Assessment of Groundwater Drinking Sources in Eku and Its Environs, in the Niger-Delta Region of Nigeria

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Abstract: This study assessed the quality of hand-dug drinking water sources in Eku and its environs at Eku I, Samagidi, Eku 2, and Okuechi, using the weighted arithmetic water quality index method. Water samples collected from hand-dug wells at these locations returned values for analyzed parameters. Temperature 26 – 30(°C), dissolved Oxygen (D.O) 5.2-8mg/l, biological oxygen demand (BOD) 5.2-8(mg/l), Electrical Conductivity (EC) 77-119(µS/cm), Total suspended solids were (TSS) 20000-120000(µg/l), pH 5.31-7.09, Phosphates 2-9.2(mg/l), Alkalinity 28-160(mg/l), Turbidity, 0.02 -0.19(NTU) Total coliform 2 -48 (cfu/ml) and fungal count 1-502. Variations in the values of these parameters were only significant for phosphate, alkalinity, and turbidity between Samagidi and Okuechi at a level of significance of p≤0.05. D.O, BOD, phosphates, total coliform and TSS levels, exceeded standards recommended by NSDWQ/WHO, rendering these water sources unsuitable for drinking purposes. Cluster analysis revealed three cluster groups; cluster 1(Eku2), cluster 2(Samagidi), and cluster 3(Eku1 and Okuechi), while factor analysis showed a strong correlation with pH, D.O, BOD, phosphate, conductivity, total coliform and fungal counts with water sources in the study stations. The calculated WQI for these water sources is 107.56, 95.18, 103.45, and 110.36 for Eku I, Samagidi, Eku 2, and Okuechi, respectively, classifying them as very poor water quality. Indiscriminate waste disposal, surface runoff and poor sanitary facilities, and the exposed nature of these wells are major contributors to the deterioration of these wells.

Keywords: Eku, Hand-dug wells, Okuechi, Samagidi, Water quality index.

Introduction: Water is a naturally occurring essential compound, whose importance is shown in its diverse application to domestic, agricultural and industrial processes 1. This multiplicity in use has perhaps depleted the quantity and quality of water available for societal use. Accessibility and utilization of potable water are fundamental to attaining sustainable livelihood 2. However, this has remained an illusion in most developing countries, including Nigeria, due to total or partial disregard for laws 3,4. The challenges posed by the difficulties in attaining unhindered and sustainable access to potable water supply have resulted in people seeking alternative means of water supply amongst others, like bore-holes, and deep and shallow hand-dug wells. These alternatives are also not without challenges, due to increasing population, poor sanitary facilities, stormwater run-offs, and continuous use without proper treatment may result in outbreaks of several water-borne diseases 5, especially as groundwater and surface water sources are interconnected and recharge each other 4.

Determining water quality is indispensable in ensuring that water from various sources is fully...
utilized to serve various purposes and enforce policies targeted toward water protection⁶. Water quality assessment requires collecting and analysing of datasets from different water quality parameters. A range of tools, the water quality index (WQI), physical, chemical, and biological, have been developed to evaluate the water quality of aquatic systems ⁷, ⁸. These methods, except WQI, have remained inefficient in defining the quality of any water body as they are inferential at best. Water Quality Index (WQI) is a simple method that describes the general water quality using a group of parameters by reducing the large amounts of information to a single numerical dimensionless value. It is globally recognized and applied as an efficient method of determining the quality status of any water body ⁹. Eku and its environs are home to the Urhobo speaking people of Delta state. Inhabitants are mainly farmers, small-scale business owners and middle-class civil servants who utilize water from River Ethiope, bore-holes, and hand-dug wells of varying depths, for domestic, industrial and recreational activities. The hand-dug wells are the most utilized among these water sources because of their spread and assumed purity. This research aims to assess the water quality index (WQI) for hand-dug wells, which serve as drinking water purposes based on physicochemical and biological water quality parameters, to help the local people towards proper water management, utilization and to build up gauge information which will help in future water protection arrangements.

Materials and methods:

Study Area and Sampling Stations

Eku is a transitional settlement, located in the Ethiope-East local government area of Delta State in the western Niger-Delta region. The study area consisted of four sampling stations, namely Eku1, Samagidi, Eku 2 and Okuechi. The entire area is situated between latitude 5.72°N and 5.80°N and longitude 5.94°E and 6.08°E in the tropical region, with a terrain elevation of 63 meters above the sea level and drained by River Ethiope, which bounds Eku to the West, as shown in Fig. 1 below. The inhabitants of this area are predominantly low-and middle-class individuals of the Urhobo ethnic group who engage in small-scale; farming activities, business owners, artisans, and middle-class servants.

Figure 1. Google maps satellite image of Study Location.

Sampling

Thirty-two 32 hand-dug wells, some of which are shown in Fig. 2 below, were selected randomly within Eku and its environs. The entire region was divided into four distinct zones; Eku 1, Samagidi, Eku 2, and Okuechi, based on dominant activities of the residents; where eight wells were chosen and sampled in January 2019. Water samples were collected in acid-washed polyethylene containers that have been prewashed with the water sample to be tested. Collected samples are placed in an ice chest and transported to the Department of Animal and environmental biology laboratory, Delta state university, Abraka, where they will be analyzed for various physical, chemical and biological parameters within 48 hours of collection. The water samples collected will be analyzed for eleven physiochemical and biological..
parameters; Temperature, Dissolved Oxygen (D.O), Biological oxygen demand (BOD), Electrical Conductivity (EC), Total suspended solids (TSS), pH, Phosphates, Alkalinity, Turbidity, Total coliform and fungal count. Total and Fecal coliform was analyzed using the multiple membrane filtration method, D.O (Winkler method), BOD (Standard titrimetric method), Alkalinity (Titrimetric method) as described by the American Public Health Association 10, TSS, Turbidity, EC, and pH were measured in-situ using Hanna USA H19829 Multiparameter meter, and temperature (mercury in glass thermometer).

**Figure 2.** Image of some hand-dug wells utilized as drinking water sources at the sampling stations (A) Eku 1, (B) Samagidi, (C) Eku 2, and (D) Okuechi.

**Statistical Analysis**

Factor analysis (FA) is a statistical technique that helps to define relationships between water quality parameters and sampled stations 11. It describes the data set by revealing significant parameters while suppressing non-significant parameters 12. FA was applied to the physicochemical and biological parameters data by extracting principal components (PCs). Hierarchical Cluster Analysis (HCA) is used to classify sampling stations based on the physiochemical data set obtained from the sampling stations 13. This study used the past analytical software 14 to analyze the data set for the analysis of FA and HCA. Data derived from the analysis of water samples for physicochemical and biological parameters were subjected to descriptive statistics to determine the mean, standard deviation and range of values for each parameter using Past software version 4 14.

**Calculation of Water Quality Index (WQI)**

The calculation of the WQI was done using weighted arithmetic water quality index, which was developed by 15 for the National sanitation foundation, otherwise known as NSFWQI. The weighted arithmetic water quality index (WQIA) is shown in the equation below:

\[
WQI_A = \frac{\sum_{i=1}^{n} w_i q_i}{\sum_{i=1}^{n} w_i}
\]

\[
W_i = 1/S_i, \text{and } K = \text{constant given as; } K = 1/\sum_{i=1}^{n} S_i
\]

\[
q_i = 100 \left[ (V_i - V_{id}) / (S_i - V_{id}) \right]
\]
Where:
- $V_i$ represents the measured value of the $i$th parameter,
- $S_i$ is the benchmark value of the $i$th parameter and,
- $V_{id}$ represents the value of the $i$th parameter ideally found in pure water.
- $n$ is the number of variables or parameters,
- $w_i$ is the relative assigned weight of each parameter and,
- $q_i$ is the quality rating of the $i$th parameter.

The unit weight ($w_i$) of the various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters. This method has been adopted and used globally$^{16, 17}$. The following nine parameters: Temperature, Dissolved Oxygen (D.O), Biological oxygen demand (BOD), Electrical Conductivity (EC), Total suspended solids (TSS), pH, Phosphates, Turbidity, and Total coliform perceived to have the most impact on the water quality, was used for the calculation of WQI.

### Table 1. Weight Arithmetic Water Quality Index Method, water quality Rating

| WQI Value | Rating of water quality | Grading |
|-----------|-------------------------|---------|
| 0 – 25    | Excellent water quality | A       |
| 26 – 50   | Good water quality      | B       |
| 51 – 75   | Poor water quality      | C       |
| 76 -100   | Very Poor water quality | D       |
| 100       | Unsuitable for Drinking | E       |

**Source**$^{13}$

**indicates significant variations at $P≤0.05$, $P$-value indicates the level of significance (0.05). $F$-value indicates ANOVA $F$-ratio.

### Table 2. ANOVA, variations of physicochemical parameters and WHO/NSDWHO, standard values in Eku and its Environs (first line: mean ± SD, second line: range).

| Parameter | Eku 1 | Samagidi | Eku 2 | Okuechi | WHO/NSD WQ | P-VALUE | F-VALUE |
|-----------|-------|----------|-------|---------|------------|---------|---------|
| TEMPERATURE (°C) | 28.75±0.707 | 27.5±1.195 | 28.75±0.885 | 28.625±1.3 | 25 | 0.0666 | 2.673 |
| CONDUCTIVITY (µS/cm) | 104.875±3.8 | 106.0±3.12 | 106.25±3.1 | 105.5±5.23 | 100 | 0.9319 | 0.1453 |
| DISSOLVED OXYGENS (mg/L) | 6.35±0.4504 | 6.3±0.659 | 6.05±0.6211 | 6.525±0.39 | 6 | 0.3893 | 0.3893 |
| BOD (mg/L) | 2.125±0.477 | 2.2±0.5555 | 1.5625±0.740 | 2.275±0.46 | 3 | 0.0726 | 2.591 |
| PHOSPHATE (mg/L) | 7.075±2.85 | 5±1.94 | 7.3±1.31 | 7.66±0.89 | 3.5 | 0.0389* | 3.19 |
| ALKALINITY (mg/L) | 61.75±18.90 | 55.5±16.13 | 73.13±17.15 | 89.25±37.7 | ND | 0.047* | 3.006 |
| TURBIDITY (NTU) | 0.06±0.03 | 0.07±0.04 | 0.12±0.06 | 0.11±0.06 | 5 | 0.0325 | 3.365 |
| TSS (mg/L) | 370000±2710 | 55000±232 | 600000±2761 | 60000±338 | 500 | 0.4542 | 0.8897 |
| pH | 6.51±0.55 | 6.2±0.76 | 6.15±0.77 | 6.57±0.44 | 6.5 - 9.2 | 0.4626 | 0.8815 |
| TOTAL COLIFORM (cfu/ml) | 10.88±6.22 | 7.5±4.63 | 19.75±18.08 | 14.88±10.9 | 10 | 0.177 | 1.764 |
| FUNGI | 124.29±185 | 54.25±100 | 26.67±24.19 | 79.83±106 | ND | 0.5164 | 0.7814 |

The mean, standard deviation, range of values of the various results of analysis of Physico-chemical parameters of water samples from the sampled stations are shown in Table 2. pH ranged from 5.31-7.09, Alkalinity 28-160, Turbidity 0.02-0.19, phosphate 2.0-9.2, and TSS 20000-120000. Water temperature values ranged between 26-30, electrical conductivity, 77-119, Biological oxygen demand (BOD) 0.2-7.2, Dissolved oxygen (D.O) 5.2-8. One-way ANOVA, was applied to the results of the analysis of water samples for the various parameters from each station to determine the existence of significant variations in the values of each parameter between four water sources, at
The exposed nature of the wells sets up these wells to receive storm water runoffs. pH is a very important water quality parameter, particularly in maintaining the rate of biochemical reactions. The values reported from these wells in all the locations ranged between 5.31-7.09. These slightly acidic conditions have been reported in hand-dug wells in Imo state and in some bore-hole water sources in Obiakpor. Although the values recorded in this study are slightly below the drinking water limit, these water sources can sustain the growth of microbial life. Acidic water are limited in the provision of needful mineral elements when consumed, and the toxicity level of most metals in water increases with low pH levels when it falls below 6.5, the water develops sour taste, this study, however, did not report any sour taste. The level of phosphate ions recorded during this study was generally high, with a range value of 2mg/L - 9.2mg/L. The phosphate level generally exceeded the limit recommended for drinking water 3.5mg/L, making these water sources unsuitable for drinking. The proliferation of high phosphate levels in the study area is indicative that the source can be from natural and anthropogenic activities. reported that high phosphate levels in underground water sources could have resulted from sinks of phosphate released from fertilizers used in farmlands and indiscriminately dumped solid and liquid waste on the surface. This study agrees with since residents of Okuechi, Samagidi, Eku1 and Eku 2 are predominantly farmers or artisans without good waste disposal or treatment plants or access to good toilet facilities. Storm water runoffs, poor sanitary habits and proliferation of exposed wells would have contributed to the high heterotrophic bacteria count in all the sampled areas. The presence of E. coli and total coliform in volumes beyond the permissible levels, 0 and 10cfu/ml, respectively, in all sampling points, makes these water sources unsuitable for drinking purposes.
The dendrogram produced when the results of the analysis of physicochemical parameters from the wells from four sampling stations, Eku 1, Samagidi, Eku 2 and Okuechi, were subjected to cluster analysis reduced the four water sources into three groups, as shown in Fig.3 above. Group 1, was represented by wells in Eku 2, located in the central part of the town. The major contributor to this cluster is TSS, which was the highest in Eku 2. Other factors are conductivity, temperature, alkalinity, and total coliform. Group 2 was well clustered in Samagidi, where turbidity as well as the parameters mentioned in cluster 1 were implicated as responsible for this cluster. The third cluster represents wells in Eku 1 and Okuechi, where D.O, BOD, pH, phosphate, conductivity, and bacteria are factored in. Eleven parameters were subjected to factor analysis, to show the contribution of each parameter to the wells studied, as shown in Fig. 4. Factor 1 showed a very strong to fairly strong correlation with pH, D.O, BOD, phosphate, conductivity, total coliform and fungal counts in wells from Eku 2 and Okuechi. Factor 2, on the other hand, reported a strong correlation with pH, D.O, BOD, phosphate, Conductivity, total coliform and fungal counts in wells from Samagidi and Okuechi. To ascertain the variation in the four sampling areas, the results of all bio-physicochemical parameters of the sampled wells were subjected to principal component analysis. Three principal components (PC) were returned, out of which PC 1, accounted for the most significant variation, with an eigenvalue of 0.115634, and 69.595% variation. The bulk of this variation was contributed by fungi, total coliform, turbidity, alkalinity, BOD, and TSS, which scored -0.77926, 0.38427, 0.37772, 0.1097, -1.18010, and 0.22933, respectively, as shown in Table 3.

Table 3. Loadings of various parameters, percentage Variation and Eigenvalue along with three principal components.

| Parameter        | PC 1     | PC 2     | PC 3     |
|------------------|----------|----------|----------|
| TEMPERATURE      | 0.005258 | 0.041074 | -0.04077 |
| CONDUCTIVITY     | 0.01015  | 0.010284 | -0.01111 |
| DISSOLVED OXYGENS| -0.02657 | 0.028184 | 0.08284  |
| BOD              | -0.18108 | 0.017291 | 0.42388  |
| PHOSPHATE        | 0.058789 | 0.40263  | -0.17501 |
| ALKALINITY       | 0.1097   | 0.37436  | 0.32943  |
| TURBIDITY        | 0.37772  | 0.28899  | 0.40557  |
| TSS              | 0.22933  | -0.04099 | 0.59976  |
| pH               | -0.0266  | 0.055076 | 0.030195 |
| Total coliform   | 0.38427  | 0.5977   | -0.36325 |
| FUNGI            | -0.77926 | 0.49938  | 0.12435  |
| % variance       | 69.595   | 23.869   | 6.5361   |

Figure 4. Scatter plot showing variations of water parameters at Eku and its environs along with two principal components.

The overall WQI of the wells in Eku 1, Samagidi, Eku 2 and Okuechi are 107.56, 95.18, 103.45, and 110.36, respectively, as shown in Table 4 above. These values are graded D and E, which translates as very poor water quality to the water of unsuitable drinking quality as shown in Table 1 above. By this standard, water from wells in Eku 1, Eku 2 and Okuechi is not suitable for drinking water purposes, while those in Samagidi are of very poor quality, similar classifications have been made of some groundwater sources in the districts of Tigray, Ethiopia 29 and Uttarakhand, India 30. The result of water quality indices follows a similar pattern to the way the various sampling stations clustered. The closeness of Eku 1 and Okuechi 107.56 and 110.36 indicates that similar natural and anthropogenic conditions (poor sanitary, open defecation and indiscriminate waste disposal) permeated both communities, resulting in low DO, High BOD, Phosphate and total coliform levels in these communities. Water quality of Eku 2 and
Samagidi, were affected mostly by high levels of TSS and Turbidity. This results from the impact of surface runoffs into wells, especially the unprotected wells. The water quality values from Eku 1, Samagidi, Eku 2, and Okuechi suggest that the water should not be used for drinking purposes without proper treatment to prevent water-borne diseases and other health challenges associated with the utilization of poor-quality water. This study aligns with 31 who reported poor water quality in Al-Hila River, 19 in Anwai River, pointing to poor sewage disposal as responsible for the growth of Coliform bacteria and poor water quality rating.

### Table 4. Summary of Weight, Quality Rating of Bio and Physicochemical Parameters from all the Sampled Wells

| Water Parameters | Constant (K) | Wi | EKU 1 Qi | EKU 1 Wi.Q | SAMAGI Wi.Q | EKU 2 Wi.Q | OKEUCHI Wi.Q |
|------------------|--------------|----|----------|------------|-------------|------------|-------------|
| pH               | 0.8082       | 0.08 | -1.9575 | -36.3600   | -1.0000     | -3.396     | -19.5500    |
| E-COND. (µS/cm)  | 0.8082       | 0.00 | 10.4900  | 0.0084     | 10.4250     | 0.0086     | 10.5500     |
| TSS (mg/L)       | 0.8082       | 0.00 | 7400.00  | 11.8400    | 11000.00    | 17.60      | 20000.00    |
| BOD (mg/L)       | 0.8082       | 0.26 | 70.830   | 19.0816    | 73.3300     | 19.75      | 52.1000     |
| DO (mg/L)        | 0.8082       | 0.13 | 95.930   | 12.9218    | 96.5100     | 12.99      | 99.4200     |
| TURBIDITY (NTU)  | 0.8082       | 0.16 | 1.2000   | 0.1939     | 1.4000      | 0.226      | 2.4000      |
| PHOSPHATE (mg/L) | 0.8082       | 0.23 | 202.14   | 46.6741    | 142.8600    | 32.98      | 208.5700    |
| TEMPERATURE (°C) | 0.8082       | 0.03 | 115.00   | 3.7145     | 110.0000    | 3.553      | 115.0000    |
| TOTAL COLIFORM (cfu/ml) | 0.8082 | 0.08 | 197.50   | 15.9580    | 148.8000    | 12.02      | 108.8000    |
| WQI              |              |     |          |            | 107.56      | 95.18      | 103.4       |

### Conclusion:

Drinking groundwater sources within Eku and its environs assessed in this study have high values for measuring water parameters, regarding temperature, D.O, phosphates, total coliform and TSS levels exceeding the recommended standards NSDWQ/WHO, rendering these water sources unsuitable for drinking purposes. The calculated WQI for these water sources is 107.56, 95.18, 103.4, and 110.36 for Eku I, Samagidi, Eku 2, and Okuechi, respectively, classifying them as very poor water quality and unsuitable for drinking purposes. Therefore, using these water sources in Eku and its environs as drinking water sources should be discouraged. Unless and until the water’s quality is improved by proper water treatment process.

### Authors’ declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Besides, the Figures and images, which are not ours, have been given the permission for re-publication attached with the manuscript.

- Ethical Clearance: The project was approved by the local ethical committee in Federal College of Education (Technical).

### Authors' contributions statement:

KI, was involved in conceiving, designing, analysis, interpretation, drafting and proofreading the manuscript. NO, contributed to the manuscript’s design, analysis, interpretation, drafting, revision, and proofreading. KM, was part of the Design, Data acquisition, Interpretation, revision and proofreading the manuscript. RO, Data acquisition, drafting and proofreading of the manuscript. MA, Data acquisition, drafting and proofreading of the manuscript.

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Evaluating groundwater sources in Iko and its environs, in the Delta of Niger River in Nigeria. Ika and Okuechi, Adamu, A. et al.

The summary: The quality of groundwater sources in Iko and its environs was evaluated using the mathematical water quality index method. Water samples were collected from hand dug wells in these locations, which gave values for the analyzed parameters. Temperature 11-12°C, dissolved oxygen (D.O) 5.2-8 mg/L, biological oxygen demand (BOD) 5.2-8 mg/L, electrical conductivity (EC) 77-119 µS/cm, Total Suspended Solid (TSS) 20000-120000 mg/L, pH 5.12-1.21, Phosphate 1-1.1 mg/L, hardness 12-212 mg/L, turbidity 2.21-2.21 NTU, coliform 2-48 (cfu/ml), and fungi 2-521.

The differences in these parameters were significant only for phosphate and hardness between Samagidi and Okuechi at a significance level of p≤0.05.

NSDWQ / WHO recommended using D.O, BOD, phosphate, Total coliform and TSS as water sources, which makes these water sources unsuitable for drinking purposes. The cluster analysis revealed three cluster types; Cluster 2 (Eku2), Cluster 1 (Samagidi) and Cluster 1 (Eku1 and Okuechi), indicating a strong correlation with pH, dissolved oxygen, oxygen, phosphate, electrical conductivity, total coliform and fungi. The calculated WQI for these water sources was 221.51, 15.22 and 221.15, respectively, indicating that these waters are of very poor quality and unsuitable for drinking purposes. The random disposal of waste, surface flow and poor sanitary conditions are the main factors that deteriorate these wells.

Key words: Iko, hand dug wells, Okuechi, Samagidi, Water Quality Index.