Assessment of Ground Water Quality and Impact on Health in Open Waste Disposal Site of Damaturu, Yobe State Nigeria.

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ABSTRACT

This study assessed the spatial relationship between open dumpsites and groundwater contamination in Damaturu Metropolis, Yobe State, Nigeria. The aim was to evaluate the influence of open solid waste disposal sites on the physicochemical and bacteriological quality of groundwater sources located in their vicinity. eleven open dumpsites and eleven nearby groundwater sampling locations were selected for the study using purposive sampling techniques. Geographic Positioning System (GPS) was used to obtain the coordinates of the sampling locations, while Geographic Information System (GIS) techniques were employed to analyse the spatial distribution of the dumpsites and groundwater sources through buffer zone analysis. Groundwater samples were analyzed for selected physicochemical parameters, including pH, electrical conductivity, turbidity, total dissolved solids, hardness, cadmium, nickel and other relevant parameters, as well as bacteriological parameters comprising Total Viable Count (TVC) and Escherichia coli (E. coli). The laboratory results were compared with the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) guidelines. The results indicated variations in groundwater quality among the sampled locations. Bacteriological analysis showed the presence of E. coli in some sampling locations, with the highest contamination recorded at Nayinawa (Sabon Fage), indicating faecal contamination associated with leachate infiltration from nearby dumpsites. Spatial analysis revealed that groundwater sources located within the closest buffer zones to the dumpsites exhibited higher contamination levels than those farther away. The study concludes that the proximity of groundwater sources to open dumpsites significantly influences groundwater quality and poses potential public health risks. The study recommends the establishment of sanitary landfills, continuous groundwater quality monitoring, improved waste management practices, and strict enforcement of environmental regulations to protect groundwater resources in Damaturu Metropolis.

Keywords: Groundwater contamination, Open dumpsites, Spatial analysis, GIS, Leachate, Water quality, Damaturu Metropolis, Yobe State.

INTRODUCTION

Rapid urbanization across Nigeria has intensified municipal solid waste generation, outpacing the capacity of many local governments to provide reliable collection, treatment, and safe disposal services (World Bank, 2022). While megacities such as Lagos and Abuja have attracted the bulk of academic attention and donor support, secondary and regional capitals in the North-East including Damaturu, the administrative centre of Yobe State face distinct challenges: limited municipal budgets, weak institutional coordination, seasonal population fluxes, and infrastructure deficits that together perpetuate informal and unsafe disposal practices These contextual factors create an urgent need for localized assessments that can guide pragmatic, place-sensitive interventions.

In many Nigerian cities, common disposal strategies include open dumping, uncontrolled burning, irregular municipal collection, and ad hoc burying or waterway dumping Evidence from comparable urban centers indicates that open dumping and burning dominate where collection coverage is poor, resulting in environmental contamination, blocked drainage and increased flood risk, and adverse human health outcomes such as diarrheal and respiratory illnesses (UNEP,2021;WHO,2018)The primary environmental Hazard Associated with open waste disposal is the generation of leachate, a complex highly contaminated liquid formed when water percolates

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through decomposing waste, extracting dissolved organic matter, in-or genic compounds, Heavy metals, and xenobiotic organic substances, when precipitation infiltrates unprotected waste deposits, the resulting leachate accumulates at the base of dumpsites and progressively migrates downward through soil profile eventually reaching ground water aquifers.

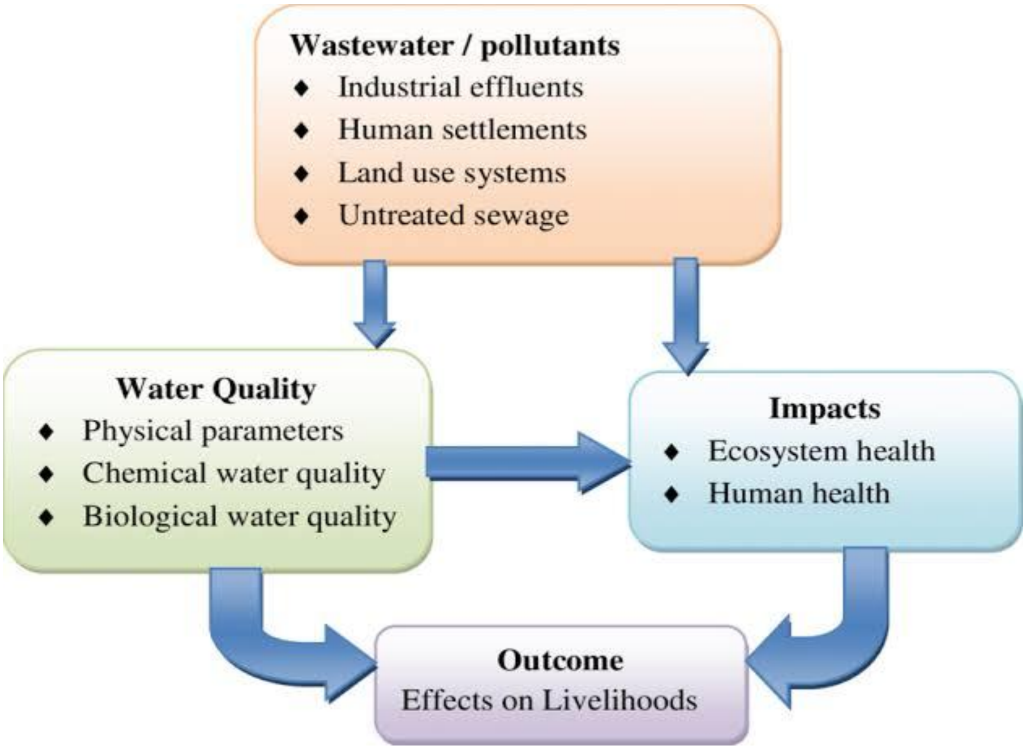
where groundwater serves as the primary source of drinking water for local communities. Nigeria exemplifies the waste management challenges confronting rapidly urbanizing countries in the Global South. The combination of burgeoning populations, inadequate regulatory enforcement, insufficient financial resources for safety infrastructure, and the widespread practice of open dumping has created conditions where soil deterioration and water quality degradation have become endemic. Across the country, municipal solid waste is frequently deposited in uncontrolled sites, including abandoned burrow pits, excavated areas, and vacant lands within residential and commercial zones, where considerations of environmental protection are subordinate to convenience and cost

The hydrogeological connection between dumpsites and groundwater resources is mediated by site- specific geological conditions. Research employing electrical resistivity techniques has demonstrated that areas affected by leachate infiltration typically exhibit low subsurface resistivity values (4.2–34 Ωm), indicating severe groundwater contamination, while control sites show high resistivity (>120 Ωm) suggestive of minimal impact. These geophysical signatures reflect the elevated ionic concentrations characteristic of leachate-contaminated groundwater and provide a means of delineating pollution plumes emanating from waste disposal sites. Studies in Lagos, Kano, and Ibadan demonstrate elevated heavy metal and microbial contamination in soils and groundwater near dumpsites, as well as higher respiratory symptoms among adjacent communities' patterns likely mirrored in smaller northern cities with fewer safeguards Olufemi et al., (2019; Aluko et al.,(2016;)

Institutional analyses highlight that policy presence alone does not guarantee improved outcomes; enforcement, clear institutional roles, sustainable financing, and meaningful community engagement are critical enablers. Informal waste workers contribute substantially to material recovery yet remain marginalized, exposing both a gap and an opportunity for circular-economy integration; Abila and kantola, 2019).

Hence, this research aim to assess the ground water quality and its impact on health in open waste disposal site of Damaturu, Yobe State Nigeria.

LITERATURE REVIEW



CONCEPTUAL FRAMEWORK

Groundwater Contamination from Waste Disposal:

Groundwater is the principal source of potable water for millions of people in Nigeria, particularly in the semi-arid North-Eastern region where surface water is seasonal and often unreliable. States such as Yobe, Borno, Adamawa, Bauchi, Gombe, and Taraba depend heavily on boreholes and hand-dug wells for domestic, agricultural, and industrial water supply. However, rapid urbanization, population growth, and poor municipal solid waste management have increased the vulnerability of groundwater to contamination from open dumpsites and unregulated waste disposal practices. The infiltration of leachate from waste disposal sites has become one of the leading environmental concerns affecting groundwater quality in many Nigerian cities, including Damaturu, Maiduguri, Bauchi, Gombe, and Yola Aluko, etals (2016).

Groundwater contamination occurs when physical, chemical, or biological pollutants enter an aquifer at concentrations capable of degrading water quality and posing risks to human health and ecosystems. Open dumpsites generate leachate through rainfall infiltration and waste decomposition. This leachate contains dissolved organic matter, nutrients, pathogens, heavy metals, and other toxic substances that migrate through the soil profile into groundwater. The rate of contaminant migration depends on rainfall intensity, soil permeability, geology, groundwater depth, and the absence of engineered landfill protection systems by Duru, et al., (2019)..

Across Nigeria, studies consistently demonstrate that groundwater sources located near waste disposal sites exhibit elevated concentrations of electrical conductivity, total dissolved solids, turbidity, nitrates, chlorides, heavy metals, and microbial contaminants compared with water sources located farther away. These findings indicate that proximity to dumpsites significantly influences groundwater quality and public health risk. Recent national evidence also shows that groundwater quality studies remain concentrated in southern Nigeria, while North-Eastern Nigeria has received comparatively limited scientific attention despite its dependence on groundwater resources.

The North-Eastern region presents unique hydrogeological conditions that increase groundwater vulnerability. Much of Yobe State lies within the Chad Basin sedimentary formation, where shallow aquifers are extensively exploited for drinking water. The combination of porous sediments, seasonal heavy rainfall, and widespread open waste dumping facilitates contaminant migration into groundwater. Rapid urban expansion in Damaturu has further intensified waste generation without corresponding improvements in waste collection, engineered landfills, or leachate management, thereby increasing the likelihood of groundwater pollution. Recent work conducted in Damaturu highlighted uncontrolled solid waste disposal as a growing threat to groundwater quality and public health.

Studies conducted in other parts of Nigeria provide evidence that is relevant to North-Eastern conditions. For example, Aralu et al. (2023)reported that boreholes located around unlined dumpsites contained significantly poorer water quality than control locations, with elevated pollution indices attributable to leachate infiltration. Similarly, more recent investigations have continued to report physicochemical and microbiological deterioration of groundwater located close to waste disposal facilities, reinforcing the conclusion that poorly managed dumpsites remain major sources of groundwater contamination in Nigeria.

A comprehensive review by Omeka et al. (2024)concluded that although groundwater contamination has become a nationwide environmental concern, significant research gaps remain in North-Eastern Nigeria. The review recommended expanded groundwater monitoring, geospatial analysis, and predictive modelling in underserved regions such as Yobe State to improve groundwater protection and sustainable water-resource management.

Table 2.2: Comparison of Groundwater Quality Results with WHO and NSDWQ Standards

Water	Unit	NSDWQ (NIS 554:2007)	WHO Guidelines (2017-2022)
pH	–	6.5–8.5	6.5–8.5
Turbidity	NTU	5	5
Colour	TCU	15	15
Total Dissolved Solids (TDS)	mg/L	500	600 (acceptable for taste)

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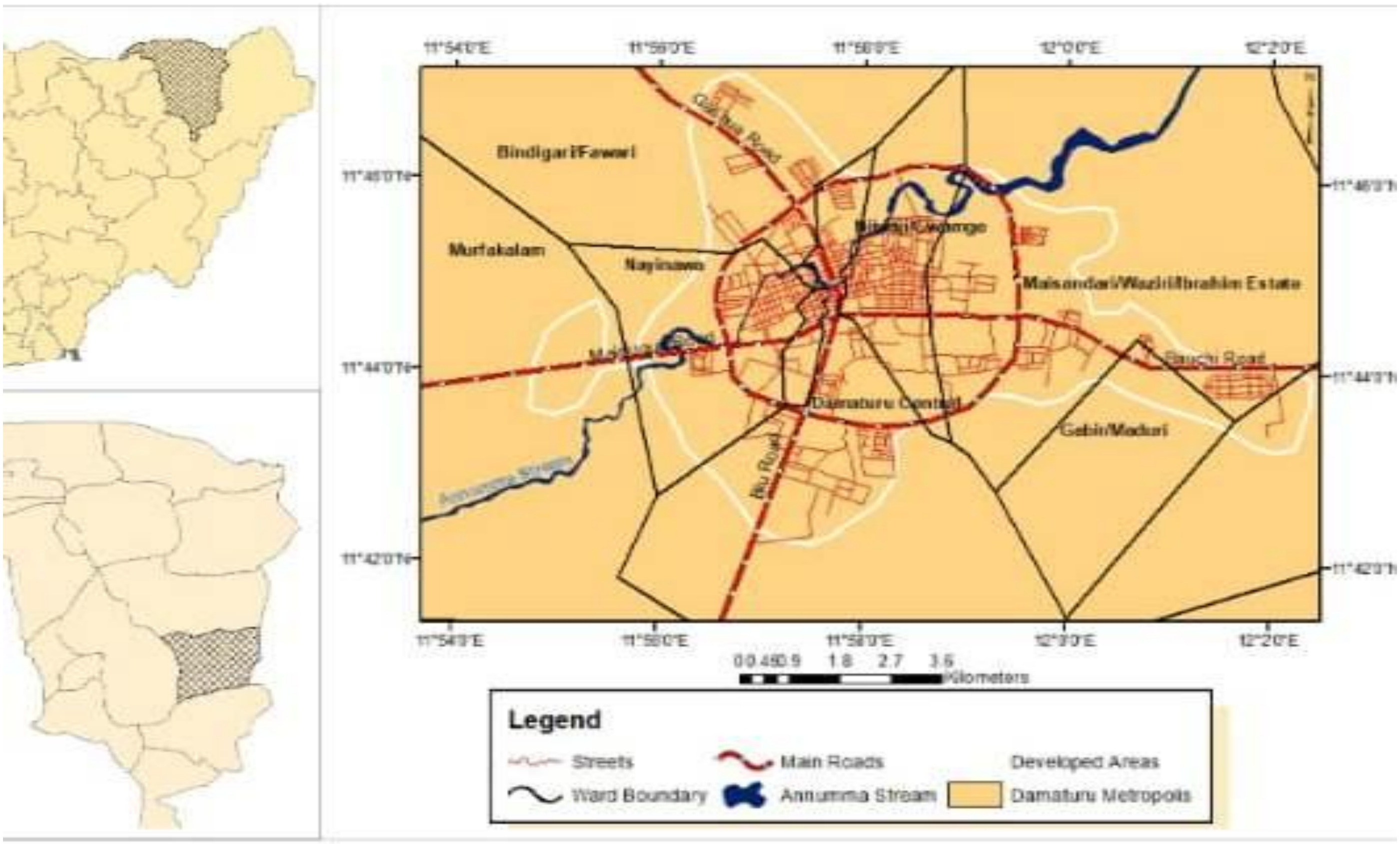
Electrical Conductivity	µS/cm	1000	No health-based guideline
Total Hardness (as $CaCO_3$)	mg/L	150	No health-based guideline
Chloride	mg/L	250	250
Sulphate	mg/L	100	250
Nitrate (NO_3^-)	mg/L	50	50
Nitrite (NO_2^-)	mg/L	0.2	0.2
Fluoride	mg/L	1.5	1.5
Iron	mg/L	0.3	0.3
Manganese	mg/L	0.2	0.4
Copper	mg/L	1.0	2.0
Zinc	mg/L	3.0	3.0
Lead	mg/L	0.01	0.01
Arsenic	mg/L	0.01	0.01
Cadmium	mg/L	0.003	0.003
Chromium	mg/L	0.05	0.05
Escherichia coli (E. coli)	CFU/100 mL	0	0
Total Coliform	CFU/100 mL	0	0

MATERIALS AND METHODS

For the purpose of this study about 22 locations within Damaturu were selected for sample collection within which eleven ground water locations were selected during the period of (May to July) the following parameters were analyzed in chemistry laboratory department Yobe state university damaturu. PH, electrical conductivity, total dissolved solid, hardness, colour, nickel, cobalt,cupper.were carried out using. spectrometer. PH meter, conductivity instrument with de-ionized distilled water, calorimeter, turbidimeter and serial dilution for bacteriological analysis. data for well depth. mode of discharge source of pollution and distance to pollution source obtained.

Fig. 1: map of the study areas



RESULTS AND DISCUSSION

Table 4.1 below presents the results obtained from the reconnaissance survey conducted across the sampled locations. The findings indicate that groundwater sources situated close to waste disposal sites are slightly alkaline. Elevated pH levels can influence biological activity and may also result in an undesirable taste of drinking water. Information gathered from community respondents further revealed that both the taste and colour of groundwater have been adversely affected in several locations. Water with objectionable taste was predominantly obtained from reservoirs located near waste disposal sites.

Field observations identified several practices contributing to groundwater contamination, including uncontrolled withdrawal of water from open dams, washing activities within dam premises, and poorly constructed or damaged aprons and linings around water sources. These conditions facilitate the percolation of leachate and other contaminants into groundwater. Evidence of waste system interference with groundwater quality was confirmed by the elevated concentrations of chromium, nickel, electrical conductivity, and total coliform counts recorded in the analysed samples.

Similarly, Agada et al. (2023) reported that pit latrines and septic tanks were located in close proximity to several wells within the study area. Most of these sanitation facilities were inadequately covered, thereby increasing the likelihood of groundwater contamination through seepage and leachate infiltration.

The groundwater samples collected from all monitoring locations further indicate that the distance between water abstraction points and waste disposal sites falls within the contamination influence zone, although most physicochemical parameters remained within the permissible limits for drinking water. However, elevated iron concentrations observed in some samples may impart colour to the water and promote the growth of iron bacteria, thereby affecting its aesthetic quality (Ogundele et al., 2018). In addition, the high levels of coliform bacteria detected in wells located near refuse dumps are consistent with findings by Ogundele et al. (2018), who attributed such contamination to poor construction and inadequate maintenance of pit latrines and septic tanks situated close to groundwater sources.

Table 4.1: Reconnaissance Survey of Sample Locations in Damaturu

S/N	Location	Water Source/Depth (m)	Mode of Discharge	Source of Pollution	Distance to Pollution Source
1.	Nyanya	Bore-hole 50 (m)	Tube pipe	Leachate from Soak Away	3 m
2.	Abba Ibrahim Way	Bore-hole 55 (m)	Tap	Waste Disposal	5 m
3.	Buhari Estate	Bore-hole 45 (m)	Tap	Waste disposal	15 m
4.	Nayinawa Sabon Fage	Bore-hole 80 (m)	Tube pipe	Leachate from soak away	10 m
5.	Ajari	Open Dam 50 (m)	Hand dug	Grave yard	70 m
6.	Bindigari/Fawari	Bore-hole 55 (m)	Tube Pipe	Abattoir	25 m
7.	Nasarawa	Open Dam 55 (m)	Hand dug	Low Risk Contamination	Above 250 m
8.	Don Etebet	Bore-hole 60 (m)	Tube Pipe	Low Risk Contamination	Above 250 m
9.	Gwange	Open-Dam 50 (m)	Hand dug	Low Risk Contamination	Above 250 m
10.	Maisandari	Open Dam 55 (m)	Rope and Bucket	Low Risk Contamination	Above 250 m
11.	Shagari	Open Dam 45 (m)	Rope and Bucket	Low Risk Contamination	Above 250 m

Source: Filed Work Survey 2026

Table 4.2: Some physical Parameters of Groundwater Sample (Mean $\pm$ SD)

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S/N	SAMPLE LOCATIONS	SAMPLE	pH (pH Unit)	EC (mS/cm)	TDS (mg/L)
1.	Nyanya	L1	6.30 ± 0.10	0.32 ± 0.00	237 ± 0.00
2.	Abba Ibrahim Way	L2	6.53 ± 0.15	0.71 ± 0.00	512 ± 0.00
3.	Buhari Estate	L3	6.33 ± 0.15	0.21 ± 0.00	153 ± 0.00
4.	Nayi Nawa (Sabon Fege)	L4	6.30 ± 0.26	0.17 ± 0.00	125 ± 0.00
5.	Ajari	L5	6.40 ± 0.20	0.16 ± 0.00	123 ± 0.00
6.	Bindigari/Fawari	L6	6.33 ± 0.06	0.41 ± 0.00	299 ± 0.00
7.	Nasarawa	L7	6.60 ± 0.36	0.17 ± 0.00	129 ± 0.00
8.	Don Etibe	L8	7.07 ± 0.06	0.14 ± 0.00	108 ± 0.00
9.	Gwange	L9	7.03 ± 0.12	0.13 ± 0.00	99 ± 0.00
10.	Maisandari	L10	6.73 ± 0.21	0.14 ± 0.00	105 ± 0.00
11.	Shagari	L11	6.93 ± 0.15	0.13 ± 0.00	98 ± 0.00

Source: Filed Work Survey 2026

pH values

The table above reveals that the pH values of the groundwater samples ranged from 6.3 to 7.1. The lowest mean pH value of 6.3 was recorded in samples L1, L3, L4, and L6, while the highest value of 7.1 was recorded in L8. Other samples recorded values of 6.4, 6.5, 6.6, 6.7, and 6.9.

The results indicate that the groundwater samples were generally slightly acidic to neutral, with some samples approaching slightly alkaline conditions. The relatively low pH values observed in some locations may be associated with the influence of decomposing organic waste and the production of acidic leachate from the dumpsites. Organic matter decomposition can generate acidic substances that may infiltrate into the subsurface and affect groundwater quality.

The gradual increase in pH observed in some locations, particularly L8 and L9, may indicate differences in local geological conditions, groundwater flow, or the degree of influence of waste-derived leachate. Overall, the pH results show spatial variation among the sampling locations, suggesting that groundwater chemistry is not uniform throughout the study area. The laboratory results recorded pH values between 6.3 and 7.1.

The PH values (6.3-7.1) indicate slightly acidic to neutral groundwater although these values are generally acceptable, slightly acidic water may increase the corrosion of pipes and plumbing fixtures. Corrosion can enhance the release of metals such as lead and copper into drinking water, thereby increasing human exposure to toxic metals over time.

The slightly acidic pH values (6.3) observed in some groundwater samples may therefore be attributed to the infiltration of leachate from nearby dumpsites, as reported by Aliyu (2025). This finding is consistent with those of previous studies conducted in Nigeria, which documented similar reductions in groundwater pH in areas surrounding open waste disposal sites. Comparable observations have been reported in Maiduguri (Borno State), Abuja (Federal Capital Territory), and Benin City (Edo State), where groundwater sources located close to dumpsites exhibited slightly acidic conditions due to the decomposition of organic waste and the generation of acidic leachate. Nevertheless, these studies also concluded that although landfill leachate can temporarily reduce groundwater pH, the natural buffering capacity of aquifer materials often moderates these effects, maintaining groundwater pH within the acceptable limits recommended for drinking water quality.

TDS concentrations

The table also indicates the TDS concentrations ranged from 98 to 512 mg/L. The highest concentration of 512 mg/L was recorded at L2, followed by 299 mg/L at L6 and 237 mg/L at L1. The lowest TDS concentration of 98 mg/L was recorded at L11, while L9 recorded 99 mg/L.

The high TDS values observed at L2, L6, and L1 indicate that these locations contain relatively higher concentrations of dissolved substances in the groundwater. This pattern is consistent with the EC results, where the same locations also recorded relatively higher conductivity values. The relationship between elevated EC and TDS suggests that the groundwater at these locations contains greater amounts of dissolved ionic and mineral substances.

The elevated TDS may be associated with the dissolution and transport of soluble materials from waste deposits, leachate infiltration, and natural mineral dissolution. In contrast, the lower TDS values observed at L8, L9, L10, and L11 indicate comparatively lower concentrations of dissolved materials. The results demonstrate clear spatial variability in groundwater quality across the sampling locations.

The TDS values ranged from 98 to 512 mg/L, with sample L2 slightly exceeding the desirable limit. Elevated TDS can affect the taste of water and may indicate the presence of dissolved inorganic and organic contaminants. Although moderate TDS is not usually toxic, long-term consumption of water containing elevated dissolved contaminants may contribute to adverse health outcomes depenv

Similar findings have been reported in groundwater quality investigations conducted around dumpsites in Jos (Plateau State), Kaduna State, and Maiduguri (Borno State), where elevated total dissolved solids (TDS) concentrations were attributed to the infiltration of dissolved salts, organic compounds, and other decomposition products originating from municipal solid waste (Abdullahi & Suleman, 2023). These studies demonstrated that leachate generated from waste decomposition can significantly increase the concentration of dissolved constituents in nearby groundwater sources, particularly in wells located closest to disposal sites. Therefore, the elevated TDS concentration observed at sampling location L2 strongly suggests a localized influence of landfill leachate on groundwater quality, indicating the potential migration of contaminants from the nearby dumpsite into the surrounding aquifer.

Electrical Conductivity Values

The table further indicates that the electrical conductivity values ranged from 0.13 to 0.71 mS/cm. The highest mean EC value of 0.71 mS/cm was recorded at L2, followed by L6 with 0.41 mS/cm and L1 with 0.32 mS/cm. The lowest values of 0.13 mS/cm were recorded at L9 and L11.

The relatively high EC values recorded at L2 and L6 indicate a greater concentration of dissolved ions in the groundwater at these locations. This may be related to the infiltration of leachate from nearby waste disposal areas, dissolution of minerals from the surrounding soil and geological formations, or other anthropogenic activities. In contrast, the lower EC values recorded at L8, L9, L10, and L11 suggest relatively lower concentrations of dissolved ionic substances.

The spatial variation in EC indicates differences in the degree of groundwater mineralization among the sampling locations. The high EC values at particular locations may therefore indicate areas that are more influenced by dissolved contaminants or mineral constituents. The reported EC values ranged from 0.13 to 0.71 mS/cm.

Electrical conductivity range from 0.13 to 0.71 mS/cm. while it does not directly cause adverse health effects, elevated EC reflects increase concentrations of dissolved ions in groundwater. High ionic content may indicate contamination from leachate and can reduce the palatability of drinking water.

Comparable findings have been reported in several studies across Nigeria. For example, Akinbile and Yusoff (2018), in their investigation of groundwater quality in Ibadan, observed that wells located in close proximity to municipal dumpsites exhibited significantly higher electrical conductivity than those situated farther away. Similarly Egbueri, j.c.(2018) in a study conducted in Lagos, documented elevated electrical conductivity levels in groundwater sources surrounding landfill sites. These increases were attributed to the infiltration of landfill leachate, which contains high concentrations of dissolved ions such as chlorides, sulphates, nitrates, calcium, magnesium, sodium, and potassium. As leachate percolates through the soil profile into underlying aquifers, it enriches groundwater with these dissolved constituents, resulting in increased electrical conductivity. These findings reinforce the widely accepted relationship between landfill leachate migration and groundwater mineralization, highlighting electrical conductivity as a reliable indicator of contamination in wells located near waste disposal sites.

Table 4.3: Chemical Parameters of Groundwater Samples (Mean ± SD)

Sample ID	Chromium (Cr) (µg/L)	Lead (Pb) (µg/L)	Cadmium (Cd) (µg/L)	Nickel (Ni) (µg/L)	Arsenic (As) (µg/L)	Copper (Cu) (µg/L)	Cobalt (Co) (µg/L)
L1	14.04 ± 0.65	9.72 ± 0.51	8.08 ± 0.85	12.10 ± 0.77	5.04 ± 0.90	39.88 ± 1.17	8.12 ± 1.06
L2	43.92 ± 2.98	27.83 ± 1.64	24.93 ± 0.57	35.32 ± 0.43	14.95 ± 0.71	119.69 ± 4.79	25.38 ± 1.42
L3	9.34 ± 0.49	6.79 ± 0.56	4.92 ± 0.98	8.05 ± 0.87	4.06 ± 1.09	24.92 ± 0.62	5.08 ± 1.09
L4	7.77 ± 0.53	4.84 ± 0.64	3.59 ± 0.90	6.06 ± 1.14	3.24 ± 0.80	17.93 ± 0.51	4.07 ± 1.08
L5	6.79 ± 0.56	4.44 ± 0.89	4.21 ± 0.82	6.03 ± 1.05	3.03 ± 1.03	15.94 ± 0.52	4.06 ± 1.03
L6	24.43 ± 2.31	14.61 ± 0.68	12.30 ± 1.03	17.71 ± 0.99	8.08 ± 0.85	59.86 ± 2.98	12.04 ± 0.83
L7	5.68 ± 1.35	4.10 ± 1.03	3.20 ± 0.95	5.04 ± 0.90	3.02 ± 0.95	14.58 ± 1.62	3.05 ± 1.06
L8	3.71 ± 0.66	2.66 ± 0.89	2.48 ± 0.43	2.97 ± 0.91	4.49 ± 1.13	10.01 ± 1.41	2.04 ± 1.04
L9	2.77 ± 0.72	2.98 ± 0.95	2.01 ± 0.96	3.03 ± 1.03	4.74 ± 1.11	8.20 ± 1.03	1.99 ± 1.00
L10	4.70 ± 1.08	4.03 ± 0.92	4.80 ± 1.16	4.03 ± 0.92	4.09 ± 1.05	11.98 ± 1.18	3.03 ± 0.97
L11	3.80 ± 1.20	2.68 ± 0.88	2.05 ± 1.03	3.18 ± 0.85	4.92 ± 1.23	8.95 ± 0.66	2.03 ± 1.03

Source: Filed Work Survey 2026

Table 4.3 indicates that the mean of the chromium concentrations as reveals in the table ranged from 2.77 to 43.92 µg/L. The highest concentration was recorded at L2 (43.92 µg/L), followed by L6 (24.43 µg/L) and L1 (14.04 µg/L). The lowest concentration was recorded at L9 (2.77 µg/L).

The relatively high chromium concentrations at L2 and L6 indicate greater accumulation or input of chromium at these locations. Chromium may originate from several anthropogenic sources associated with waste materials, including metal-containing materials, industrial products, pigments, and other discarded materials. The spatial variation in chromium concentrations suggests that contamination is not evenly distributed across the study area.

Comparable studies conducted in Lagos, Port Harcourt, and Abuja have reported elevated chromium concentrations in groundwater surrounding waste disposal sites. These increases were attributed to the improper disposal of chromium-containing materials, including metal scraps, paints, batteries, electronic waste, and other industrial residues, which release chromium into the subsurface through landfill leachate (Mbah & Nzeadibe, 2017). These findings support the view that indiscriminate waste disposal can contribute to chromium contamination of nearby groundwater, particularly where waste management practices are inadequate.

Chromium concentrations remained below the who guidelines values although current levels are not considered to pose as immediate health risk, long term exposure to elevated concentrations particularly of hexavalent chromium (Cr Vl) _ can affect the lever, kidneys and digestive system.

Similarly, the mean lead concentrations ranged from 2.66 to 27.83 µg/L. The highest concentration was observed at L2 (27.83 µg/L), followed by L6 (14.61 µg/L) and L1 (9.72 µg/L). The lowest value was recorded at L8 (2.66 µg/L). the higher lead concentrations at L2 and L6 may reflect the influence of waste derived materials and leachate migration lead can be associated with batteries metal waste, paint, electronic materials and other discarded products.the results show a clear spatial patterns with high concentration occuring at particular location and lower concentration at others this indicates that the distribution of lead may be influence by proximity of of sampling points to waste source and local subsurface conditions.

Lead concentrations exceeded the recommended drinking water guideline in some groundwater samples. Lead is one of the most hazardous contaminants found in drinking water because of its cumulative toxicity and its ability to cause serious health effects even at relatively low concentrations following prolonged exposure. Chronic ingestion of lead-contaminated water has been associated with reduced intelligence, impaired brain development, learning disabilities, and behavioural problems in children. In adults, long-term exposure may result in kidney damage, hypertension, and other cardiovascular diseases. Furthermore, pregnant women exposed to elevated lead levels face an increased risk of pregnancy complications and developmental disorders in unborn children. The detection of lead concentrations above the recommended limits in some samples

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therefore raises significant public health concerns and underscores the need for regular groundwater quality monitoring and appropriate measures to prevent contamination.

This finding is consistent with previous studies conducted in Kaduna, Lagos, Kano, and Abuja, where groundwater sources located near open dumpsites frequently contained elevated concentrations of lead. Researchers attributed the contamination to the indiscriminate disposal of lead-containing waste materials, including used batteries, electrical cables, electronic waste (e-waste), paints, and other industrial and household products. As these materials deteriorate, lead can leach into the surrounding soil and eventually infiltrate groundwater systems. The occurrence of elevated lead concentrations in the present study therefore suggests that waste materials deposited at the dumpsite may be contributing to groundwater contamination through leachate migration, posing potential environmental and public health risks (UNEP,2015).

The mean cadmium as revealed concentrations ranged from 2.01 to 24.93 µg/L. The highest concentration was recorded at L2 (24.93 µg/L), followed by L6 (12.30 µg/L) and L1 (8.08 µg/L). The lowest concentration was recorded at L9 (2.01 µg/L).

The elevated cadmium levels at L2 and L6 suggest possible influence from anthropogenic waste sources. Cadmium may be associated with batteries, electronic waste, pigments, metal products, and other materials deposited at waste disposal sites. The spatial variation in cadmium concentrations indicates differences in the intensity of contamination among the sampling locations.

Cadmium concentrations exceeded the recommended guideline values in several groundwater samples, indicating a potential public health concern. Cadmium is a highly toxic heavy metal that accumulates in the human body and is eliminated only slowly, making chronic exposure particularly hazardous. Prolonged consumption of cadmium-contaminated drinking water has been associated with kidney dysfunction, liver damage, bone demineralization, and an increased risk of fractures. Long-term exposure has also been linked to an elevated risk of certain cancers. The detection of cadmium concentrations above the recommended limits therefore underscores the need for continuous groundwater quality monitoring and the implementation of effective waste management practices to minimize cadmium contamination and protect public health.

This result is consistent with findings from studies conducted in Kano, Benin City, and Ibadan, where cadmium contamination of groundwater was associated with municipal waste disposal and the migration of landfill leachate. Previous researchers concluded that the indiscriminate disposal of cadmium-containing materials, including batteries, plastics, pigments, electronic waste (e-waste), and other industrial and household products, constitutes a major source of cadmium contamination in groundwater surrounding dumpsites (Odewumi, S. G., 2021). These findings suggest that the elevated cadmium concentrations observed in the present study may similarly be linked to the leaching of hazardous waste constituents into the surrounding aquifer.

The mean nickel concentrations ranged from 2.97 to 35.32 µg/L. The highest value was recorded at L2 (35.32 µg/L), followed by L6 (17.71 µg/L) and L1 (12.10 µg/L). The lowest value was recorded at L8 (2.97 µg/L).

The relatively higher nickel concentrations at L2 and L6 may be associated with the dissolution of nickel-containing materials and the movement of contaminants from waste deposits into the groundwater system. Nickel may be present in metal waste, alloys, batteries, and other discarded materials. The observed spatial variability indicates that the concentration of nickel differs considerably among the sampling locations.

Nickel concentrations were generally below the World Health Organization (WHO) guideline value, although some samples exceeded the Nigerian drinking water standard. Prolonged exposure to elevated nickel levels may cause allergic skin reactions and, over time, may adversely affect kidney and liver function. These findings highlight the need for regular groundwater quality monitoring to protect public health.

Similar observations have been reported in groundwater studies conducted around refuse dumps in Abuja and Lagos, where elevated nickel concentrations were attributed to the corrosion of metallic materials and the indiscriminate disposal of industrial and municipal waste (Odewumi, S. G., 2021). Although the detected nickel concentrations remained below the World Health Organization (WHO) guideline values, some exceeded the Nigerian drinking water standard, suggesting localized contamination resulting from landfill leachate infiltration.

These findings indicate that waste disposal activities may be contributing to the gradual enrichment of nickel in nearby groundwater, highlighting the need for continuous monitoring to prevent further deterioration of water quality.

The mean arsenic concentrations ranged from 3.02 to 14.95 µg/L. The highest concentration was recorded at L2 (14.95 µg/L), followed by L6 (8.08 µg/L) and L1 (5.04 µg/L). The lowest concentration was recorded at L7 (3.02 µg/L).

The relatively high arsenic concentration at L2 indicates that this location may be more affected by sources capable of releasing arsenic into the groundwater. Arsenic can originate from both natural geological materials and anthropogenic sources. In the context of the study area, waste materials and leachate migration may contribute to the observed spatial differences.

Arsenic concentrations exceeded the recommended guideline value in sample L2, indicating potential groundwater contamination. Prolonged exposure to arsenic-contaminated drinking water may cause skin lesions, nerve damage, cardiovascular disease, and an increased risk of cancers of the skin, bladder, and lungs.

This finding is consistent with previous studies conducted in northern Nigeria, where arsenic concentrations in groundwater generally remained low but increased in areas influenced by waste disposal activities and local geological conditions. Researchers have suggested that elevated arsenic levels may result from a combination of landfill leachate infiltration and the natural geochemical characteristics of the underlying aquifer (Abdullahi & Suleman, 2023). Therefore, the elevated arsenic concentration observed in sample L2 may reflect the combined influence of waste-derived contaminants and natural geochemical processes affecting groundwater quality.

The mean copper concentrations ranged from 8.2 to 119.7 µg/L. The highest concentration was recorded at L2 (119.7 µg/L), followed by L6 (59.9 µg/L) and L1 (39.9 µg/L). The lowest concentration was recorded at L9 (8.2 µg/L).

The elevated copper concentrations at L2 and L6 may be related to the presence and degradation of copper-containing materials in waste deposits. Copper is commonly associated with electrical wires, metal scraps, plumbing materials, electronic waste, and other anthropogenic sources. The spatial distribution of copper demonstrates substantial variation between the sampling locations and suggests differences in the intensity of contamination.

Copper concentrations in all groundwater samples remained below the recommended drinking water guideline values, indicating that the water is unlikely to pose a significant health risk with respect to copper contamination. Although copper is an essential trace element required for normal human physiological functions, excessive intake may cause adverse health effects, including stomach irritation, nausea, vomiting, and diarrhoea. However, the concentrations detected in this study are considered safe and are not expected to result in harmful health effects.

This observation is consistent with findings from groundwater studies conducted in Maiduguri, Kaduna, and Lagos, where copper concentrations generally remained below the permissible limits despite the presence of nearby open dumpsites. Previous researchers reported that although copper can enter groundwater through the corrosion of metal pipes, metallic waste, and landfill leachate, it is typically detected at concentrations that do not pose immediate health risks to consumers (Agada & Yakubu, 2024). These findings suggest that, while waste disposal activities may contribute to copper occurrence in groundwater, the concentrations are often insufficient to significantly compromise drinking water quality.

Finally, the mean cobalt concentrations ranged from 1.99 to 25.38 µg/L. The highest concentration was recorded at L2 (25.38 µg/L), followed by L6 (12.04 µg/L) and L1 (8.12 µg/L). The lowest concentration was recorded at L9 (1.99 µg/L).

The elevated cobalt concentrations observed at L2 and L6 may be related to the presence of metal-containing waste and other anthropogenic materials. The results show that cobalt concentrations vary spatially across the study area, with certain sampling locations exhibiting considerably higher concentrations than others. This pattern is consistent with the general distribution of the other heavy metals analyzed.

Cobalt was detected in the groundwater samples, but no WHO or NSDWQ drinking water guideline value is available for comparison. Although excessive cobalt exposure may affect the heart, thyroid gland, and blood cells, the health significance of the detected concentrations remains uncertain.

Comparable findings have been reported in groundwater studies conducted in Nigeria, where cobalt (Co) was detected in groundwater surrounding waste disposal sites (Asibor,G.2018) Although neither the World Health Organization (WHO) nor the Nigerian Standard for Drinking Water Quality (NSDWQ) has established guideline values for cobalt in drinking water, its presence in groundwater warrants attention. Excessive exposure to cobalt has been associated with adverse health effects, including disorders of the heart, thyroid gland, and blood cells. However, the concentrations detected in this study should be interpreted with caution, as the absence of established drinking water guideline values limits the assessment of their potential health significance.

Table 4.4: Bacteriological Quality of Water Samples Around Selected High Contamination Zone in Damaturu

S/N	Location	Latitude	Longitude	Total Coliform	E. coli	WHO/NSDWQ Standard	Remark	Status
1	Nyanya	11.732847	11.952435	5×10^3 CFU	2×10^3 CFU	0 CFU/100 mL	Contaminated: Both total coliform and E. Coli are present	Not safe for drinking without treatment
2	Abba Ibrahim Way	11.763694	11.956654	10×10^3 CFU	0×10^3 CFU	0 CFU/100 mL	Contaminated: High total coliform but no E. Coli.	Unsafe for drinking
3	Buhari Estate	11.766406	11.964282	3×10^3 CFU	0×10^3 CFU	0 CFU/100 mL	Contaminated: Moderate Coliform, no E. Coli	Unsafe for drinking
4	Nayinawa/ Sabon Fage	11.728674	11.996297	43×10^3 CFU	13×10^3 CFU	0 CFU/100 mL	Severely contaminated. High total coliform and E. coli, high risk	Not safe for drinking
5	Ajari	11.7492235	11.9781748	17×10^3 CFU	0×10^3 CFU	0 CFU/100 mL	Contaminated: High total coliform, no E. Coli	Unsafe for drinking
6	Bundigari/ Fawari	11.710833	11.963722	6×10^3 CFU	2×10^3 CFU	0 CFU/100 mL	Contaminated: both total coliform and E. Coli present.	Not safe for drinking

Source: Filed Work Survey 2026

Table 4.4 above reveals that the Nyanya groundwater sample contained 5×10^3 CFU total coliforms and 2×10^3 CFU E. coli, exceeding the WHO/NSDWQ permissible limit of 0 CFU/100 mL. The water sample is collected nearby the waste disposal site; the proximity of the water source to the waste disposal site suggests that leachate infiltration might have contributed to faecal contamination, rendering the water unsafe for drinking.

It further indicates that Abba Ibrahim Way sample recorded 10×10^3 CFU total coliforms with no detectable E. coli. The water sample is collected with short proximity to the waste disposal site; although faecal contamination

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was not evident, the high coliform count indicates microbial pollution likely associated with the adjacent waste disposal site, making the water unsuitable for direct consumption.

The table also reveals that Buhari Estate groundwater contained 3×10^3 CFU total coliforms and no detectable E. coli, representing the lowest bacterial load among the study sites. The water sample is collected a bit far from the waste disposal site. The relatively greater distance from the waste disposal site may have reduced contamination, although the water still fails to meet drinking water standards.

Similarly, Nayinawa/Sabon Fage This location exhibited the highest bacteriological contamination, with 43×10^3 CFU total coliforms and 13×10^3 CFU E. coli. The water source is located around the waste disposal site, indicating severe leachate influence and a high risk of waterborne diseases if consumed untreated.

Ajari's sample contained 17×10^3 CFU total coliforms without detectable E. coli, indicating substantial microbial contamination. The water sample is collected nearby the waste disposal site; the close proximity of the water source to the waste disposal site suggests that waste-derived pollutants have adversely affected groundwater quality.

Finally, Bundigari/Fawari groundwater sample recorded 6×10^3 CFU total coliforms and 2×10^3 CFU E. coli, indicating faucal contamination despite the water source being relatively farther from the waste disposal site. This suggests that, other environmental or sanitation-related factors may be contributing to groundwater pollution.

CONCLUSION

Based on the results obtained, this study concludes that open dumpsites contribute to groundwater contamination in Damaturu Metropolis. The detection of E. coli in some groundwater samples confirms faecal pollution, while elevated microbial counts in other locations indicate the influence of waste disposal activities on groundwater quality.

The spatial analysis demonstrated a clear relationship between proximity to open dumpsites and the level of groundwater contamination. Groundwater sources located within shorter distances from the dumpsites generally exhibited poorer water quality than those located farther away.

Therefore, groundwater obtained from wells situated close to open dumpsites should not be considered safe for drinking without appropriate treatment. The findings also emphasize the importance of proper waste management practices and continuous groundwater quality monitoring to safeguard public health.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

- Open dumping of municipal solid waste should be replaced with properly engineered sanitary landfills to reduce leachate generation.
- Government agencies should establish regular groundwater quality monitoring programmes in areas surrounding waste disposal sites.
- Boreholes and hand-dug wells should be located at safe distances from dumpsites to minimize contamination risks.
- Residents should treat groundwater before drinking through boiling, chlorination, filtration, or other approved treatment methods.
- Environmental protection agencies should enforce waste management regulations and monitor compliance.
- Public awareness campaigns should be conducted to educate communities about the health risks associated with groundwater contamination near open dumpsites.
- Local authorities should improve waste collection and disposal systems to reduce indiscriminate dumping.

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