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# Assessing the Influence of Land Use on Water Quality in Nigeria: A Case Study of Goronyo Local Government Area, Sokoto State

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## *Abstract*

This study examines the impact of land use on water quality in Nigeria, focusing on Goronyo Local Government Area. The study area comprises predominantly residential zones along with open refuse dumpsites and auto-mechanic workshops. Over a period of twelve months, water samples were collected from residents and various locations within and around these two impact points, covering both the dry and rainy seasons. A total of 69 sampling points were distributed across different land use categories. The collected samples were analyzed for parameters such as pH, electrical conductivity, temperature, total dissolved solids, basic anions and cations using standard methods. Heavy metal analysis (including Fe, Pb, As, Cr) was conducted using Atomic Absorption Spectrophotometer, while microbiological analysis employed the most probable number method for counting coliform. The results showed that the mean pH of water samples in the residential area, dumpsite, and mechanic site were 5.61, 6.31, and 4.63 respectively. The maximum concentration of total dissolved solids (TDS) was 1022mg/L in the residential area and 733mg/L at the dumpsite. Concentrations of heavy metals exceeded permissible limits in all areas, with the highest microbial distribution observed at the dumpsite. Statistical analysis revealed significant differences among the sources at $p<0.05$. Overall, the findings indicate that the identified impact points significantly influence water characteristics. The study suggests a need for policymakers to reassess land use patterns and implement a continuous monitoring program for the study area.

**Keywords**: Land use, Water, Water Quality, Dumpsite, Goronyo Nigeria

## *Introduction*

Groundwater is part of the precipitation that infiltrates into the soil; so it is a component of the hydrologic cycle. The major ions or electrically charged particles present in rain water are Ca, Mg, Na, Si (as Si(OH)4), SO4,Cl, nitrogen compounds and the total concentrations of all constituents typically are less than 5 to 10 mg/L. The majority of the remaining ions are typically from airborne particulate matter and gases from industrial emission, automobile exhaust and the evaporation of volatile chemicals. The sustainable development of every country is controlled by the availability of surface and groundwater (Zaki, *et al.,* 2019). In Africa, groundwater is a critical resource playing a vital role in both human life and ecosystem (Adelana, *et al.,* 2011). Currently, groundwater contamination has become a challenging problem, because of its susceptibility to pollution both by natural and anthropogenic processes (Malik and Shukla, 2019). Malomo *et al.,* (1990) reported that there is human activity imprint on the hydro-geochemistry of groundwater in Goronyo shallow wells.

Ocheri et al., (2014) recommended further treatment for groundwater in Goronyo town. Ogunlesi et al., (2004) associated cases of diarrhea reported in Goronyo with the poor quality of drinking water among children. Ayoade and Ibitoye, (2012) documented high numbers of coliform bacteria in wells and boreholes in Goronyo. On a national scale, Odebunmi et al., (2014) reported that the quality of Nigeria's urban groundwater is influenced by various factors including the geology and geochemistry of the environment, leachate from landfills/dumpsites, heavy metals, urbanization rate, industrialization, bacteriological pollution, and seasonal effects. Okpanachi, (2015) found that wells located near dumpsites exhibit higher concentrations of physico-chemical parameters compared to those located farther away (>50 m) from the dumpsite. Bayode et al., (2012) observed elevated concentrations of pH, EC, TDS, Mg, NO3, PO4, and Fe in groundwater, suggesting pollution from dumpsite leachate. Aderemi et al., (2011) reported that groundwater within a 0.55 km radius of municipal solid waste landfills had high concentrations of Fe, leading to contamination from dumpsite leachate.

Several studies have documented varying concentrations of groundwater parameters, leading to the conclusion that dumpsites will continue to pose a significant source of pollution to groundwater in the foreseeable future. Additionally, research has highlighted the potential threat to groundwater from activities in auto-mechanic villages, as heavy metals pollution emerges as one of the most serious environmental concerns today (Karnib et al., 2014). In Nigeria, auto-mechanic activities represent a

major pathway for the introduction of heavy metals into the environment, resulting in soil and groundwater contamination (Usman et al., 2013). The leachates from these activities, being non-degradable in soil, further exacerbate the risk to groundwater (Olade, 2014).

Goronyo LGA, located within the coordinates of 07°36'N and 04°40'E to 07°42'N and 04°46'E, encompasses diverse land use patterns, including residential areas, agricultural lands, industrial zones, and waste disposal sites. As a result, the water quality of groundwater sources, such as wells and boreholes, may be susceptible to contamination from various sources, including agricultural runoff, industrial discharges, and improper waste management practices. The need to investigate the effect of land use on water quality in Goronyo LGA arises from the potential risks posed to human health and ecosystems. Poor water quality can lead to a range of adverse effects, including waterborne diseases, ecosystem degradation, and economic losses. Moreover, as access to safe drinking water remains a pressing issue in many Nigerian communities, understanding the factors influencing water quality is essential for ensuring access to clean and potable water for all residents.

In this context, the study aims to evaluate the influence of land use on groundwater quality, encompassing its physical, chemical, and compound characteristics, including alterations induced by human activities. Ultimately, the findings of this research are expected to contribute to evidence-based decision-making and sustainable water resource management practices in Goronyo LGA and similar regions across Nigeria.

**Study Area**

The study was conducted in Goronyo Local Government Area (LGA) within Sokoto State, Nigeria, situated at geographical coordinates 07°36'N and 04°40'E to 07°42'N and 04°46'E. The area covers a total land area of 63 square kilometers. Goronyo LGA experiences a humid tropical climate characterized by consistent humidity levels throughout the year and an average annual rainfall of 1600 mm. Geologically, the study area lies within the basement complex of Nigeria, predominantly composed of amphibolites, biotitegneisis schist, and complex formations (Malomo et al., 1990). To assess the impact of land use on groundwater quality, the study classified the area into three categories: fully residential areas, areas proximate to dumpsites, and areas near mechanic workshops. A total of 69 well points were surveyed and mapped using ArcGIS 10.1 software, as depicted in Figure 2. Water sampling was conducted during both rainy and dry seasons to adequately represent variations throughout the year. Well depths were measured at the onset of each sampling session using a water level meter. Analysis of basic anions, cations, and heavy metals was performed according to

standard methods outlined in the American Public Health Association (APHA) guidelines (1998). Microbiological analysis involved quantifying coliform bacteria using the most probable number (MPN) method. The obtained results underwent various statistical analyses, including descriptive statistics, to elucidate patterns and trends in groundwater quality.

**Materials and Methods**

The study utilized Landsat imagery to classify the various land cover types within the study area. Subsequently, a field survey was conducted to identify and categorize different land use patterns. Statistical analyses were employed to facilitate data interpretation, including Analysis of Variance (ANOVA), Pearson correlation, factor analysis, and cluster analysis. The hydro-chemical phases of groundwater were established using PAST (Paleontological Statistics) software.

**Results and Discussion**

The descriptive statistics of all parameters investigated in the study area, including wells located in fully residential areas, wells around dumpsites, and wells in the vicinity of mechanical areas, indicated that the majority of the parameters met the standards set by the World Health Organization (WHO). However, deviations from these standards were observed in pH, total dissolved solids (TDS), electrical conductivity (EC), potassium (K), and heavy metal concentrations.

**Wells Located Within Fully Residential Areas.**

In fully residential areas, groundwater with a low pH level may contain higher concentrations of toxic metals, potentially leading to premature corrosion of metal piping and causing aesthetic issues such as a metallic or sour taste. The average pH recorded (5.61±0.73) around the fully residential area indicated acidic groundwater conditions, although the pH range (4.1-7.3) suggested some wells exhibited alkaline characteristics. The pH exhibited temporal fluctuations during the sampling period, particularly when hydrogen ions were abundant. It's noteworthy that acid rain, often containing elevated levels of potassium (K), can influence groundwater pH, as evidenced by a strong correlation ($r=0.91$). The observed variations in pH levels differed significantly from those observed at dumpsites and mechanic areas.

Typically, low pH levels in groundwater are associated with limited dissolved carbonate and hydroxyl ions, or when pH values approach 5.6 (Knutsson, 1994). Acidic precipitation infiltrating into the ground can further influence groundwater pH. Interestingly, pH levels did not exhibit significant correlations with other parameters

examined in this study. However, the pH values obtained align with previous findings reported by Malomo et al. (1990).

This indicates that the acidity levels in the study area have remained relatively stable over time. The average total dissolved solids (TDS) concentration was 147.29±201.11, with a range of 8.3 to 1022, indicating elevated levels of dissolved solids in some wells. When TDS levels surpass 1000 mg/L, it is generally deemed unsuitable for human consumption due to potential health risks associated with certain mineral salts comprising TDS. The TDS levels around the residential area exhibited strong correlations with electrical conductivity (EC) ($r = 0.99$), chloride (Cl) ($r = 0.91$), calcium (Ca) ($r = 0.84$), hardness ($r = 0.84$), and sodium (Na) ($r = 0.88$). While a strong correlation with Cl may suggest anthropogenic influence, this was not conclusively established. Elevated TDS levels can impact the taste and odor of water, particularly when it exceeds moderate to high levels.

Temporal variations in TDS did not exhibit significant fluctuations across the sampling periods. In general, most EC values in residential areas were below the WHO limit of 1000 µS/cm, although some wells exceeded this threshold. The temporal variation of EC followed a distinct pattern, with the month of June recording the highest levels. The range of potassium in residential areas was notably high, exhibiting variations distinct from those observed at dumpsites and auto-mechanic areas. Potassium, commonly present in soils and rocks, gradually releases into groundwater over time, leading to increased concentrations with prolonged residence time.

According to Oyinloye (2011), the elevated levels of Na2O and K2O in the Goronyo basement complex suggest that the high concentration of potassium may be attributed to geological factors. The average concentration of iron (Fe) in wells around residential areas was 1.37 mg/L, exceeding the permissible limit of 0.3 mg/L in almost all water samples. While iron is commonly found in hydrogeological environments, its dissolution in groundwater occurs primarily under reducing (anaerobic) conditions. The low pH observed in the study area enhances the solubility of metals, leading to increased concentrations in acidic groundwater. Although these values did not align with those reported by Malomo et al. (1990), Ayoade and Ibitoye (2012) documented higher iron concentrations in some boreholes, suggesting a gradual increase in iron dissolution over the years, with varying concentrations observed across seasons.

Lead concentrations in residential areas exceeded the permissible limit of 0.01 mg/L. Lead can leach into water from household plumbing systems containing lead in pipes, solder, and fittings. The amount of lead dissolved from plumbing systems depends on factors such as pH, temperature, water hardness, and standing time, with soft, acidic water being particularly conducive to lead leaching (WHO, 2006). Excessive lead in water poses serious health risks, especially for infants, children, and pregnant women

(Oyekunle et al., 2012). The observed concentrations were consistent with the findings of Ayoade and Ibitoye (2012). Temporal variations in arsenic concentrations in residential areas exceeded the permissible limit of 0.01 mg/L.

Arsenic is commonly found in groundwater and can also result from human activities that migrate into the soil. Due to the slow movement of groundwater, arsenic may continue to dissolve and concentrate in the aquifer. Adetoyinbo et al. (2015) reported high arsenic content ranging from 0.12 to 8.60 mg/L at a mining site in a peri-urban area near Goronyo, suggesting the need to investigate the study area for gold tailings. Long-term ingestion of high concentrations of arsenic from drinking water can lead to various health issues, including internal cancers such as lung, bladder, liver, and kidney cancers (Ajayi and Osibanjo, 1981).

Similarly, the highest mean concentration of chromium was detected in water samples around residential areas, surpassing the permissible limit of 0.05 mg/L. Cr (VI) anions can be absorbed by positively charged surfaces like oxides and hydroxides of iron, manganese, and aluminum.

The adsorption of Cr (VI) on these adsorbents is typically restricted and diminishes as pH increases. The obtained values were consistent with the findings of Ayoade and Ibitoyo (2012). Low-level exposure to chromium can lead to skin irritation and ulceration. Prolonged exposure may result in kidney and liver problems, as well as damage to circulatory and nerve tissues.

**Wells Situated in the Vicinity of the Dumpsite.**

The average pH concentration of wells around the dumpsite indicated slightly acidic to alkaline groundwater conditions. pH did not exhibit strong correlations with any parameter at the dumpsite; however, ANOVA analysis revealed statistically significant differences ($p<0.05$) in water samples across the three land use categories, indicating distinct variations between them. The mean pH observed at the dumpsite aligned with values reported by Aderemi et al. (2011), Bayode et al. (2012), and Okpanachi (2015). Prolonged exploitation of landfills can lead to the generation of alkaline leachate (Longe and Balogun, 2010), as observed in the dumpsite, where various forms of solid waste, primarily biodegradable, were disposed.

The mean concentration of total dissolved solids (TDS) was moderate, with the majority of wells around the dumpsite exhibiting moderate levels. Notably, one well (M090), situated uphill from the dumpsite and possessing the greatest depth, recorded the highest TDS concentration. TDS exhibited moderate correlations with chloride (Cl) ($r = 0.65$) and potassium (K) ($r = 0.53$) at the dumpsite, while demonstrating strong correlations with electrical conductivity (EC) ($r = 0.89$) and sodium (Na) ($r = 0.73$). ANOVA analysis confirmed significant differences ($p<0.05$) between wells

around the dumpsite and those around residential areas. The mean depth of wells around the dumpsite was 4.55 meters, indicating a high water table in this area. This observation is supported by the correlations between depth and TDS (r = 0.76), Na (r = 0.87), and K (r = 0.78), as expected.

Some wells in the study area recorded concentrations of 176.01 mg/L, exceeding the recommended limit of 10 mg/L. These findings are consistent with previous studies by Malomo et al. (1990) and Bayode et al. (2012), although other literature reports a lower range of parameters in the basement complex of southwestern Nigeria. Potassium and sodium concentrations in the study area have remained relatively stable over time.

The average concentration of iron (Fe) in the dumpsite area was higher compared to the residential area, although the range was lower. Various forms of waste, including metal scraps, were indiscriminately disposed of at the dumpsite. Temporal distribution of Fe exhibited fluctuating trends across residential, dumpsite, and mechanic areas, with consistently high concentrations exceeding permissible limits observed at the dumpsite. There were strong correlations (r = 0.71, r = 0.75, and r = 0.98) with well depth, depth to water level, and total dissolved solids (TDS), while the correlation with pH (r = 0.60) was moderate.

The mean concentration of lead (Pb) in wells around the dumpsite area was 0.03 mg/L, surpassing the permissible limit of 0.01 mg/L. Open-air incineration of waste materials at dumpsites can contribute to increased Pb concentrations. Pb presence in groundwater samples around the dumpsite area did not exhibit a definitive trend but remained consistently present in two dugwells (M090 and M091) in Figure 2, with no correlation observed with other parameters.

The average concentration of arsenic (As) and chromium (Cr) in water samples around the dumpsites exceeded the permissible limits of 0.01 mg/L and 0.05 mg/L, respectively. The correlation of Cr with other parameters was similar to that of Fe. However, As exhibited a very strong correlation (r=0.97, r=0.76) with pH and the temperature of the water samples.

**Wells around Mechanic Area**

In the mechanic area, the parameter that fell outside the permissible range was pH, with no correlation observed with any other parameter, along with the heavy metals. The mean concentration and range of pH values indicated acidic groundwater. The ranges of Fe, Pb, As, and Cr values exceeded the permissible limits. Activities at the mechanic area included stockpiling of metals and engine parts, with observed infiltration of leachates into the bare floor.

**Principal Component Analysis (PCA), Cluster Analysis, and Hydro-Geochemical Facies Analysis.**

For the physico-chemical parameters, 5 principal components (PCs) were obtained, explaining 82.937%, 81.92%, and 79.001% of the total variance for residential, dumpsite, and auto-mechanic areas respectively. The first PC in the residential area (Figure 3a) was characterized by Na, TDS, EC, K, Cl, Ca, and hardness. However, in the dumpsite and mechanic areas (Figure 3b and 3c), hardness was absent, indicating distinct differences in the PCs.

The dendrogram generated from the cluster analysis (Figures 4a, 4b, and 4c) facilitated the identification of three clusters of associated characteristics in water samples around the residential areas, three around the dumpsite, and four around the mechanic area. The hydro-chemical phases in the study area revealed that the dominant anions in the residential area were HCO3 (100%) > Cl (92%) > SO4 (70%), while the cations followed the order of Na + K (100%) > Ca (100%) > Mg (80%). In contrast, the dumpsite exhibited a different trend with anions in the order of HCO3 (100%) > Cl (89%) > SO4 (22%) and cations in the order of Na + K (100%) > Ca (62%) > Mg (14%). At the mechanic area, the anions followed the order of Cl (70%) > HCO3 (59%) > SO4 (50%), and the cations were Na + K (100%) > Ca (50%) > Mg (29%).

**Microbiological Analysis**

The occurrence and percentage distribution of microbes were highest in wells around the dumpsite and the mechanic area, although the period of occurrence differed. In wells around the residential area, E. coli accounted for 52% of the occurrences, while other organisms varied over the months. Bacteria can infiltrate groundwater and water supply wells through various factors such as land use, soil types, and depth to water, geologic strata, and well construction methods, suggesting that the presence of microbes in the water samples may be influenced by anthropogenic factors

**Conclusion and Recommendations**

In conclusion, the various statistical analyses conducted in this study have revealed distinct water chemistry profiles for different land uses within the study area. Particularly, the location of the dumpsite emerged as a significant contributing factor to the poor water quality observed. Although the activities of the auto-mechanic area have not significantly impacted groundwater quality, the current practices of discharging oil and petroleum products onto cemented floors are unsustainable.

Based on these findings, it is recommended that the present land use in the area be reassessed. Additionally, a routine monitoring program for wells should be established to continuously assess groundwater quality and ensure early detection of any potential

contamination or degradation. By implementing these recommendations, proactive measures can be taken to safeguard groundwater resources and protect public health in the study area.

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