this study were contaminated. This may be attributed to the dumping of domestic wastes near the wells and the closeness of the wells to septic tanks, therefore adequate treatment facilities must be put in place to avoid an outbreak of water-borne diseases in the metropolis.

CONCLUSIONS
The water samples from the shallow hand-dug wells studied in Awka metropolis were of poor physicochemical quality. Most of the physical and chemical parameters for both seasons were within the WHO permissible limits. However all the heavy metals- iron, lead, cadmium and arsenic were above the limits, hence it is crucial to treat the shallow wells water adequately before drinking by humans to avert a public health problem. Government efforts should be geared towards the provision of waste disposal infrastructures such as sanitary landfills, incinerators and waste recycling facilities. Necessary legislations should also be put in place by the government to regulate, standardize and monitor water supply sources in the area to ensure public health safety.

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CONFLICTS OF INTEREST
There is no conflict of interest.

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