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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(ºC), 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(mg/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 $p \leq 0.05$. 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 and unsuitable for drinking purposes. 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 protection[6].

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.

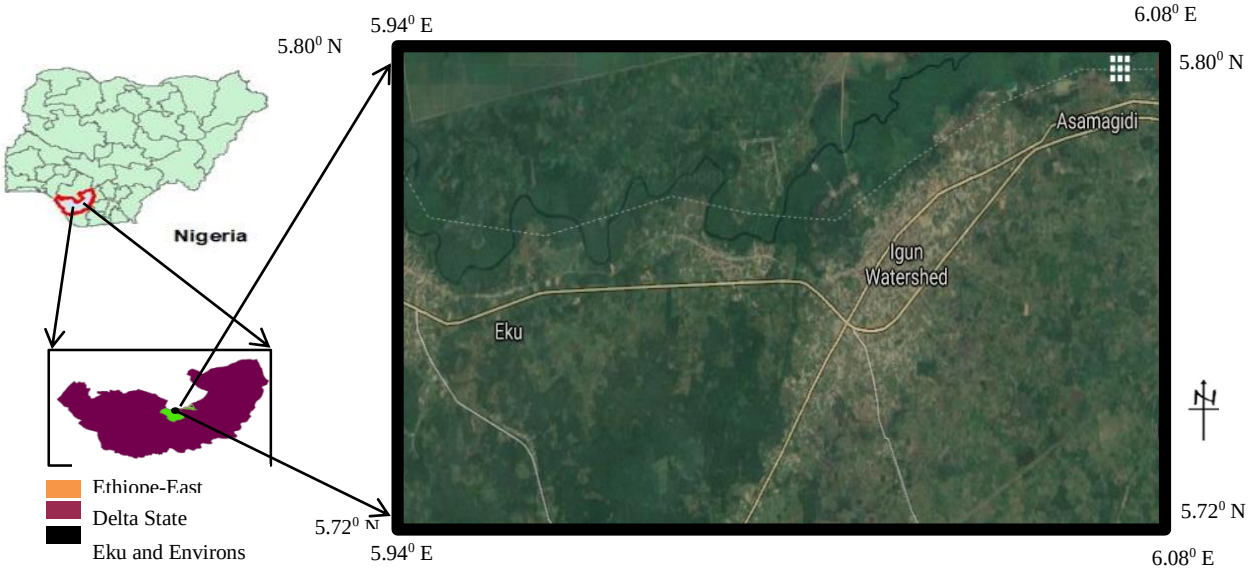

Figure 1. Google maps satellite image of Study Location.

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:

$$WQI_A = \sum_{i=1}^{n} w_i q_i \,/\, \sum_{i=1}^{n} w_i \quad (1)$$

$$Wi = 1/Si, and\ K = \ constant\ given\ as;\ K = 1/\sum 1/Si \quad (2)$$

$$qi = \ 100\ [(Vi - Vid)\ /\ (Si - Vid)] \quad (3)$$

Where:

- Vi represents the measured value of the ith parameter,
- Si is the benchmark value of the ith parameter and,
- Vid represents the value of the ith parameter ideally found in pure water.
- n is the number of variables or parameters,
- wi is the relative assigned weight of each parameter and,
- qi is the quality rating of the ith parameter.

The unit weight (wi) 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 - Above	Unsuitable for Drinking Purpose	E

Source[17]

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

	Eku 1	Samagidi	Eku 2	Okuechi	WHO/NSDWQ	P-VALUE	F-VALUE
TEMPERATURE (◦C)	28.75±0.7071 (28-30)	27.5±1.1952 (26-29)	28.75±O.8854 (28-30)	28.625±1.3025 (26-30)	25	0.0666	2.673
CONDUCTIVITY (µS/cm)	104.875±3.8336 (100-109)	104.25±3.2404 (100-109)	106.625±13.1686 (77-119)	105.5±5.2372 (100-115)	1000	0.9319	0.1453
DISSOLVED OXYGENS (mg/L)	6.35±0.450495 (4-6.8)	6.3±0.6590 (5.4-7)	6.05±0.6211 (5.2-7)	6.525±0.3991 (5.6-7)	6	0.3893	0.3893
BOD (mg/L)	2.125±0.4773 (1.4-2.6)	2.2±0.5555 (2.2-7.2)	1.5625±0.7405 (0.2-2.6)	2.275±0.4652 (1.6-3)	3	0.0726	2.591
PHOSPHATE (mg/L)	7.075±2.85 (2-9.2)	5±1.94 (2.2-7.2)	7.3±1.31 (5.3-8.9)	7.66±0.86 (6.6-8.9)	3.5	0.0389*	3.19
ALKALINITY (mg/L)	61.75±18.90 (38-85)	55.5±16.13 (28-73)	73.13±17.15 (45-105)	89.25±37.75 (40-160)	ND	0.047*	3.006
TURBIDITY(NTU)	0.06±0.03 (0.03-0.12)	0.07±0.04 (0.02-0.13)	0.12±0.06 (0.05-0.19)	0.11±0.06 (0.04-0.18)	5	0.0325	3.365
TSS (mg/L)	37000±27108.35 (20000-100000)	55000±23299.3 (20000-80000)	60000±42761.8 (20000-120000)	60000±33806.2 (20000-100000)	500	0.4542	0.8897
pH	6.51±0.55 (5.62-7.07)	6.20±0.76 (5.31-7.09)	6.15±0.77 (5.48-7.07)	6.57±0.44 (6.08-7.09)	6.5 - 9.2	0.4626	0.8815
TOTAL COLIFORM (cfu/ml)	10.88±6.22 (5-21)	7.5±4.63 (2-14)	19.75±18.08 (3-48)	14.88±10.90 (5-33)	10	0.177	1.764
FUNGI	124.29±185.81 (1-502)	54.25±100.81 (1-295)	26.67±24.19 (4-68)	79.83±106.36 (3-263)	ND	0.5164	0.7814

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

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

p≤0.05 level of significance. Table 2 shows that the physical (temperature), chemical (pH, D.O, BOD, electrical conductivity, total suspended solids, and biological (total coliform and fungi) did not record any significant variation, except phosphate, alkalinity and turbidity. Turkey's pairwise test indicated points of significant comparison for alkalinity and phosphate between Samagidi and Okuechi in each case, with values of 0.0436 and 0.0421, respectively. Temperature values from the wells range from 26 ºC – 30ºC. These values are higher than those recorded by [4] in some drinking water wells in the southeastern part of Nigeria 28 ºC -29.2ºC. Well water temperature is influenced by a combination of climatic conditions (Atmospheric temperature) and the depth of the well. [18], attributed high water temperatures recorded in the Ethiope river to the seamless transfer of heat from the environment into the water. High water temperatures have been reported to negatively impact the oxygen holding capacity of water [19] and the drinkability of water, increasing the BOD volume in aquatic environments [20]. The D.O content recorded in this study 0.07mg/L -0.11mg/L, was within the standard limits recommended [21]. Similar values 5.09mg/L -6.03mg/L were recorded by [22], in their assessment of groundwater quality in Yobe state, Nigeria. This value is indicative that the well water sources in Eku and its environs are good for drinking, based on the assessment of its dissolved oxygen content. The BOD values 0.2mg/L - 3.2mg/L, recorded in this study, although higher than the values recorded by [19], 1.32-1.40 mg/L, and [22], 0.07mg/L -0.11mg/L in Anwai River, Delta State, and Gombe state, respectively, is still below the standard limit of BOD for drinking water sources. The slightly higher BOD can be attributed to surface runoff from floodwater into the wells. The surface runoff inflow into wells has been indicted for the high BOD [23] and low DO [12]. The study area's location in Delta state is located in the tropical rainforest zone in the Niger-Delta region. 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 [4] in Imo state and [24] in some bore-hole water sources in Obiakpor. Although the values recorded in this study are slightly below the drinking water limit [25], these water sources can sustain the growth of microbial life [24]. Acidic water are limited in the provision of needful mineral elements when consumed [26], and the toxicity level of most metals in water increases with low pH levels [27] when it falls below 6.5, the water develops sour taste [24], 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 [25], 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. [28] 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 [28] 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 [5].

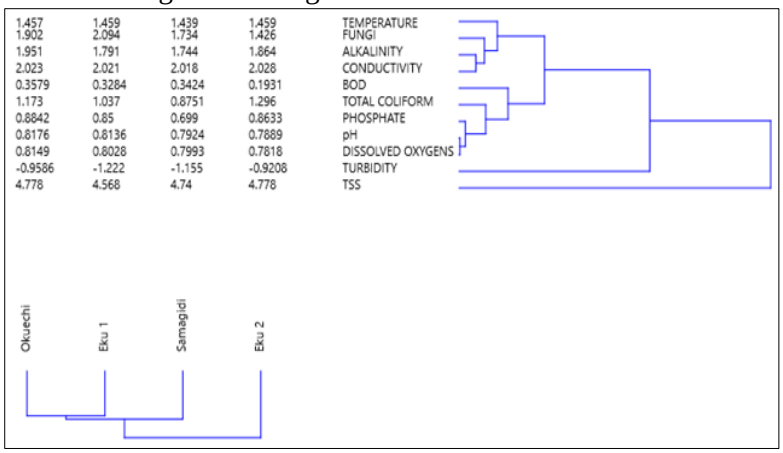

Figure 3. Hierarchical Clustering Analysis

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 I 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, -1.180108, and 0.22933, respectively, as shown in Table 3.

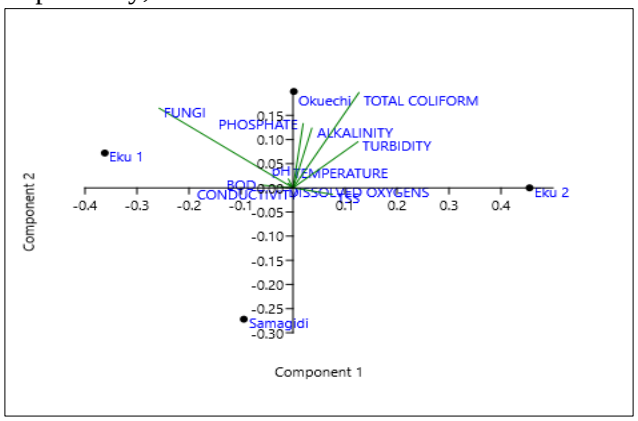

Figure 4. Scatter plot showing variations of water parameters at Eku and its environs along with two principal components.

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

	PC 1	PC 2	PC 3
TEMPERATURE	0.005258	0.041074	-0.04077
CONDUCTIVITY	0.01015	0.010284	-0.0111
DISSOLVED OXYGENS	-0.02657	0.02818	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
Eigenvalue	0.115634	0.039659	0.01086
% variance	69.595	23.869	6.5361

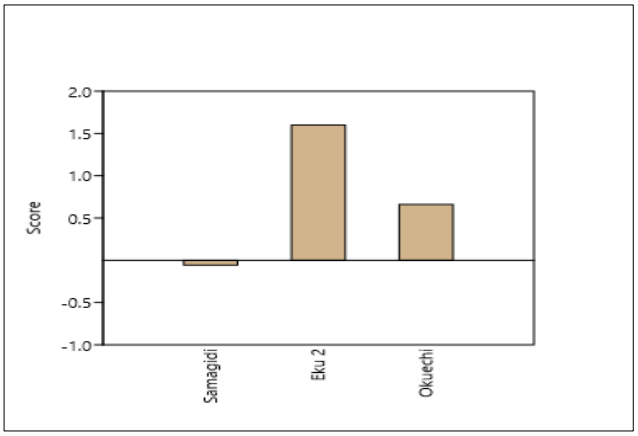

Figure 5. Factor Analysis Score plot showing correlation of factor 1 with different sample locations

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	EKU1 Wi.Qi	SAMAGI DI Qi	Wi.Q i	EKU 2. Qi	Wi.Q i	OKUECH I Qi	Wi.Q i
pH	0.8082	0.0879	-22.2700	-1.9575	-36.3600	-3.1960	-38.6364	-3.3961	-19.5500	-1.7184
E-COND. (µS/cm)	0.8082	0.0008	10.4900	0.0084	10.4250	0.0083	10.6600	0.0085	10.5500	0.0084
TSS (mg/L)	0.8082	0.0016	7400.0000	11.8400	11000.0000	17.6000	12000.0000	19.2000	12000.0000	19.2000
BOD (mg/L)	0.8082	0.2694	70.8300	19.0816	73.3300	19.7551	52.1000	14.0357	76.0000	20.4744
DO (mg/L)	0.8082	0.1347	95.9300	12.9218	96.5100	12.9999	99.4200	13.3919	93.8400	12.6402
TURBIDITY (NTU)	0.8082	0.1616	1.2000	0.1939	1.4000	0.2262	2.4000	0.3878	2.2000	0.3555
PHOSPHATE (mg/L)	0.8082	0.2309	202.1400	46.6741	142.8600	32.9864	208.5700	48.1588	218.8600	50.5348
TEMPERATURE (ºC)	0.8082	0.0323	115.0000	3.7145	110.0000	3.5530	115.0000	3.7145	114.5200	3.6990
TOTAL COLIFORM (cfu/ml)	0.8082	0.0808	197.5000	15.9580	148.8000	12.0230	108.8000	8.7910	75.0000	6.0600
WQI				**107.56**		**95.18**		**103.45**		**110.36**

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, 103.45, 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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تقييم مصادر شرب المياه الجوفية في ايكو وضواحيها، في منطقة دلتا النيجر في نيجيريا

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الخلاصة:

قيمت هذه الدراسة جودة مصادر مياه الشرب المحفورة يدويا في ايكو وضواحيها. باستخدام طريقة مؤشر جودة المياه الحسابية. تم جمع عينات المياه من الآبار المحفورة يدويًا في هذه المواقع والتي أعطت قيمًا للمعلمات التي تم تحليلها. درجة الحرارة 26 - 30، الأكسجين المذاب 5.2-8 (D.O)ملجم / لتر، الطلب على الأكسجين البيولوجي 5.2-8 (BOD)(ملجم / لتر)، التوصيل الكهربائي 77-119 (EC) (µS / سم).إجمالي المواد الصلبة العالقة 20000-120000 (TSS)(مجم / لتر) ، الرقم الهيدروجيني 5.31-7.09 ، الفوسفات 2-9.2 (مجم / لتر) ، القلوية 28-160 (مجم / لتر) ، التعكر ، 0.02 -0.19 (NTU)المجموع 48 -2 coliform (cfu / ml)وعدد الفطريات 1-502. كانت الاختلافات في قيم هذه المعلمات مهمة فقط للفوسفات والقلوية والعكارة بين Samagidiو Okuechiعند مستوى معنوية $p\leq0.05$. أوصت NSDWQ / WHOباستخدام D.O، BOD، الفوسفات، إجمالي القولون ومستوى TSS، مما يجعل مصادر المياه هذه غير مناسبة لأغراض مياه الشرب. كشف التحليل العنقودي عن ثلاث مجموعات عنقودية؛ المجموعة 1 (Eku2)والمجموعة 2 (Samagidi) والمجموعة 3 Eku1)و (Okuechi، بينما أظهر تحليل العوامل ارتباطًا قويًا مع الأس الهيدروجيني ، والأكسجين المذاب ، والأكسجين الحيوي ، والفوسفات ، والتوصيلية ، والتعداد القولوني الكلي والفطريات مع مصادر المياه في الدراسة المحطات WQI .المحسوب لمصادر المياه هذه هو 107.56 و 95.18 و 103.45 و 110.36 لـ Eku I وSamagidi و Eku 2وOkuechi، على التوالي ، وتصنيفها على أنها ذات نوعية مياه سيئة للغاية وغير مناسبة لأغراض الشرب. يعتبر التخلص العشوائي من النفايات والجريان السطحي وسوء المرافق الصحية والطبيعة المكشوفة لهذه الآبار من العوامل الرئيسية في تدهور هذه الآبار.

الكلمات المفتاحية: ايكو، الآبار المحفورة يدويًا، اوكيجو، سماجيدي، مؤشر جودة المياه.