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Assessment of Land Use and Water Quality Changes on Anambra River in Otuocha Anambra State Nigeria: A Remote Sensing and Hydrochemical Apporach

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Abstract
This study investigated the impact of anthropogenic activities on Anambra River quality in Otuocha and environs, Anambra State, Southeastern Nigeria, where rapid urbanization and agricultural intensification have raised concerns about water quality degradation. Using remote sensing and hydrochemical techniques, Landsat satellite imageries from 1999 and 2023 were utilized to classify land use into three categories: Impervious surfaces, pervious surfaces, and water. A 24-year land use change assessment and prediction model were developed. Fifteen surface water samples were collected from various points along the Anambra River and Ezechi River, and analysed for physical, chemical, and microbiological parameters using various methods. Water quality indices, including Water Quality Index (WQI), Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Integrated Water quality index (IWQI) and Degree of Contamination (Cd) were calculated to evaluate overall water quality and suitability for various uses. The integration of land use change assessment with water quality parameters revealed significant correlations between urban expansion, agricultural intensification, industrialization and declining water quality. Results indicate poor water quality for drinking without treatment, moderate suitability for irrigation with long-term risks, and widespread faecal contamination, indicating possible poor sanitation. This study provides valuable insights into the complex interactions between human activities and water resources, offering a basis for informed land use planning and water resource management strategies in the area.

Keywords: Water Quality, Remote Sensing, Anthropogenic Activities, Land Use

1. Introduction
Surface water is a vital component of natural resources, supporting ecosystems, human livelihoods and economic activity. However, due to the rapid increase in human activities, surface waters have undergone significant changes in both quantity and quality, resulting in negative environmental and economic impacts. The Anambra River and its tributaries form the primary surface water network in Otuocha, Anambra State, South-Eastern Nigeria. Over time, human activities, such as industrialization, urbanization, improper waste disposal, intensive agricultural practices, and unsanitary indigenous religious rituals[e.g animal sacrifice] have compromised the quality of surface water in this area.

The Geographic Information System(GIS) is a valuable, cost-effective, and readily available tool for investigating the impacts of human activities on surface water resources. By leveraging GIS, researchers and decision makers can gain critical insights into the status of surface water resources and the potential consequences of human activities. GIS provides a comprehensive and reliable framework for collecting, storing, analyzing, and visualizing geographic data (Longley *et al*., 2005) [17].

The Anambra River, which flows through Otuocha and environs is a vital water source for domestic, commercial and agricultural purposes (Nwajiuba, 2014) [20]. However, in recent years, Otuocha town and its surrounding areas have experienced significant urbanization and population growth, resulting in increased pressure on the river and its connected ecosystems. Like many rivers worldwide, the Anambra River faces several challenges, including pollution from urban and industrial activities, and changes in its flow regime due to land use changes (Ogueke and Nwokoye, 2013) [23]. The rapid expansion of Otuocha town, driven by its proximity to the commercial city of Onitsha has led to an increase in impervious surfaces, such as roads, and sidewalks, resulting in increased surface runoff, erosion, and changes in natural drainage patterns. Furthermore, industries along the riverbanks often discharge effluents containing pollutants, chemicals, and other waste materials directly into the Anambra River, leading to deterioration in water quality (Nwachukwu and Okoye, 2016, Okolo *et al*, 2018) [18, 27].

Therefore, the combination of industrial effluent discharge, urban runoff, and agricultural activities in the Anambra River watershed poses significant threats to the river's water quality. Consequently, agriculture which is also a stable components of the area's micro-economy can have a detrimental impact on the river. However, runoff from agricultural fields contaminated with pesticides and other chemicals from fertilizers is introduced into the river, leading to water quality degradation and potential harm to aquatic life (Obiakor *et al.*, 2017, Nwilo and Badejo, 2017) [22, 21]. Furthermore, land use changes can significantly impact surface water quality. Deforestation and other land use practices can alter a river's flow pattern and contribute to the channel erosion

Given the complex relationships between land use changes, industrial activities and water quality, Geographic Information System (GIS) technology offers a valuable tool for assessing the impacts of anthropogenic activities on surface waters. Specifically, the spatial analysis capability of GIS enables the integration of spatial data from different sources which allows for identifying of areas most affected by anthropogenic activities and most at risk (hotspots) (Ding and Fotheringham, 1992, Fotheringham and Rogerson, 2005) [10, 13].

Moreover, the capabilities of GIS extend beyond spatial analysis, offering excellent data visualization capabilities that enable spatial data to be visualized using maps and other graphical representations. This facilitates the intuitive and comprehensive communication of complex information (Pundt and Brinkkotter-Runde, 2000) [30]. Furthermore, the application of GIS to study the impacts of anthropogenic activities on surface waters enables the modeling of environmental components, such as the transport and dispersion of pollutants in surface waters (Corwin and Wagenet, 1996) [9]. Ultimately, the aforementioned features make GIS a valuable decision-support tool for creating policies and informing decisions related to land use planning, pollution control measures and sustainable development.

In view of the situations mentioned above this study aims at evaluating the effects of land use on water quality deterioration of Anambra River using remote sensing and hydrochemical methods and possibly proffer solutions to the water quality and land use problems in the study area.

Geology of Study Area

The study area Otuocha is situated within the Niger Delta Basin. Specifically, the Eocene Ameki Group and the Quaternary (recent) Alluvium deposits are the two lithostratigraphic units that outcrop in the study area (Okezie and Onuogu, 1985) [24] (Fig 1). Notably, Anambra State is primarily located within the Niger Delta basin, except for its extreme southeast tip, which is covered by a portion of the Anambra Basin. Furthermore, the mega-tectonic structural pattern associated with the breakup of Gondwanaland during the Late Jurassic to Early Cretaceous is closely linked to the geological origins of the Anambra and Delta Basins (Onuigbo *et al.*, 2015) [29]. Consequently, the depression in the area surrounding the southern Benue Trough, led to the formation of the Anambra Basin, coinciding with the folding of the Benue Trough during the Santonian (Onu, 2017) [28]. Additionally, the Niger Delta Basin formed through continuous subsidence of the Southern Benue Trough and Anambra Basin as indicated by the Chain, Charcot, and Romanche rupture zones (Onu, 2017) [28]. Ultimately, the Benue Trough and Anambra Basin in the south are superimposed with the Cenozoic Niger Delta (Nwajid, 2013) [19].

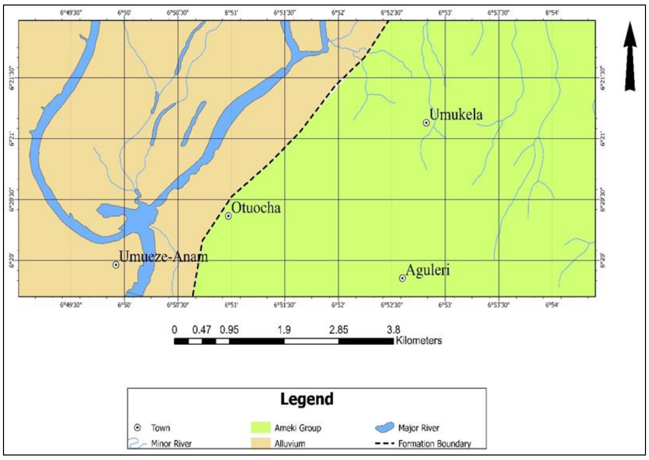


Fig 1: Geology Map of the study area

2. Materials and Method

To achieve the objectives of this study, remotely sensed data (Landsat) and results of hydrochemical analysis from surface water samples were utilized. Specifically, Landsat data acquired through the United States Geology Survey (USGS) Explorer system for two years representing a 23-year interval (1999 and 2023) and water samples collected from the Anambra River along its profile bordering Otuocha formed the main materials for the study. The following software were used for the analysis of the data: Esri ArcGis Pro and Clark's lab Terrset.

A systematic sampling technique was employed to sample surface water from the length of the profile of the Anambra River bordering the study area. Consequently, a total of fifteen (15) surface water samples were collected and preserved according to APHA (2005) [3] specifications. GPS was used to record the coordinate of each sample location. Furthermore, the samples were collected with a 2-litre polyethylene bottle, which was washed and rinsed several times before the sample collection. The sample bottles were fully submerged before the collecting the samples, and the samples were immediately covered with their caps and preserved in ice packs prior to laboratory analysis within 24 hours.

The laboratory analysis involved using a Varian AA 240 Atomic Absorption Spectrophotometer (AAS), and titrimetric methods according to APHA Standard Method 4500-P B.5 and 4500-PE (APHA, 1998) and APHA 2510 B guideline Model DDS-307 (APHA, 2005) [3]. Moreover, methodology for this study included two important steps: Land use changes assessment and hydrochemical analyses of water samples. The land use change assessment was used to determine the spread and extent of anthropogenic activities within the study area. Meanwhile, the results of water sample analysis were used to determine the surface water suitability for various purposes using different indices (water quality index (WQI), integrated water quality index (IWQI), sodium adsorption ratio (SAR), magnesium adsorption ratio (MAR) and degree of contamination (CD). Fig 2 below describes the workflow used for this study. Ultimately, the second part of this workflow involves determining water quality based on the results of analysis of surface water samples from the part of the Anambra River bordering Otuocha town. The steps for determining each water quality indices have been described and demonstrated by various researchers (Wilcox, 1955, Horton, 1965, Raghunath 1987, Backman *et al.*, 1997) [6, 15, 31, 8].

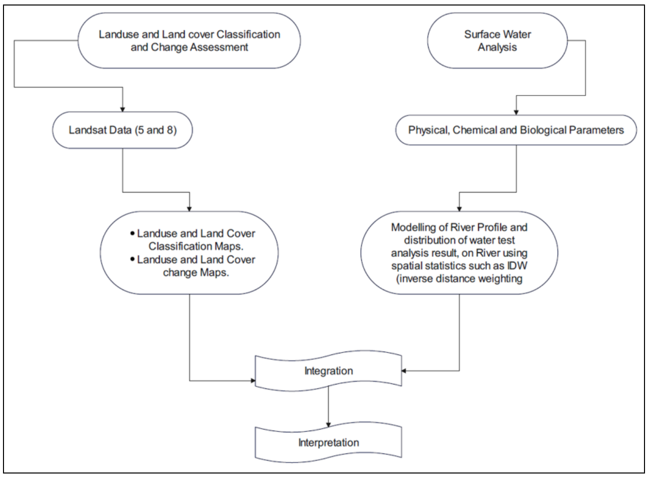


Fig 2: Schematic diagram showing the methodology used for the study

Land use Classification and Land use Change Assessment

This study employed Landsat images from two different time periods (1999 and 2023) to analyse land use classification and assess land use changes in the study area. The analysis utilized Landsat-5 data from 1999 and Landsat-9 data form 2023 covering a period of 24 years. The Landsat images provided a basis for land use classification and offered a visual representation of the Earth's surface at these two points in time (Figures. 3 and 4). Moreover, the transition from Landsat 5 to Landsat 9 reflected improvements in satellite imaging technology, providing better spectral and resolution data for the 2023 dataset.

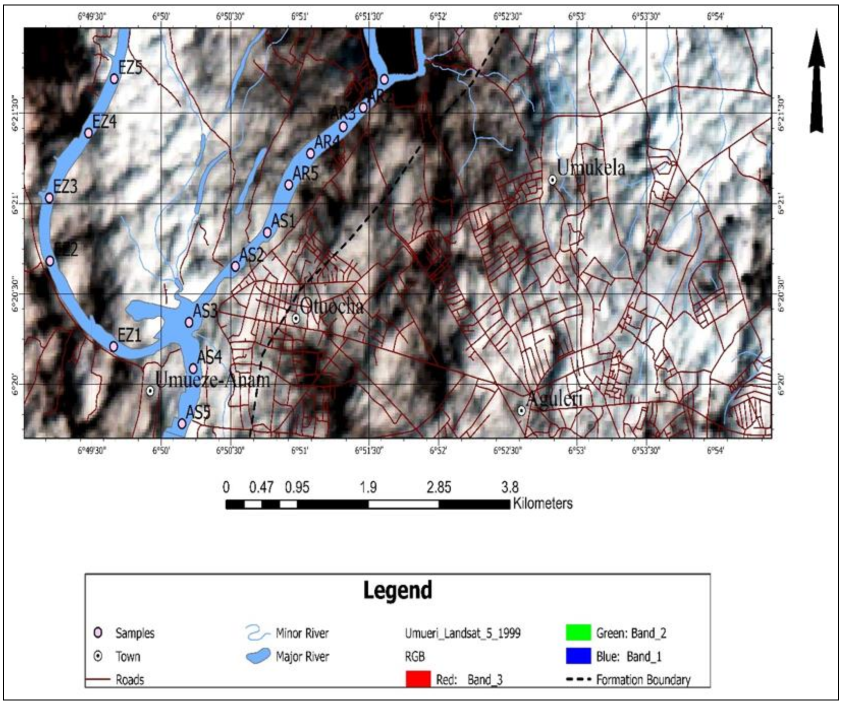


Fig 3: Landsat 5 (1999) data for land use classification

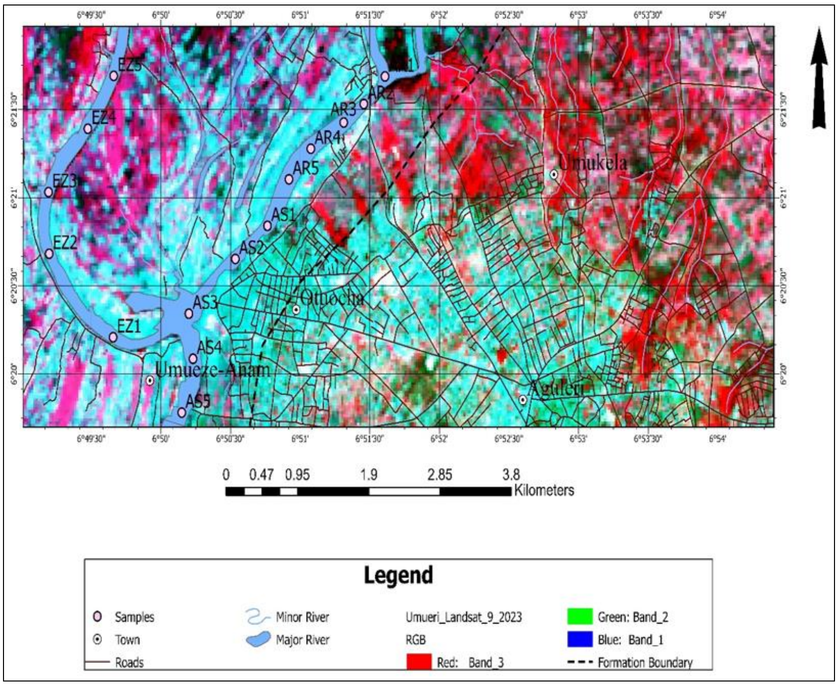
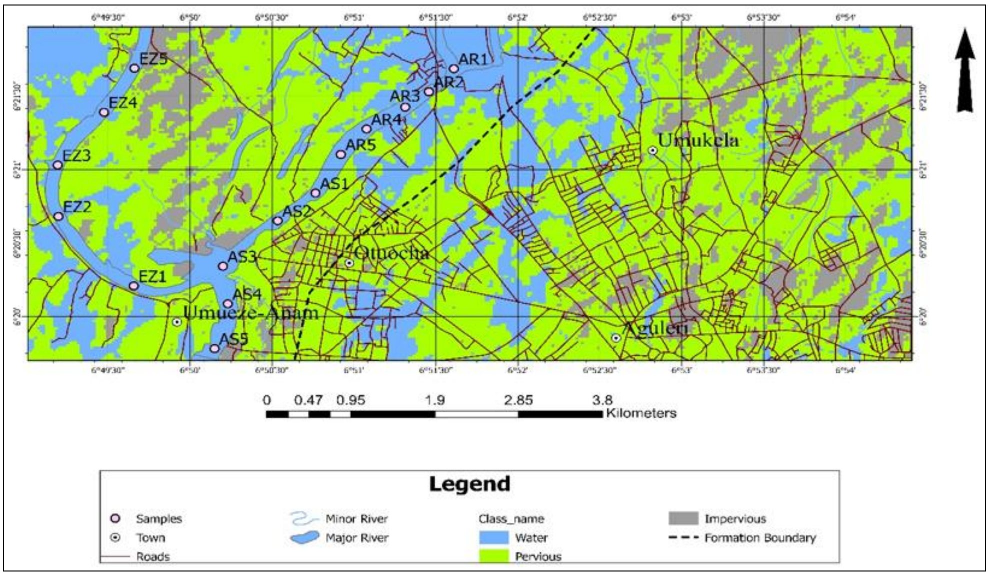


Fig 4: Landsat 9 (2023) data for land use classification

Notably, most land use classification schemes consider streams, rivers, lakes and other surface waters as pervious (Shuster *et al.,* 2005; Arnold and Gibbons, 1996) [32, 5]. However, this study introduced a minor modification, categorising water bodies and similar features as a separate class. This decision was made for three reasons. Firstly, the study aimed to assess the distribution of pollutants and surface water quality in a stretch of the Anambra River, necessitating a separate classification for water bodies. Secondly, this simple scheme was chosen to capture the complexity required for land use classification without introducing excessive errors. The simple classification overcame the limitations of working with both old Landsat 5 data and modern Landsat 9 data. Finally, most of the vital anthropogenic activities or effect would be reflected more under the class of features impervious, tracking the change from other classes namely, water and pervious, which is a good reflection of the measure of the degree of change in the anthropogenic or human activities.

3. Results and Discussion

Figures 5 and 6 illustrate the results of the land use classification process for 1999 and 2023 respectively. These maps provide a clear visual representation of land use patterns over time by converting the raw satellite data into discrete land use categories. To simplify the analysis, three primary land use categories were employed: Impervious, pervious, and water. Pervious surfaces, which allow water to penetrate the soil, play a critical role in natural water cycles and ecosystem health (Shuster *et al.*, 2005) [32]. Conversely, impervious surfaces prevent or significantly reduce water infiltration, often resulting in increased surface runoff (Shuster *et al.,* (2005) [32].



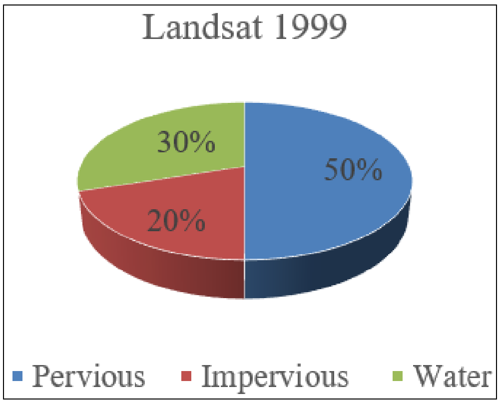
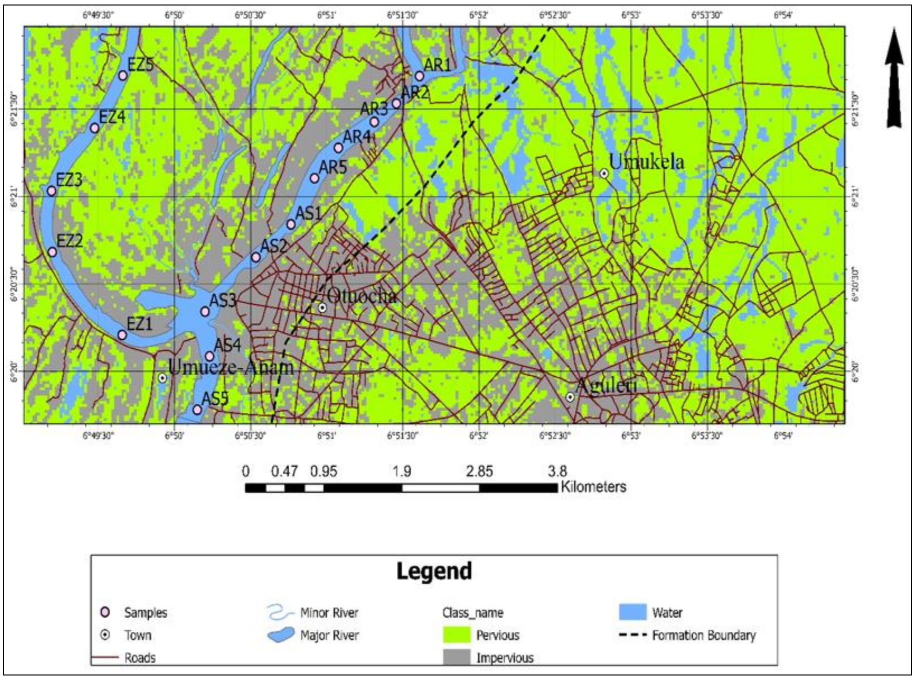


Fig 5: Landsat 5 (1999) Land use classification map and pie chart showing percentages of each class



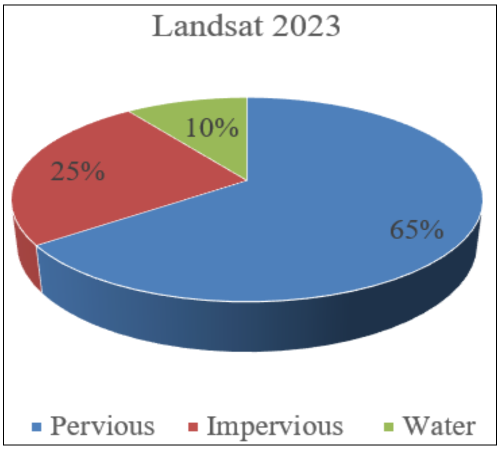


Fig 6: Landsat 9 (2023) Land use classification map and pie chart showing percentages of each class

The comparative analysis of the two land use maps (Figures 5 and 6) reveals significant changes in land use patterns over the 24-year period. There has been a 5% increase in the impervious, 15% increase in the pervious, and 20% decrease in water surfaces over the years. Furthermore, Figure 7 presents the land use change prediction map for the period from 1999 to 2023 which is a crucial output of this study. This map illustrates the projected changes in land use based on the observed patterns between the two time periods. Notably, the assessment map highlights areas of significant change, indicating major urban expansion (areas changing from water and pervious to impervious) and other changes such as possible deforestation (changing from pervious to impervious), or agricultural intensification (changing from impervious to pervious). These changes have significant implications for water quality, groundwater recharge, flooding and erosion.

As observed in this study, the conversion of pervious areas to impervious surfaces can lead to increased runoff, river volume, flow rate, and erosion (Fletcher *et al.*, 2013) [12]. This is because impervious surfaces, such as roads, buildings, and pavements, reduce the amount the land available for infiltration, causing more rainfall to become surface runoff. The present result is in agreement with the results of Arnold and Gibbons (1996) [5]. Additionally, impervious areas can reduce the rate of infiltration, resulting in decreased groundwater recharge as was equally noted by Klein (1979) [16]. The increased runoff and flow rate can also facilitate the distribution of surface contaminants into the river, leading to contamination or pollution. This is consistent with previous findings by Sutherland (1998).

However, this study found that water-pervious areas have the highest percentage, which can enhance groundwater recharge and reduce flooding and erosion due to higher infiltration rates compared to runoff rate in line with the observations of Fletcher *et al.*, (2013) [12]. This suggests that the study area still has a significant amount of pervious surfaces, which can help to mitigate the adverse effects of urbanization on the environment. Notably, this study demonstrates the importance of land use change analysis in understanding its impacts on water quality and environmental sustainability. Additionally, the findings from this study can promote sustainable land use practices, such as preserving pervious surfaces.

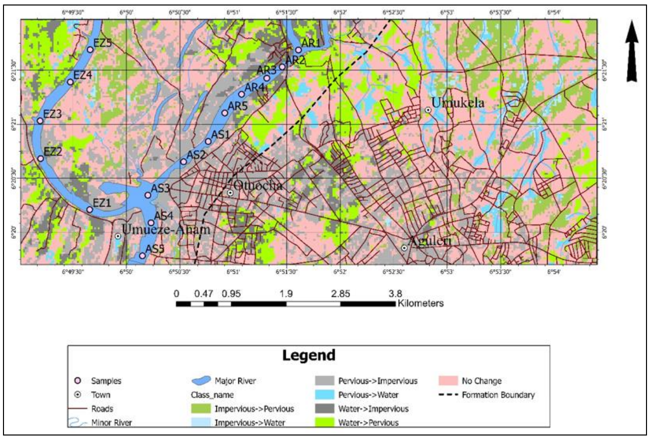


Fig 7: Land use change assessment map (1999-2023)

3.1 Water Quality Parameters

The water samples collected from the Anambra-Ezechi watershed were divided into three groups (AR, AS, and EZ) based on their geographical coordinates, representing a relatively small area within the watershed. Interestingly, despite their proximity, notable differences in water quality were observed between these groups, suggesting input from factors such as geology and land use. (Drever 1997) [11]. This variation in water quality highlights the importance of considering local factors when assessing water quality, as even small changes in geology or land use can have significant impacts on water chemistry (Liu *et al*, 2022, Nwankwo *et al.*, 2023).

Physical parameters of water quality indicated that most samples had low turbidity ranging from 0.45 and 0.8 NTU, except for the EZ group, which had higher levels of suspended particles (4.3 to 7.3 NTU) (Table 1). This increased turbidity in the EZ group may be attributed to the presence of nearby agricultural activities or construction sites, which can lead to increased sedimentation and turbidity in nearby water sources. This observation collaborates with the study of Okpala *et al.*, (2022). pH values were generally slightly acidic ranging from 5.5-6.6, with one sample (AS2) showing a concerning acidity level (4.2). the value is below the WHO (2022) [34] guideline values. Similarly, Eze *et al.*, (2023) had made similar observation on a watershed in Nigeria. This acidity maybe attributed to the presence of acidic pollutants, such as sulfuric acid or nitric acid, which can originate from industrial or agricultural activities (Liu *et al.*, 2022).

Total dissolved solids (TDS) varied between groups, with EZ samples having the highest concentrations (95–128 mg/L). Notably these values are within the WHO permissible limit. This increased TDS in the EZ group may be attributed to the presence of nearby industrial or agricultural activities, which can lead to increased levels of dissolved solids in nearby water sources as previously reported by Nwosu *et al.*, (2023).

Furthermore, the Chemical parameters revealed moderate levels of nutrients and chlorides in all samples. It has been previously reported that elevated chloride levels are usually a sign of anthropogenic encroachment (Okolo *et al.*, 2023 [25], Okpala *et al.*, 2022). However, EZ samples showed significantly higher sulphate levels (82–85 mg/L) compared to the others. This increased sulfate level in the EZ group may be attributed to the presence of nearby industrial activities, which can release sulfate-rich effluent into river (Hem, 1985) [14]. Additionally, alkalinity was generally low, ranging from 20–50 mg/L, while hardness varies considerably, with EZ samples having the highest values (130–190 mg/L). The result of the present study is in agreement with the results obtained by Eze *et al* (2023). The values for hardness exceeded the values for Nigeria Standard for Drinking Water (NSDW, 2017). However, the presence of organic material, as indicated by chemical oxygen demand (COD) and biological oxygen demand (BOD), suggested moderate to high levels of organic pollution in all samples as previously noted by Clesceri *et al.*, (1998). This organic pollution may be attributed to agricultural or industrial activities which can release organic pollutants into nearby water sources.

Table 1: Water analysis results of the study area

Samples	AR1	AR2	AR3	AR4	AR5	AS1	AS2	AS3	AS4	AS5	Ezichi str 1	Ezichi Str 2	Ezichi 3	Ezichi 4	Ezichi 5
Turbidity NTU	0.8	0.5	0.6	0.45	0.5	-1.5	-5.5	-6	-4.8	-5	4.3	-7.3	5.8	6.3	4.7
pH	5.7	6.6	5.8	6.5	6.3	5.5	4.2	5.7	6.1	5.5	6.3	5.6	6.5	5.9	5.7
TDS mg/l	72	65	60	75	65	89	92	80	85	82	106	128	120	100	95
Nitatre titre ml	1.07	1.06	1.05	1.08	1.07	1.013	1.05	1.03	1.04	1.06	1.038	1.037	1.053	1.043	1.063
Conc. Mg/l	7.041	6.970	7.150	6.810	6.941	6.656	6.866	6.721	6.921	6.689	6.820	6.813	6.901	6.862	6.843
Phosphate titre	1.128	1.110	1.134	1.125	1.115	1.100	1.090	1.112	1.101	1.122	1.087	1.085	1.082	1.084	1.081
Conc. Mg/l	7.054	6.942	7.103	7.122	6.990	6.879	6.817	6.862	6.834	6.899	6.798	6.785	6.772	6.721	6.746
Chloride mg/l	54	53	55	52	58	35	66	62	65	68	56	53	55	52	58
Sulphate mg/l	84.470	77.576	85.453	82.565	80.543	74.891	76.778	75.432	72.665	74.454	84.978	82.656	85101	84.776	83.222
Alkalinity mg/l	22.500	20.000	24.002	21.088	22.226	35.000	32.500	36.963	35.001	32.332	85.000	72.500	82.882	85.665	84.123
Hardness mg/l	14.000	44.000	33.200	25.780	40.886	28.000	32.000	35.023	30.881	32.201	48.000	20.000	50.992	38.093	28.930
COD mg/l	40	100	50	80	65	140	140	120	100	130	190	130	150	120	140
DO mg/l	26	16.5	28.0	15.9	30.8	12.9	16.2	15.8	12.4	18.9	20.2	21.7	24.3	25.9	22.7
BOD mg/l	89.2	78.40	80.5	75.5	78.6	92.9	102.5	70.2	82.8	85.7	89.90	90.30	92.6	90.5	88.8
EC (usm/cm)	32.80	42.89	56.78	55.76	49.76	46.10	40.28	44.81	42.78	41.18	57.20	42.90	52.75	48.67	46.80
TSS mg/l	3.83	6.20	4.82	5.80	5;.22	7.49	5.22	7.25	6.73	6.22	5.89	5.22	5.88	5.18	5.72
Sodium ppm	6.783	4.900	6.235	5.990	4.894	6.178	6.278	6.875	6.445	6.690	7.183	7.479	7.287	7.005	7.568
Calcium ppm	4.122	4.978	4.876	4.675	4.650	5.478	4.043	5.453	5.567	5.543	5.893	5.489	5.879	5.908	5.764
Magnesium ppm	4.189	4.455	4.233	4.765	4.898	5.278	5.089	5.953	5.7564	5.134	6.178	5.726	6.265	6.211	5.890
Potassium ppm	4.922	4.892	4.826	4.776	4.897	5.943	4.992	5.835	5.645	5.003	7.783	7.078	7.876	7.247	7.676
Bicarbonate ppm	25.40	21.80	28.65	24.76	22.65	36.90	34.20	36.99	34.87	35.88	49.20	22.90	50.76	38.66	45.76
TC (cfu/100ml)	2.9×10^1	2.1×10^1	2.6×10^1	2.5×10^1	2.3×10^1	2.6×10^1	1.8×10^1	2.1×10^1	1.9×10^1	2.2×10^1	1.7×10^1	1.4×10^1	1.8×10^1	1.6×10^1	1.5×10^1
Total faecal cfu/100ml	12	18	15	12	14	10	11	13	10	15	17	11	10	14	15

Moreover, microbiological parameters raise concerns for water safety, as all samples contained total coliform and faecal coliform bacteria, indicating possible faecal contamination (WHO, 2022 [34]; CDC, 2023). Hence, this finding has significant implications for human health and highlights the need for proper water treatment if the river water is to be used for domestic use or consumption. Furthermore, the presence of fecal coliform bacteria in all samples suggests that the Anambra river may be contaminated with human or animal waste which can pose serious health risks (WHO, 2022 [34], USEPA, 2023). In summary, the results of this study highlight the importance of considering local factors when assessing water quality as even small changes in geology or land use can have significant impacts on water chemistry as depicted by the quality variations in the different groups (AR, AS and EZ).

3.2 Water Quality Assessment

The water quality indicators provide a comprehensive overview of the overall condition of the Anambra-Ezechi river and its suitability for various uses. Specifically, the water quality index (WQI) values indicate poor water quality in all samples (191.53–220.89), underscoring the need for treatment before human consumption. This result is largely influenced by the elevated microbiological parameters. However, despite this finding, the integrated water quality index (IWQI) suggests that the river water is moderate to good for various purposes, albeit with some raise parameters. Furthermore, the high degree of contamination (Cd) values in all samples (10.2-12.9) indicate significant anthropogenic influences on water quality in the area. Conversely, the irrigation indices reveal a different picture, with the sodium adsorption ratio (SAR) indicating a low sodium hazard (0.95-1.45). On the other hand, the magnesium adsorption ratio (MAR) indicates a moderate to high risk of magnesium accumulation (46.47%-55.72%). This is consistent with previous studies that have shown that magnesium can accumulate in soil and cause problems for plant growth (Okpala *et al.*, 2022). These water quality indicators, suggests that the water requires treatment before consumption, and that anthropogenic activities are significantly impacting water in the study area.

Notably, the degree of contamination (Cd) values for samples indicates significant anthropogenic influences on water quality in the area. The present result aligns with previous studies that have linked human activities such as agriculture, industrial processes, and urbanization to increased levels of pollutants in water sources (Okolo *et al.*, 2023; Liu *et al.*, 2022, Anakwuba *et al*, 2020 [1]). Also, Enekwechi *et al.*, (2022) found that agricultural activities were the main source of water pollution in a watershed. As a matter of fact, the irrigation indices SAR indicate the water is good for irrigation while MAR indicates moderate to high risk, aligning with previous studies (Okpala *et al.*, 2022).

3.3 Spatial Distribution Maps of Water quality Indices

The spatial maps generated using the Geographic coordinates and the calculated water quality indices provide a visual representation of the distribution of water quality in the study area. Specifically, the maps (Figures 8, 9, 10, 11 and 12) show the land use change prediction map and the distribution of water quality indices. Geographically, the AR group of samples in the northern part of Anambra River show the best overall quality, with lower total dissolved solids (TDS) and contaminants. This suggests that the water in this area is less polluted and may be suitable for various uses. In contrast, the AS group of samples in the southern part of Anambra River exhibit signs of acidification and slight contamination. This change can be attributed to differences in local geology, land use patterns, or specific pollution sources which collaborates with the results of Enekwechi *et al.*, (2022). Similarly, the EZ group of samples from the Ezechi River has the highest level of dissolved solids and sulphate which could be due to anthropogenic activities.

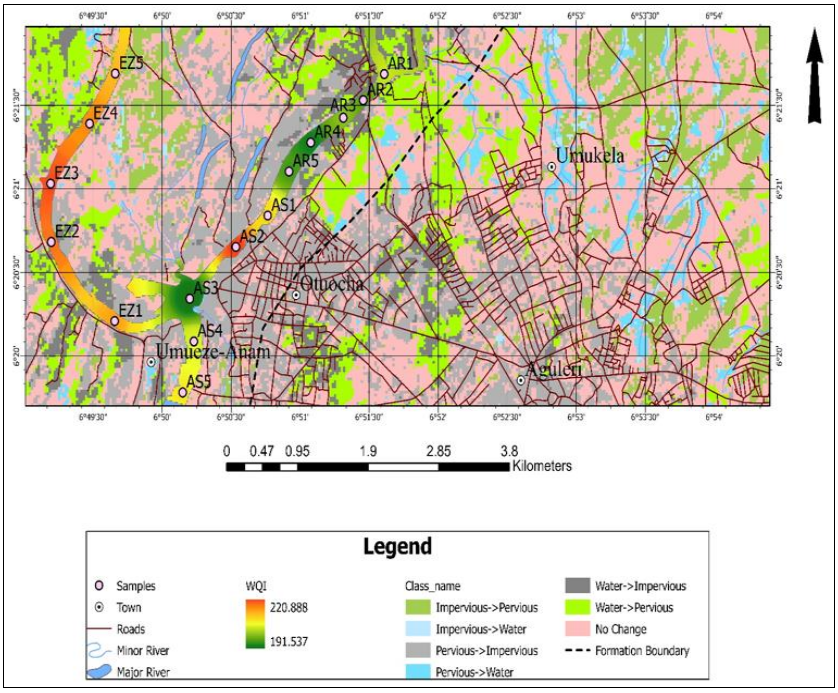


Fig 8: Land use change assessment map with a model of the area of interest along the river profile showing the distribution of the WQI parameter

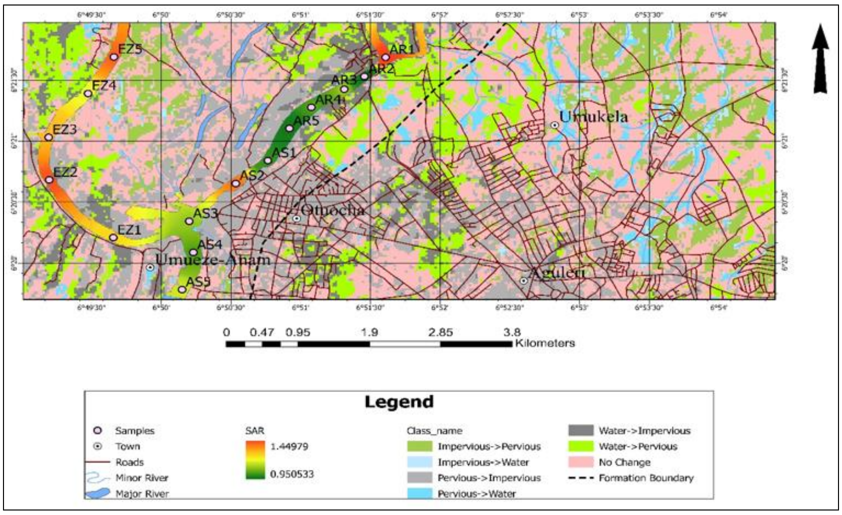


Fig 9: Land use change assessment map with a model of the area of interest along the river profile showing the distribution of the SAR parameter

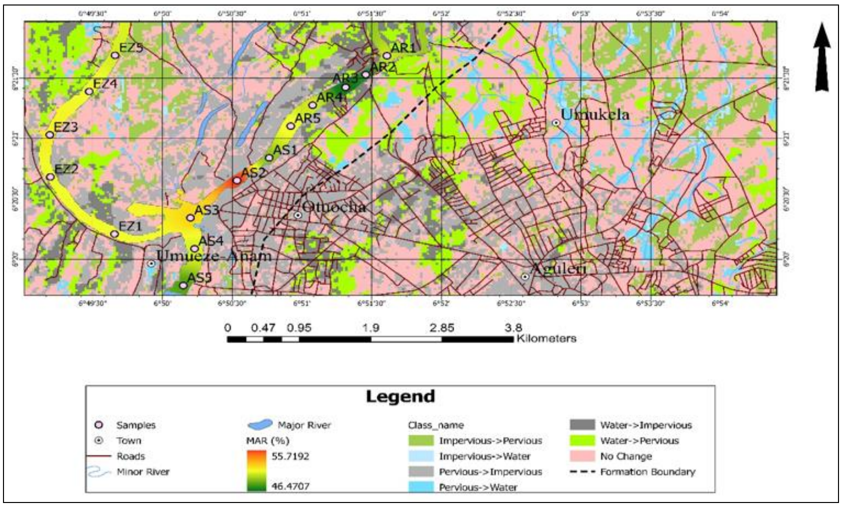


Fig 10: Land use change assessment map with a model of the area of interest along the river profile showing the distribution of the MAR parameter

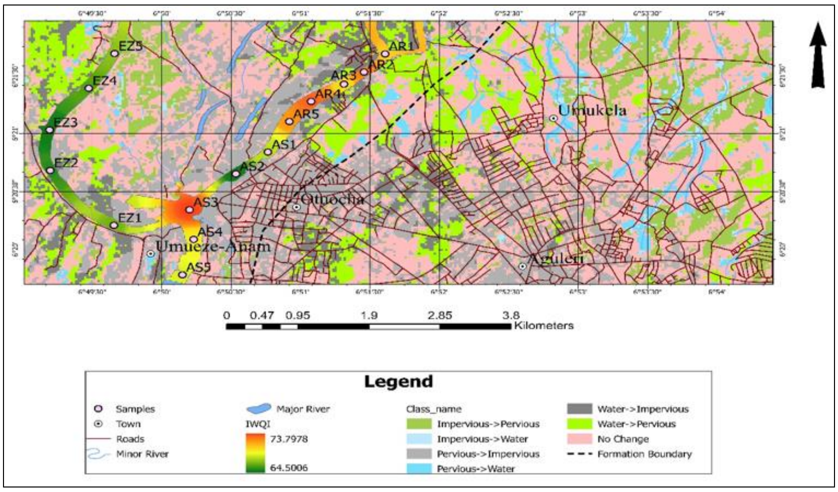


Fig 11: Land use change assessment map with a model of the area of interest along the river profile showing the distribution of the IWQI parameter

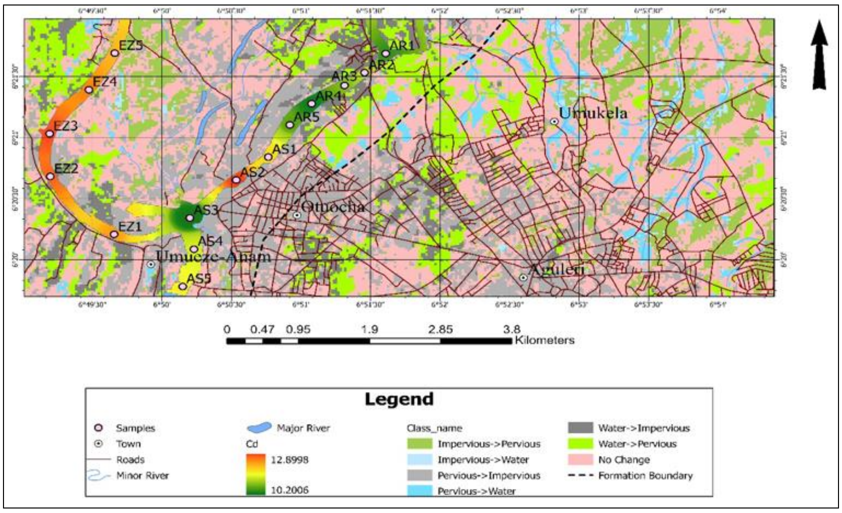


Fig 12: Land use change assessment map with a model of the area of interest along the river profile showing the distribution of the CD parameter.

Spatial distribution maps of the water quality parameters

Integration of Water Quality with Land use change assessment

integration of water quality parameters with land use change assessment provides valuable insights into the complex interactions between human activities and water resources in the study area. Specifically, this holistic approach provides a more comprehensive understanding on the potential sources of water contamination and the impact of land use changes on water quality. Specifically, this holistic approach provides a more comprehensive the understanding of the potential sources of water contamination and the impact of land use changes on water quality. Moreover, the land use classification was based on Landsat 5 (1999) and Landsat 9 (2023) imagery and shows significant changes in the landscape over an approximately 24-year period.

When overlaid with the water quality characteristics of water sample, several important observations were made. Notably, the water quality characterization showed distinct variations among the AR, AS, and EZ sample groups chosen due to the proximity and distribution of the water samples. Furthermore, this spatial variation aligns with a somewhat heterogeneous land use patterns observed in our classification maps (Figures 5, 6 and 7). In addition, the AR samples, located in the northern part of the Anambra River indicated the best overall water quality. This is attributed to potentially less intensive land use or better preservation of natural land cover in this region, as seen in the land use classification maps.

Also, the land use change assessment map (1999-2023) indicates major urban expansion. Consequently, this urban growth explains the poor water quality index (WQI) values across samples, within the AS and EZ groups, especially at AS 2. Urbanization often leads to increased impervious surfaces, reducing natural filtration and potentially increasing runoff with pollutants into water bodies. Urbanization has previously been associated with major water quality degradation, with increased levels of pollutants in areas with high levels of urbanization (Okolo *et al*, 2025, Wang *et al*, 2020, Liu *et al*, 2022).

Furthermore, the moderate to high levels of organic pollution, as indicated by Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD), suggest impacts from agricultural runoff. This aligns with the major land use changes observed around sample group EZ. Specifically, it is suggested that due to the nature of the towns close to EZ and AS, the major land use change in areas around EZ would involve agriculture while that of AS would be urbanization. In addition, the Irrigation Water Quality Index

(IWQI) also suggest moderate suitability for agriculture, further evidence of the presence of significant agricultural activities in areas around the EZ group which is consistent with the studies of Enekwechi *et al*, 2022 on a water shed.

The elevated sulphate levels in the EZ samples, combined with elevated Total Dissolved Solids (TDS), could indicate the presence of industrial or other anthropogenic activities in the southern part of the study area. There have been known illegal extraction of hydrocarbon, which could be a source of the sulphate in the water due to minor oil spillage and other chemicals involved in the extraction. The study of Nwankwo *et al.*, (2023) collaborates the present result that oil spillage is a major source of water pollution.

The high level of Degree of Contamination (Cd) values across all samples point to significant anthropogenic influences on water quality. This is well reflected in the land use changes observed between the 1999 and 2023 classifications, showing a shift from natural landscapes to more human-altered environments.

In addition, the presence of faecal coliform bacteria in all samples suggests point source pollution from inadequate wastewater management, growth of residential areas due to rapid urbanization, and lack of proper sanitation. Moreover, Okpala *et al.*, (2022) observed that inadequate wastewater management is a major source of water pollution, with high levels of pathogens and other pollutants in areas with poor wastewater management which supports the result of the present study.

4. Conclusion

In conclusion, the integration of water quality parameters with land use change assessment provides valuable insights into the complex interactions between human activities and water resources in the study area. The results suggest that urbanization, agricultural activities, and industrial activities are major drivers of water quality degradation in the study area. Therefore, further research is needed to understand the specific factors contributing to water quality.

5. References

1. Anakwuba EK, Okolo CM, Ahaneku CV, Chibuzor SN, Chinwuko AI. Hydrogeological and water quality evaluation of parts of River Mamu Sub Basin, Southeastern Nigeria. Bulletin of the Mineral Research and Exploration. 2020; 167:65-82.
2. APHA (America Public Health Association). Standard Methods for the Examination of Water and Wastewater, Washington, D.C, 1985.
3. APHA (America Public Health Association). Standard Methods for the Examination of Water and Wastewater. 21st Edition, Washington, D.C, 2005.
4. APHA (America Public Health Association). Standard Methods for the Examination of Water and Wastewater, Washington DC, 1999.
5. Arnold CL, Gibbons CJ. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. Journal of the American Planning Association. 1996; 62:243-258.
6. Wilcox LV. Classification and use of irrigation water (Circular 969). U.S. Department of Agriculture. 10.1007/s11356-017-0168-y International, 12, 12, 1–16. Environ. and Urban systems, 16: 3-19. Water and Wastewater. 18th Edition, Washington, D.C., 1955, 4-17.
7. Ayers RS, Westcot DW. Water quality for agriculture (FAO Irrigation and Drainage Paper 29 Rev. 1). Food and Agriculture Organization of the United Nations, 1985.
8. Backman B, Bodis D, Lahermo P, Rapant S. Application of a groundwater contamination index in Finland and Slovakia. Environmental Geology. 1997; 36(1-2):55-64.
9. Corwin DL, Wagenet RJ. Application of GIS to the modelling of Nonpoint source pollutants in the vadose zone: A conference overview. Journal of Environmental Quality. 1996; 25.
10. Ding Y, Fotheringham S. The integration of spatial analysis and GIS. Comput, 1992.
11. Drever JI. The Geochemistry of Natural Water: Surface and Groundwater Environments. 3rd Edition, Prentice Hall, New Jersey, 1997.
12. Fletcher TD, Andrieu H, Hamel P. Understanding, management and modelling of urban hydrology and its consequences for receiving waters: A state of the art. Adv. Water Resour. 2013; 51(2013):261-279.
13. Fotheringham, Rogerson. Spatial Analysis and GIS. Technical Issues in Geographic Information Systems (Taylor and Francis), 2005.
14. Hem JD. Study and Interpretation of the Chemical Characteristics of Natural Water. 3rd Edition, US Geological Survey Water-Supply Paper 2254, University of Virginia, Charlottesville, 1985, 263.
15. Horton R. An Index Number System for Rating Water Quality. J. Water Pollut. Control Fed. 1965; 37:300-306.
16. Klein RD. Urbanization and stream quality impairment. Water Resources Bulletin. 78091, 1979.
17. Longley PA, Goodchild MF, Maguire DJ, Rhind DW. Geographic information systems and science. 2nd ed. New York: Wiley, 2005.
18. Nwachukwu OU, Okoye O. Assessment of the impact of industrial effluents on the water quality of the Anambra River, Nigeria. Journal of Environmental Protection. 2016; 7(07):1024-1034.
19. Nwajide CS. Nigeria Sedimentary Basins, 2013, 321-332.
20. Nwajiuba CA. Impacts of human activities on the Anambra River basin: A review. African Research Review. 2014; 8(4):293-305.
21. Nwilo PC, Badejo OT. Municipal solid waste disposal in Nigeria: Issues and challenges. International Journal of Environmental Studies. 2017; 74(3):413-425.
22. Obiakor MO, Tighe M, Wang Z, Ezeonyejiaku CD, Pereg L, Wilson SC. The relative sensitivity of freshwater species to antimony (III): Implications for water quality guidelines and ecological risk assessments. Environ Sci Pollut Res, 2017. DOI
23. Ogueke NV, Nwokoye NN. Anthropogenic impacts of urbanization on the hydrology and water quality of Aba River, Southeastern Nigeria. Journal of Environmental Protection. 2013; 4(03):283-293.
24. Okezie CN, Onogu SA. The lignite of the southeastern Nigeria Geol survey of Nigeria. Occasional paper. 1985; 10:28.
25. Okolo CM, Onuorah ID, Madu FM. Seasonal Variation in Physicochemical Properties of Water in Onitsha Metropolis, Southeastern, Nigeria. Asian Journal of Environment & Ecology. 2023; 22(4):39-52.

26. Okolo CM, Alichi AU, Madu FM. Groundwater Quality Assessment in Parts of Aba Metropolis, Southeastern Nigeria. African Journal of Environment and Natural Science Research. 2025; 8(1):158-176.
27. Okolo CM, Akudinobi BEB, Obiadi II, Onuigbo EN, Obasi PN. Hydrochemical evaluation of lower Niger drainage area, southern Nigeria. Applied Water Science. 2018; 8(201). Doi: https://doi.org/10.1007/s13201-018-0852-1.
28. Onu FK. The southern Benue trough and Anambra Basin, Southeastern Nigeria: A stratigraphic review, Journal of Geography, Environment and Earth Science, 2017.
29. Onuigbo EN, Okoro AU, Etu-Efeotor JO, Akpunonu EO, Okeke HC. Palaeoecology of Enugu and Manu Formations in Anambra Basin Southeastern Nigeria. Advances in Applied Science Research. 2015; 6(4):25-39.
30. Pundt H, Brinkkotter-Runde K. Visualzation of spatial data for field-based GIS. Computers and Geosciences. 2000; 26:51-56.
31. Raghunath HM. Groundwater (2nd ed.). Wiley Eastern Limited, 1987.
32. Shuster WD, Bonta J, Thurston H, Warnemuende E, Smith DR. Impacts of Impervious surface on watershed hydrology: A review. Urban Water Journal. 2005; 2(4):263-275.
33. Simsek C, Gunduz O. IWQ Index: A GIS-integrated technique to assess irrigation water quality. Environmental Monitoring and Assessment. 2007; 128(1):277-300. Doi: https://doi.org/10.1007/s10661-006-9312-8
34. WHO. Guidelines for Drinking Water Quality. 4th Edition World Health Organization, Geneva, Switzerland, 2022. http://apps.who.int/iris/bitstream/10665/44584/1/9789241548151 _eng.pdf