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Water Quality Assessment using GIS based Multi-criteria evaluation (MCE) and Analytical Hierarchy Process (AHP) Methods in Yenagoa Bayelsa State, Nigeria

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***Abstract*— The study examined the quality of groundwater in Yenagoa, a metropolitan area, using Geographic Information System (GIS)-based methods such as Multi-criteria evaluation (MCE) and Analytical Hierarchy Process (AHP). The research emphasizes the crucial nature of protecting and managing groundwater quality in this region, as it is vulnerable to contamination. The spatial distribution patterns of groundwater quality in the area are depicted in this article. The physicochemical properties of fifty (50) water samples are directly related to residents' environmental and health status. The physicochemical parameters measured using the American Public Health Association procedure (APHA)—including pH, conductivity, total dissolved solids, sulphate, nitrate, sodium, chloride, and total hardness—were below the limit established by WHO (2011). Iron in most boreholes is found to be above the WHO standard for drinking water. With the help of ArcGIS software, these results were modeled using the inverse distance-weighted method to provide the spatial pattern of groundwater. The spatial distribution map delineates groundwater suitability zones of 55% and unsuitability zones of 45% for groundwater extraction of water points in yenagoa affected by high iron content. As a result, GIS is a powerful tool for making critical decisions in waste management-related issues, such as identifying areas where waste management practices may be deficient and allowing for targeted initiatives to improve waste management practices and reduce waste's negative impact on the ecosystem and public health.*

I. INTRODUCTION

Groundwater is characterized by biological and chemical characteristics. However, these characteristics are inadequate for understanding the geospatial relation between groundwater quality and its occurrence. As a result, this relationship requires the use of geographical information systems and statistical techniques (Arulbalaji et al., 2019). With the use of these techniques, groundwater data is critically examined, managed, and spatially displayed. The use of GIS in groundwater resource management is anchored on the inverse overlay method using an inverse weighted technique (Tsihrintzis et al., 1996; Veysel and Recep, 2021). These attributes are critical in the management of design tools (Stafford, 1991). GIS tools are effective in the critical analyses of water suitability, groundwater vulnerability, groundwater leaching, modeling of solute transport, groundwater flow mapping, and groundwater quality index (Oki and Eteh, 2018; Mukate et al., 2019). Statistically, two techniques are critical in the assessment of groundwater quality. These parameters are anchored on the physico-chemical characteristics of the groundwater. In this region, the chemical characteristic of interest remains the iron content of the groundwater (Nwankwoala et al., 2014; Wan et al., 2019). Besides, a high or low pH outside the limits of the World Health Organization is critical to human health (WHO, 2011). Water quality evaluation is an essential task for sustainable water resource management. The analytical hierarchy process (AHP) and GIS-based multi-criteria evaluation (MCE) are two commonly used techniques for assessing water quality. MCE based on GIS is a method for evaluating and comparing numerous factors based on spatial data. This method entails giving weights to each criterion based on their respective significance, then combining the criteria to create a total evaluation of water quality. Physical, chemical, and biological factors such as pH, temperature, dissolved oxygen, turbidity, and nutrient concentrations may be used to evaluate water quality. Hence, multi-criteria evaluation (MCE), the analytical hierarchy process (AHP), and GIS are relevant to the understanding of the water quality in this region. In this study, GIS techniques were used in assessing the distribution pattern of groundwater quality. The results provided by these techniques delineate potable water and non-potable water in Yenagoa, Bayelsa State.

II. GEOLOGY OF THE STUDY AREA

The area is in the middle section of the Niger Delta region and consists of sedimentary basin structures (Figure1). The area covers Latitude 5º3'30"N to 4º68'30"N and Longitude 6º15'0"E to 6 21'0"E. and possesses low-lying topography elevating up to 40m elevation (Reyment, 2018). The Niger Delta Basin constitutes a failed rift junction developed by the pulling apart of the South American plate from the African plate. The rifting began during the late Jurassic period and was truncated during the mid-Cretaceous. Several faults' lines are associated with this rifting resulting in the formation of thrust faults (Reijers, 2011). These structures constitute the facies of the pro-delta Akata Formation and the Agbada Formation which constitute a paralic delta front. The Benin Formation comprises a delta facies that is continental in nature. The basal lithostratigraphic comprises the Akata Formation and ranges from Paleocene to Holocene age (Reyment, 2018; Etu–Efeotor, 1997). The Akata formation comprises deep marine deposits under high pressure and low density. Thick shales, turbidite sands, and small amounts of silt and clay constitute the mega marine facies. (Chukwu, 1991). These characteristics are evidence of a shallow marine shelf depositional environment (Etu-Efeotor, 1997).

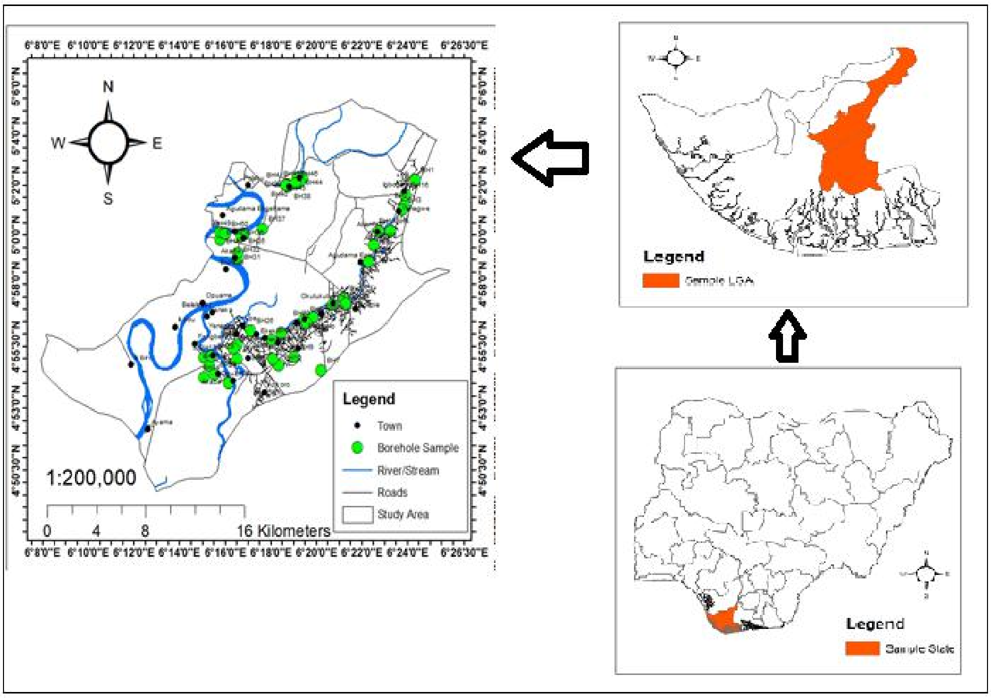

Fig.1: Study Area map showing Borehole location

III. MATERIALS AND METHODS

Data Collection

The locations of the boreholes in the study area were determined using a handheld global positioning system (GPS) instrument GARMIN GPS-60 receiver. Field sampling generated the primary data for the physical and chemical characteristics of the groundwater obtained from several boreholes located in Yenagoa. Polypropylene plastic bottles were used to collect Fifty (50) samples of the groundwater (Figure 1). These samples were collected during pumping to ensure that fresh samples were collected. Besides, there was a need to homogenize the water samples and minimize the impacts of rusty pipes.

Data Analysis

The physical and related characteristics such as pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were determined on-site using portable pH, Electrical Conductivity, Total Dissolved Solid meter (HANNA) the United Kingdom respectively. Metal analyses of water samples were conducted since nitric acid (50 % v/w) was used for acidification to Magnesium (Mg2+), Calcium (Ca2+) and Sodium (Na+) contents in the water samples were determined using an Atomic Absorption Spectrometer (AAS) Chloride (Cl-), Sulphate (SO4), Nitrate (NO3-) contents in the water samples were using ion chromatography. The bicarbonate (HCO3-) content in the water samples was determined using the American Public Health Association titrimetric method (APHA, 2017). The results from the chemical analysis were processed in an excel format and imported into a GIS environment to produce some spatial distribution maps.

Data Processing

The non-spatial database was arranged in excel format and aligned with the spatial data format in ArcMap. These data set were import to generate the geospatial distribution thematic maps of the groundwater using spatial interpolation with inverse distance weighted method. The method was used to delineate the natural and subsurface groundwater contaminants.

The index overlay method was used to analyze the data layers. This spatial technique comprises the superposition of multiple layers using a thematic scheme, thus providing a new layer. The map classes were designated to different value scores with different weightages as supported by Mageshkumar et al., 2019. The weighted overlay method delineated groundwater suitability and selection. The input layers for the analysis of groundwater suitability were the pH, Total Hardness (TH), Total Dissolved Solids (TDS), Sodium (Na+), Nitrate (NO3-), Chloride (Cl-), electrical conductivity (EC), Sulphate (SO42-), Magnesium (Mg2+), and Iron (Fe2+) contents.

The score reading for these parameters was classed for each map and assigned along with the map weightages.

The following lists the general steps to perform overlay analysis:

1. Describe the problem.
2. Break the problem into sub-models.
3. Determine weighty or important layers.
4. Reclassify or change the information inside a layer.
5. Weight the input layers.
6. Add or combine the layers.
7. Inspect Result.

Inverse distance weighted (IDW) technique

To map water quality assessment, we performed an inverse distance weighting (IDW) interpolation on each parameter before classifying it into 3 classes using WHO standard (2011) limit and reclassify them base on highly suitable, suitable, and unsuitable (Figure 2). In an examination of a few distinctive deterministic interpolation methodology, Burrough and McDonnell (2015) found that utilizing IDW with a squared distance term yielded results generally reliable with unique information. Since Inverse Distance Weighted is not a probabilistic way of spatial interpolation approach to estimate an unknown value at a location using some known values with equated weighted values and the Inverse Distance formula is given in equation 1

$$x^* = \frac{w_1 x_1 + w_2 x_2 + w_3 x_3 + \ldots + w_n x_n}{w_1 + w_2 + w_3 + \ldots + w_n} \quad (1)$$

Where x* is the unknown value at a location to be resolved, w is the weight, and x is the known point value.

The weight is the inverse distance of a point to each known point value that is used in the calculation and the weight formula is given in equation 2.

$$w_i = \frac{1}{d_{ix^*}^{P}} \quad (2)$$

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Table 1: Physico-Chemical Parameters of Groundwater in Yenagoa

Borehole	Lat	long	pH	EC (us/cm)	TDS(mg/l)	NO3 (mg/l)	Cl(mg/l)	SO4(mg/l)	TH(mg/l)	Iron(mg/l)	Na(mg/l)
BH1	5.036889	6.405972	6.12	406	203	0.36	39	1.4	25	0.6	10.86
BH2	5.01975	6.398167	6.3	715	356	0.165	15	0.8	45	0.14	4
BH3	5.016722	6.396528	6.38	857	430	0.335	21	1.67	18	0.4	6.5
BH4	5.002366	6.387691	6.1	782	391	0.175	14	0.86	37	0.37	4.85
BH5	4.957417	6.35375	5.99	164	82	0.165	14	0.82	35	0.38	4.54
BH6	4.94325	6.324806	5.93	175	84	0.094	16	0.48	32	0.3	5.2
BH7	4.908472	6.337083	5.6	763	383	0.085	14	0.45	30	0.15	4.74
BH8	4.929167	6.300806	6.69	1156	578	0.096	22	0.5	46	0.35	5.8
BH9	4.917722	6.317583	6.14	269	135	0.348	34	1.75	101	0.14	9.95
BH10	4.91175	6.305972	6.74	1652	826	0.42	47	2.1	45	0.36	13.58
BH11	4.925861	6.275583	6.05	422	211	0.204	37	0.96	91	0.16	9.84
BH12	4.916	6.2755	6.87	722	361	0.49	23	2.45	33	0.36	7.6
BH13	4.917028	6.251222	6.43	928	464	0.078	16	0.39	27	0.26	5.4
BH14	4.903722	6.251222	6.2	160	80	0.162	24	0.8	56	0.12	6
BH15	4.91125	6.255611	6.91	530	265	0.17	8	0.86	15	0.18	3.85
BH16	5.026869	6.398981	6.33	496	248	0.137	13	1.28	65	0.39	5.82
BH17	5.002678	6.379307	6.13	164	82	0.341	55	5.6	93	0.4	15.9
BH18	4.992793	6.375336	5.88	334	167	0.23	58	5.5	200	0.7	17.4
BH19	4.98176	6.37166	6.01	173	87	0.22	46	4.38	128	0.68	13.54
BH20	4.953314	6.355015	5.99	164	82	0.165	14	0.82	35	0.8	4.54
BH21	4.952838	6.34541	5.85	91	46	0.132	14	1.42	56	0.32	4.62
BH22	4.94409	6.331098	5.93	84	42	0.374	43	3.4	90	0.65	12.43
BH23	4.940728	6.326492	6.38	94	48	0.41	65	5.6	115	0.4	14.9
BH24	4.933825	6.307698	5.86	348	174	0.127	14	1.38	26	0.11	4.86
BH25	4.916093	6.301615	6.4	422	211	0.318	90	10.8	148	0.44	28.64
BH26	4.935199	6.285502	6.74	194	97	0.187	22	0.28	47	0.11	6.38
BH27	4.923142	6.272686	6.46	486	243	0.172	19	1.64	116	0.35	5.38
BH28	4.905837	6.258554	5.99	77	38	0.213	40	4	111	0.4	12.58
BH29	4.918221	6.25624	6.2	160	80	0.162	24	0.8	56	0.12	6
BH30	4.899849	6.269169	6.28	172	86	0.348	52	5.25	41	0.43	16.7
BH31	4.983667	6.276111	6.14	285	142	0.218	14	2.48	17	0.31	5.48
BH32	4.987861	6.275722	6.59	355	178	0.231	20	3.5	34	0.36	7.6
BH33	5.000389	6.279556	6.01	420	210	0.31	20	4	52	0.136	6.5
BH34	4.999861	6.280667	5.97	583	292	0.318	34	4.8	48	0.32	9.45
BH35	4.999656	6.279361	5.96	363	182	0.22	20	3.85	36	0.36	6.84
BH36	4.999222	6.2785	5.92	364	182	0.23	30	3.64	30	0.13	8.35
BH37	5.004056	6.294028	6.15	310	155	0.197	12	3	26	0.38	5.42
BH38	5.032306	6.312556	6.49	379	189	0.271	13	4.3	43	0.35	5.46
BH39	5.033528	6.311917	6.35	304	152	0.176	14	2.34	27	0.19	4.96
BH40	5.034	6.311778	6.52	279	140	0.185	11	2.97	30	0.36	3.75
BH41	5.033361	6.311056	6.08	285	143	0.121	12	2.58	21	0.37	4.34
BH42	5.038194	6.323444	6.15	382	191	0.278	62	4.84	43	0.39	18.68
BH43	5.038	6.319889	5.99	457	274	0.328	16	4.75	44	0.37	7.48
BH44	5.035417	6.321361	6.6	348	174	0.281	12	3.84	41	0.33	4.72
BH45	5.034306	6.318833	6.83	298	199	0.217	12	3.76	35	0.15	5.46
BH46	5.03425	6.31789	6.62	306	153	0.227	13	4	35	0.35	4.8
BH47	4.996806	6.262944	6.24	436	218	0.29	14	3.46	45	0.33	5.75
BH48	5.001417	6.263	6.08	307	154	0.214	21	3.2	22	0.39	6.58
BH49	5.000861	6.265528	6.1	376	188	0.245	32	4	19	0.14	9.36
BH50	5.000639	6.266833	5.67	357	178	0.235	33	3.85	10	0.38	9.65
WHO(2011)			6.5-8.5	1000	500	50	250	150	100	0.3	200

In the Weighted formula, there is a *P* variable which stands for Power. There is no particular rule in defining the *P* value, but from the equation, we can see that the higher *P* value will give lower weight. d_i is the total number for verifications and x* is the determine value at a location.

IV. RESULTS AND DISCUSSIONS

Characteristics of Groundwater

According to the findings in Table 1, the groundwater in the study region appears to satisfy the WHO standards for pH, electrical conductivity (EC), total dissolved solids (TDS), sulphate (SO4), nitrate (NO3), sodium (Na), chlorine (Cl), and total hardness. (TH). However, the iron content of groundwater exceeds the WHO recommendation for potable water, with most boreholes having iron levels varying from 0.13 mg/L to 0.60 mg/L. The spatial interpolation map also shows that the findings for pH, electrical conductivity, total dissolved solids, sulphate, nitrate, sodium, chlorine, and total hardness are lower than the WHO guideline for drinkable water. This information, along with the information in Tables 1 and 4 and Figure 2, indicates that the water quality in the research region is usually suitable for drinking, with the exception of the iron content. It's essential to remember that excessive amounts of iron in drinking water can cause stomach cramps, vertigo, vomiting, and diarrhea. As a result, measures should be taken to address the higher levels of iron in the affected boreholes in order to guarantee the safety of the drinking water supply. With the exception of the high iron levels in some boreholes, the results indicate that the groundwater in the study region is usually safe for drinking

Table 2: Descriptive Statistics of Physiochemical in groundwater

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
Parameter	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
NO3	50	0.08	0.49	0.23	0.09	0.57	0.34	-0.05	0.66
Fe	50	0.11	0.80	0.33	0.16	0.76	0.34	1.00	0.66
SO4	50	0.28	10.80	2.83	1.99	1.27	0.34	3.62	0.66
pH	50	5.60	6.91	6.23	0.31	0.45	0.34	-0.39	0.66
Na	50	3.75	28.64	8.26	4.90	2.02	0.34	5.10	0.66
Cl	50	8.00	90.00	26.56	17.55	1.57	0.34	2.45	0.66
TH	50	10.00	200.00	52.42	38.43	1.88	0.34	3.81	0.66
TDS	50	38.00	826.00	205.48	146.04	2.08	0.34	6.07	0.66
EC	50	77.00	1652.00	407.08	291.76	2.12	0.34	6.23	0.66

Table 2 summarizes statistics for various surface water physiochemical parameters such as nitrate, iron, sulfate, pH, sodium, chloride, total hardness, TDS, and electrical conductivity. For each measure, the data includes the lowest, maximum, mean, standard deviation, skewness, and kurtosis. The minimum number for Nitrate (NO3) is 0.08, the highest is 0.49, and the mean is 0.23. The data is closely grouped around the mean, as indicated by the standard deviation of 0.09. The skewness is 0.57, showing a small positive skew, and the kurtosis is -0.05, indicating that the distribution is slightly flatter than a normal distribution. The minimum number for Iron (Fe) is 0.11, the highest is 0.80, and the mean is 0.33. The standard deviation is 0.16, showing that the data is more dispersed than in the case of Nitrate. The skewness is 0.76, suggesting a positive skew, and the kurtosis is 1.00, showing that the distribution is more peaked than a normal distribution. The minimum number for Sulphate (SO4) is 0.28, the highest is 10.80, and the mean is 2.83. The standard deviation is 1.99, showing that the data is more dispersed than in the cases of Nitrate and Iron. The skewness is 1.27, showing a positive skew, and the kurtosis is 3.62, suggesting a distribution that is more strongly peaked than a normal distribution. The minimum pH number is 5.60, the highest is 6.91, and the average is 6.23. The data is closely grouped around the mean, as indicated by the standard deviation of 0.31.

Table 3: Pearson correlation coefficient in groundwater

		pH	EC	TDS	NO3	Cl	SO4	TH	Fe	Na
pH	Pearson Correlation	1	.343*	.351*	0.197	-0.113	-0.036	-0.113	-0.160	-0.091
	Sig. (2-tailed)		0.015	0.012	0.170	0.434	0.802	0.433	0.267	0.530
EC	Pearson Correlation		1	.998**	0.076	-0.070	-0.235	-0.206	-0.118	-0.068
	Sig. (2-tailed)			0.000	0.600	0.627	0.100	0.151	0.415	0.641
TDS	Pearson Correlation			1	0.082	-0.080	-0.225	-0.210	-0.124	-0.072
	Sig. (2-tailed)				0.571	0.583	0.116	0.143	0.391	0.619
NO3	Pearson Correlation				1	.528**	.527**	0.202	0.259	.527**
	Sig. (2-tailed)					0.000	0.000	0.159	0.069	0.000
Cl	Pearson Correlation					1	.673**	.655**	.347*	.977**
	Sig. (2-tailed)						0.000	0.000	0.014	0.000
SO4	Pearson Correlation						1	.445**	.309*	.748**
	Sig. (2-tailed)							0.001	0.029	0.000
TH	Pearson Correlation							1	.358*	.637**
	Sig. (2-tailed)								0.011	0.000
Fe	Pearson Correlation								1	.376**
	Sig. (2-tailed)									0.007
Na	Pearson Correlation									1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The skewness is -0.39, which indicates a slightly negative skew, and the kurtosis is 0.66, which indicates a slightly flatter than usual distribution. The minimum number for Sodium (Na) is 3.75, the highest is 28.64, and the mean is 8.26. The standard deviation is 4.90, showing that the data is more dispersed than in the Nitrate and pH cases. The skewness is 2.02, showing an extremely positive skew, and the kurtosis is 5.10, suggesting a distribution with a high peak. The minimum number for Chloride (Cl) is 8.00, the highest is 90.00, and the mean is 26.56. The standard deviation is 17.55, which indicates that the data is widely dispersed. The skewness is 1.57, indicating that there is a positive skew, and the kurtosis is 2.45, showing that the distribution is more elevated than a normal distribution. Total Hardness (TH) has a minimum of 10.00, a maximum of 200.00, and a mean of 52.42. The data is widely dispersed, as indicated by the standard deviation of 38.43. The skewness is 1.88, showing a positive skew, and the kurtosis is 3.81, indicating a distribution with a high apex. The minimum number for Total Dissolved Solids (TDS) is 38.00, the highest is 826.00, and the mean is 205.48. The standard deviation is 146.04, which indicates that the data is widely dispersed. The skewness is 2.08, showing a skew that is extremely positive, and the kurtosis is 6.

The result from Table 3 shows that the Pearson correlation coefficients between various factors in a dataset are shown in this chart. pH, EC, TDS, NO3, Cl, SO4, TH, Fe, and Na are the factors. The chart displays the correlation coefficient between each set of variables, as well as the correlation's importance at the 0.05 and 0.01 levels.

A correlation coefficient quantifies the magnitude and direction of a linear connection between two factors. The number runs from -1 to 1, with -1 representing perfect negative correlation, 1 representing perfect positive correlation, and 0 representing no correlation.

We can see that there are substantial correlations between some of the factors in this dataset. pH and EC, have a significant positive association (r=0.343, p=0.015), as do pH and TDS (r=0.351, p=0.012), and TDS and EC (r=0.998, p0.01). NO3 and Cl (r=0.528, p0.01), NO3 and SO4 (r=0.527, p0.01), and Cl and SO4 (r=0.673, p0.01) all have a significant positive association.

Furthermore, some factors are strongly correlated with one another. There is, for example, a very strong positive association between Na and Cl (r=0.977, p0.01), as well as a strong positive connection between Cl and SO4 (r=0.673, p0.01). These correlations imply that there may be some underlying forces affecting these variables in the same direction.

Table 4: Guideline for potable water as recommended by WHO 2011

Parameter	Limit	Suitability Class
PH	6.5	Highly Suitable
	7.5	Suitable
	>8.5	Unsuitable
EC (us/cm)	500	Highly Suitable
	1000	suitable
	>1000	Unsuitable
TDS (mg/l)	250	Highly Suitable
	500	suitable
	>500	Unsuitable
N03 (mg/l)	25	Highly Suitable
	50	suitable
	>50	Unsuitable
Cl (mg/l)	100	Highly Suitable
	250	suitable
	>250	Unsuitable
SO3 (mg/l)	50	Highly Suitable

	150	suitable
	>150	Unsuitable
TH (mg/l)	50	Highly Suitable
	100	suitable
	>100	Unsuitable
Na (mg/l)	100	Highly Suitable
	200	suitable
	>200	Unsuitable
Fe (mg/l)	0.15	Highly Suitable
	0.3	suitable
	>0.3	Unsuitable

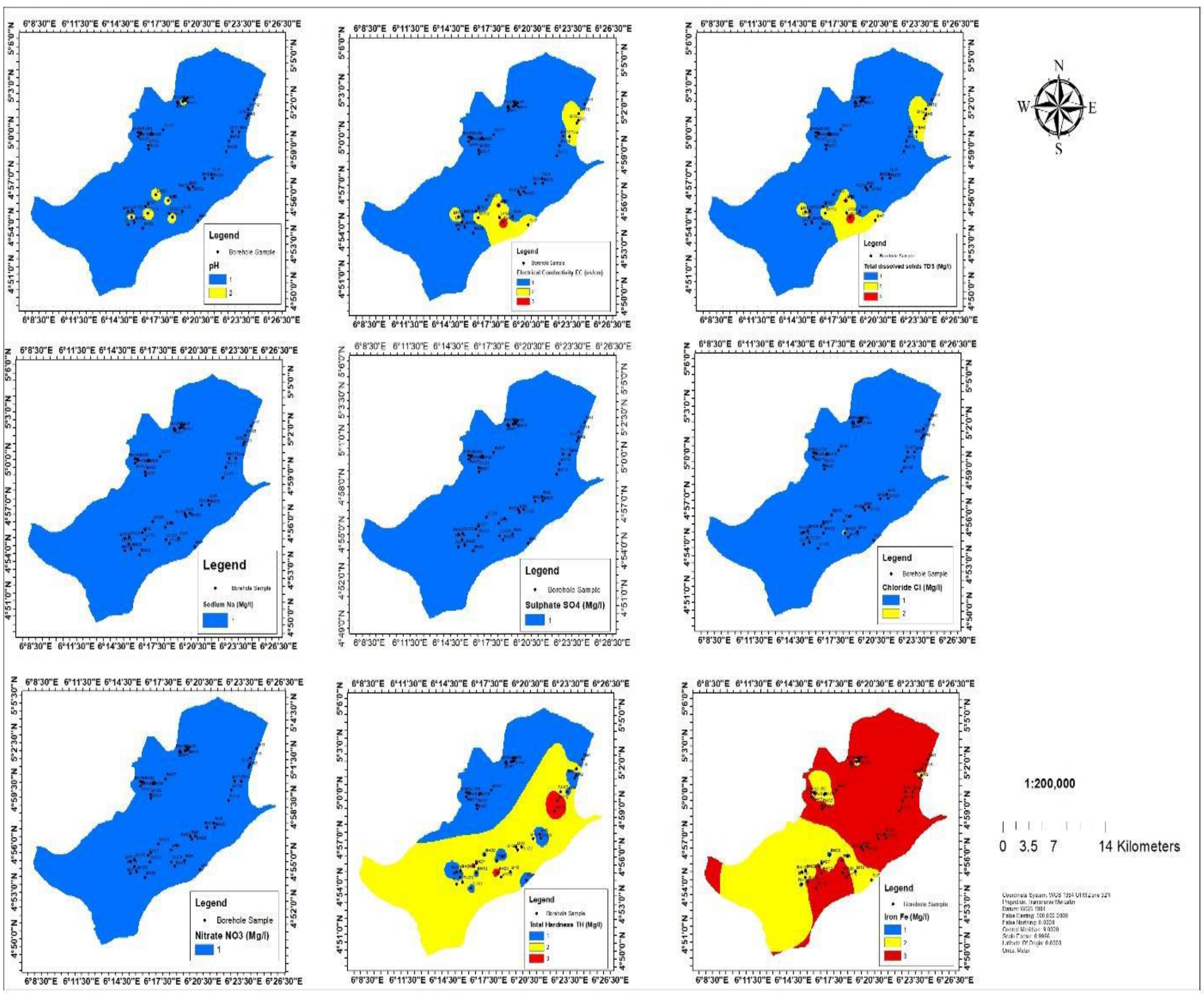

Fig.2: Water quality assessment map performed on the study area using WHO standard 2011.

Multi-criteria evaluation (MCE) and Analytical Hierarchy Process (AHP) Methods

The bigger the weight, the more significant the model in the general utility. The weights were created by giving a sequence of pairwise comparisons of the general significance of variables to the suitability of pixels for the activity being estimated. The methodology by which the weights were delivered follows the rationale created under the Analytical Hierarchy Process (AHP). Weight rates were given based on a pairwise comparison 9-point continuous scale (Table 5). This pair-wise comparison was then analyzed to produce weights that sum to 1. The consistency ratio of this study indicated that 0.03 was acceptable (Table 6). If the consistency ratio is less than or equal to 0.1, it signifies an acceptable reciprocal matrix (Panepinto and Zanetti., 2018; Eteh et al., 2021). The factors and their resulting weights were used as input for the multi-criteria evaluation (MCE) module for the weighted linear combination of overlay analysis.

Table 5: Pairwise comparison 9-point continuous scale.

	Fe	Cl	TH	TDS	NO3	Na	SO4	pH	EC
Fe	1								
Cl	1/2	1							
TH	1/3	1/2	1						
TDS	1/4	1/3	1/2	1					
NO3	1/5	1/4	1/3	1/2	1				
Na	1/6	1/5	1/4	1/3	1/2	1			
SO4	1/7	1/6	1/5	1/4	1/3	1/2	1		
pH	1/8	1/7	1/6	1/5	1/4	1/3	1/2		
EC	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1
	2.8	4.7	7.5	11.3	16.3	22.1	28.8	36.5	45.0

1/9, Extremely; 1/7, very strongly; 1/5, strongly; 1/3, moderately; 1, equally; 3, moderately; 5, strongly; 7, very strongly 9, extremely.

Table 6: Standard matrix and Eigenvector weight

	Fe	Cl	TH	TDS	NO3	Na	SO4	pH	EC	sum	Eigenvector weight	Percentage (%)
Fe	0.35	0.43	0.40	0.35	0.31	0.27	0.24	0.22	0.20	2.78	0.31	30.85
Cl	0.18	0.21	0.27	0.27	0.25	0.23	0.21	0.19	0.18	1.97	0.22	21.92
TH	0.12	0.11	0.13	0.18	0.18	0.18	0.17	0.16	0.16	1.39	0.15	15.49
TDS	0.09	0.07	0.07	0.09	0.12	0.14	0.14	0.14	0.13	0.98	0.11	10.92
NO3	0.07	0.04	0.03	0.03	0.06	0.09	0.10	0.11	0.11	0.65	0.07	7.26
Na	0.06	0.04	0.03	0.03	0.03	0.05	0.07	0.08	0.09	0.48	0.05	5.34
SO4	0.05	0.04	0.03	0.02	0.02	0.02	0.03	0.05	0.07	0.33	0.04	3.71
Ph	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.23	0.03	2.60
EC	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.17	0.02	1.90
Total											1	100

Consistency ratio = 0.03, consistency is acceptable

Weighted Overlay Method

Oboshenure et al. (2019) used the Index Overlay technique in a GIS application to create a collection of maps with various value scores and weights in order to answer multi-criteria problems. These maps were used to identify suitable groundwater mapping locations in the research region. (Figure 3). The spatial maps were made using weightage and class, with M1 indicating pH times the class and M2 signifying Conductivity times the class. M3 represents the weightage times the class for TDS, M4 represents the weightage times the class for TH, M5 represents the weightage times the class for Na+, M6 represents the weightage times the class for Mg2+, M7 represents the weightage times the class for NO3-, M8 represents the weightage times the class for Cl-, and M9 represents the weightage times the class for Cl- and M10 representing Weightage times the class for Fe2+.

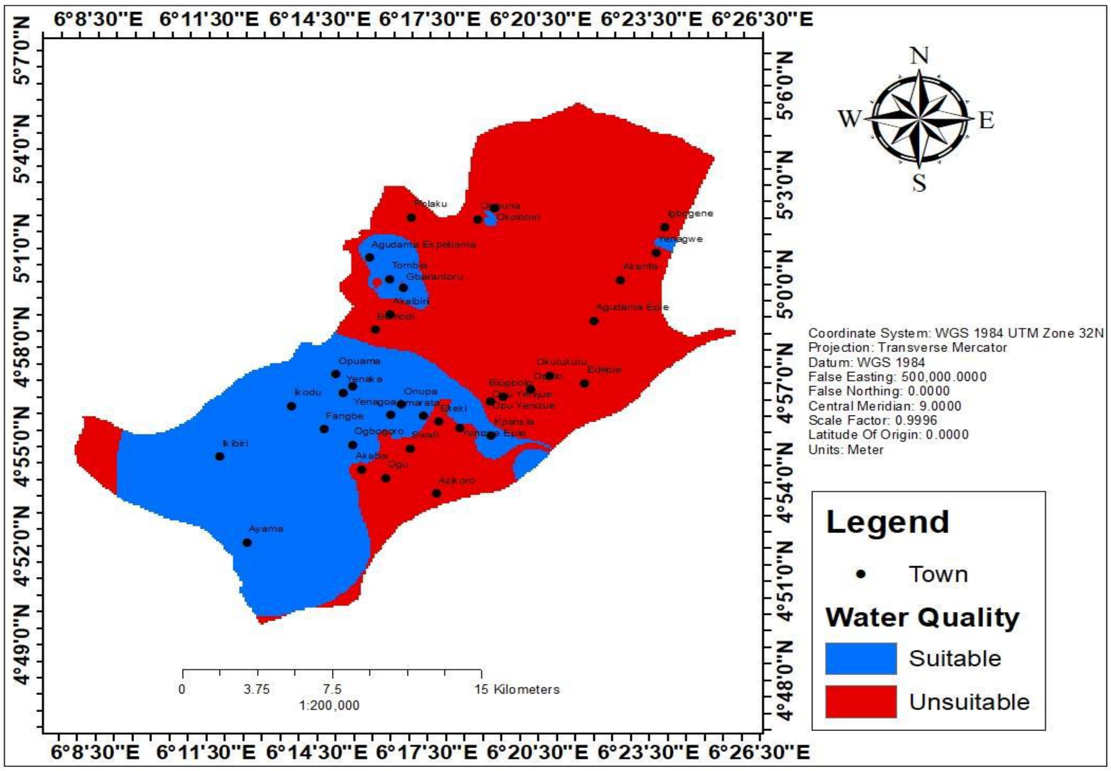

Fig.3: Suitability map for water in the study area.

Figure 3 shows that GIS analysis was able to evaluate and make critical waste management decisions by identifying suitable drinking water areas based on various determining factors such as pH, electrical conductivity, total dissolved solids, sulphate, nitrate, iron, total hardness, and sodium.

The analysis findings were color-coded, with blue showing acceptable regions for drinking water and red signaling unsuitable areas. According to the data given, the GIS analysis determined that 55% of the study region was safe to drink, while the remaining 45% was not.

As previously stated, the findings of the analysis may be subject to various assumptions and constraints, and ongoing monitoring and evaluation of water quality is still required to ensure that the water stays safe for consumption. Nonetheless, the use of GIS in solving waste management-related problems can be a useful tool for decision-making and improving the general standard of living for people in the study region.

V. CONCLUSION

As a result, the research in this study concentrated on identifying suitable drinking water locations using various deciding variables such as pH, electrical conductivity, total dissolved solids, sulphate, nitrate, and sodium. The research showed that 55% of the study region was appropriate for drinking water, while the remaining 45% was not. It should also be mentioned that the iron concentration in most boreholes exceeded the WHO drinking water guideline. In this research, the use of GIS in waste management-related problems was shown to be an efficient decision-making tool. It is essential to note, however, that the government is responsible for supplying secure and pure drinkable water. As a result, the results of this research should be communicated to the appropriate government authorities, who should take the required steps to provide portable water, particularly given the rise in population. In summary, the analysis in this study emphasizes the significance of using GIS in waste management-related problems, as well as the need for the government to provide portable water to guarantee the safety and well-being of people in the study region.

REFERENCES

[1] American Public Health Association (APHA). (2017). Standard methods for the examination of water and waste water. 23rd Edition, 1504pp

[2] Arulbalaji P, Padmalal D, Sreelash K. (2019). GIS and AHP techniques-based delineation of groundwater potential zones: A case study from Southern Western Ghats, India. Scientific Reports. 9(1):2082.

[3] Burrough PA, McDonnell RA, Lloyd CD. (2015) Principles of Geographical information systems oxford: Oxford University Press. 2015;352.

[4] Chukwu GA. (1991) The Niger delta complex basin: Stratigraphy, structure and hydrocarbon potential. Journal of Petroleum Geology.14211-220.

[5] Oki Austin Oyinkuro and Eteh Desmond Rowland (2018): Spatial Groundwater Quality Assessment by WQI and GIS in Ogbia LGA of Bayelsa State, Nigeria. Asian Journal of Physical and Chemical Sciences 4(4):1-12: DOI: 10.9734/AJOPACS/2017/39055

[6] Eteh Desmond R., Francis Omonefe, Jonathan Lisa E. (2021) "Site Suitability Study for Solid Waste Dumpsite Selection Using Geospatial-Based Multi-Criteria Analysis in Yenagoa, Bayelsa State Nigeria", Annals of Geographical Studies, 4(1), pp 1-12. DOI: https://doi.org/10.22259/2642-9136.0401001

[7] Etu–Efeotor, J. O. (1997). Fundamentals of petroleum geology. Paragraphic publications, Port Harcourt, Nigeria, Press page 135.

[8] Mageshkumar P, Subbaiyan A, Lakshmanan E, Thirumoorthy P. (2019). Application of geospatial techniques in delineating groundwater potential zones: A case study from South India, Arabian Journal of Geosciences.12(5):151.

[9] Mukate S, Wagh V, Panaskar D, Jacobs JA, Sawant A. (2019). Development of new integrated water quality index (IWQI) model to evaluate the drinking suitability of water, Ecological Indicators.101:348-354.

[10] Nwankwoala HO, Amadi AN, Oborie E, Ushie FA. (2014). Hydrochemical factors and correlation analysisof groundwater quality in Yenagoa, Bayelsa State, Nigeria. Applied Ecology and Environmental Services. 2014;2(4):100–105.

[11] Oboshenure K. K, Francis E E. and Davidson E. E. (2019) Application of GIS in the Assessment of Groundwater Quality in the Yenagoa Watershed of the Niger Delta Region of Nigeria Asian Journal of Physical and Chemical Sciences 7(2): 1-15, Article no.AJOPACS.49000 ISSN: 2456-7779.

[12] Oki Austin Oyinkuro and **Eteh Desmond Rowland** (2018): Spatial Groundwater Quality Assessment by WQI and GIS in Ogbia LGA of Bayelsa State, Nigeria. *Asian Journal of Physical and Chemical Sciences* 4(4):1-12: DOI: 10.9734/AJOPACS/2017/39055

[13] Panepinto, D.& Zanetti, M.C. (2018). Municipal solid waste incineration plant: a multistep approach to the evaluation of an energy-recovery configuration.Waste Management, 73, 332−341. doi:10.1016/j.

[14] Panepinto, D.& Zanetti, M.C. (2018). Municipal solid waste incineration plant: a multi-step approach to the evaluation of an energy-recovery configuration. Waste Management, 73, 332−341. doi:10.1016/j.2018.07.036

[15] Reijers, T. J. A. (2011). Stratigraphy and Sedimentology of the Niger Delta. Geologic, The Netherlands, 17(3), p.133-162.

[16] Reyment RA (2018.) Ammonitologist sensu latissimo and founder of Cretaceous Research Bengtson. P Cretaceous Research-1926-2016,88, 5-35.

[17] Stafford, D.B. (1991). Civil Engineering Applications of Remote Sensing and Geographic Information Systems. ASCE, New York.

[18] Tsihrintzis VA, Hamid R, Fuentes HR. (1996). Use of geographic information systems (Gis) in water resources: A review. Water Resources Management.10:251-277.

[19] Veysel Aslan and Recep Çelik.(2021) Integrated GIS-Based Multi-Criteria Analysis for Groundwater Potential Mapping in the Euphrates's Sub-Basin, Harran Basin, Turkey. *Sustainability , 13*, 7375 .

[20] Wan Mohtar, W.H.M., Abdul Maulud, K.N., Muhammad, N.S., Sharil, S., Yaseen, Z.M. (2019) Spatial and temporal risk quotient-based river assessment for water resources management, Environmental Pollution 248, pp. 133-144

[21] World Health Organization (WHO) (2011)."Guidelines for Drinking Water Quality", 4th edition. Geneva, Switzerland.