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EFFECTS OF URBAN SPRAWL AND PROXIMITY OF DUMPSITES ON GROUNDWATER QUALITY IN DUTSE TOWN, JIGAWA STATE, NIGERIA

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ABSTRACT

*The study examines the relationship between changes in land use from 2015 to 2025 and groundwater quality, especially near the Dutse Ultra-Modern Market Dumpsite, where commercial activities have multiplied due to urban sprawl and increased waste generation. The study also accounts for proximity effects. Only four groundwater sources were available and therefore, were taken as the sampling points. The parameters selected are: copper, lead, zinc, cadmium, iron, and manganese, due to their relevance in groundwater quality assessment, and the American Public Health Association (APHA) method was utilised. The study was triggered by reported changes in groundwater sources near the dumpsites by communities around the Dutse-Ultra Modern Market. The land use and land cover change results indicate urban expansion between 2015 and 2025, with a notable increase in built-up areas from 41.9302 Km² to 66.906 km². However, the results of the water quality analysis show that all selected parameters were within the recommended permissible limits of the WHO and NSDWQ drinking water standards, except for iron and manganese, which were elevated, particularly at sample point A. In this sample point (borehole A), iron concentration exceeded the permissible limit (**0.112**; WHO **1**), whilst manganese has surpassed the highest desirable level but is within the maximum permissible limit (**0.349**; WHO **0.5**). It is suspected that the proximity of sample point A (Lat. **0537328**, Long. **1292669**) to the dumpsites was the contributing factor for the escalated concentration of iron and manganese in sample A (Figure 1). It was recommended that water sources, such as boreholes and wells, should be located away from dumpsites.*

Keywords: Dumpsites, Groundwater, Heavy metal, Jigawa State, Urban Sprawl

INTRODUCTION

Urban sprawl has become a significant issue for cities around the world, especially in developing countries like China (Liu et al., 2024), Brazil (Tavares, 2025), India (Sharma et al., 2024), and, of course, Nigeria (Umar et al., 2023). The rapid expansion of cities has resulted in several negative consequences, such as increased soil, water, and air pollution (Gule et al., 2024), the loss of agricultural land, and worsening traffic congestion (Alkaissi, 2024). Furthermore, because urban expansion displaces low-income neighbourhoods and limits access to essential services such as healthcare and education, it exacerbates social and economic inequality (Rana et al., 2024).

In Nigeria, concerns about urban sprawl and rapid urbanisation are intensifying due to a lack of waste disposal facilities, unlike in other developing countries such as China and India, where waste disposal and management facilities are expanding rapidly (Liu et al., 2024). In those countries, areas such as markets and hospitals are often equipped with modern waste dumpsites (Tavares, 2025). The changing land use driven by an increasing human population, due to births or migration into our emerging cities, such as Dutse town, necessitates urban sprawl and an increase in commercial

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activities, and thus waste generation. Incidentally, where population increases, waste generation doubles, but the concern is how and where the waste is disposed of, and what types of waste end up there? In developing countries such as Nigeria and emerging cities such as Dutse, waste disposal and management are poor, and many contaminants enter areas where they are not supposed to be, including the underground water system (Amos et al., 2024).

Thus, there is increasing concern about contamination of groundwater by unregulated solid waste disposal within cities, particularly at dumpsites near boreholes and wells (Aladejebi & Oladapo, 2024). Although dumpsites are the preferred method of municipal solid waste (MSW) disposal, poorly designed dumpsites, sometimes necessitated by urban expansion, can contaminate not only groundwater but also the soil and air in the area under consideration (Aidonojie et al., 2024). The most commonly reported danger to human health from these dumping sites is the use of groundwater contaminated by leachate. As water percolates through the dumpsite, contaminants are leached from the solid waste (Alao et al., 2024). Leachate is produced when moisture enters the refuse in a landfill, extracts contaminants into the liquid phase, and produces a moisture content sufficiently high to initiate fluid flow. Leachate is generated in a landfill as a consequence of the contact of water with solid waste. Leachate may contain dissolved or suspended material associated with waste disposed of in the landfill, as well as byproducts of chemical and biological reactions (Olorunfemi & Aina, 2024). The strength of leachate from MSW landfills varies with the progress of biological activity occurring in dumpsites (Ale et al., 2024). The rate and characteristics of leachate produced depend on many factors, such as solid waste composition, particle size, degree of compaction, site hydrology, age of dumpsites, moisture and temperature conditions, and available oxygen. During the stabilisation of dumpsites, non-conservative leachate constituents (primarily organic) tend to decompose and stabilise over time. In contrast, conservative constituents (heavy metals, chloride, and sulfide) will remain long after waste stabilisation. Metals are often precipitated in the landfill and are infrequently found at high concentrations in leachate, except for iron (Alao, 2024). Considering the significance of water, perhaps as the most precious natural resource after oxygen, and that it is continuously being polluted via waste disposal, all sources of water contamination must be studied, often continuously, to update its status for the many uses it can be put to (Ibrahim et al., 2015). Thus, suitability categorisation can only be achieved through this type of study. Research has examined the effects of dumpsites on adjoining water tables (Arthur, 2024; Obueh et al., 2024); however, to the best of the author's knowledge, the proximity of water sources to the dumpsites and the soil type have been overlooked.

It is equally crucial to this study to determine how well groundwater quality conforms to the World Health Organisation (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) standards. The study examined the effects of urban sprawl and proximity of dumpsites on groundwater quality in Dutse town, Jigawa state.

MATERIAL AND METHODS

Study Area

Dutse, the capital city of Jigawa State, lies at a latitude of 11.69099 and a longitude of 9.33907 (Figure 1), with an estimated population of 251,135 in 2006 and 335,600 as of 2016. Dutse is currently the most populated city in Jigawa State. The average climate of Dutse is classified as Hot Semi-Arid under the Köppen climate classification. These climates tend to have hot, sometimes extremely hot, summers and warm-to-cool winters, with minimal precipitation. The average annual highest temperature in Dutse is 40.3°C (104.5°F) (Umar et al., 2019). The warmest time of year in

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Dutse is around April, when temperatures usually reach 40.3°C (104.5°F), and May 5th is the hottest day on average (Umar et al., 2019). The average annual lowest temperature in Dutse is 11.9°C (53.4°F), and December 31st is the coldest day on average (Umar et al., 2019). The months with the most rainfall occurrence are August and July. The average annual rainfall for Dutse is 576mm (23"). The primary source of water in Dutse is groundwater; thus, they rely primarily on boreholes, wells, and taps (Umar et al., 2019).

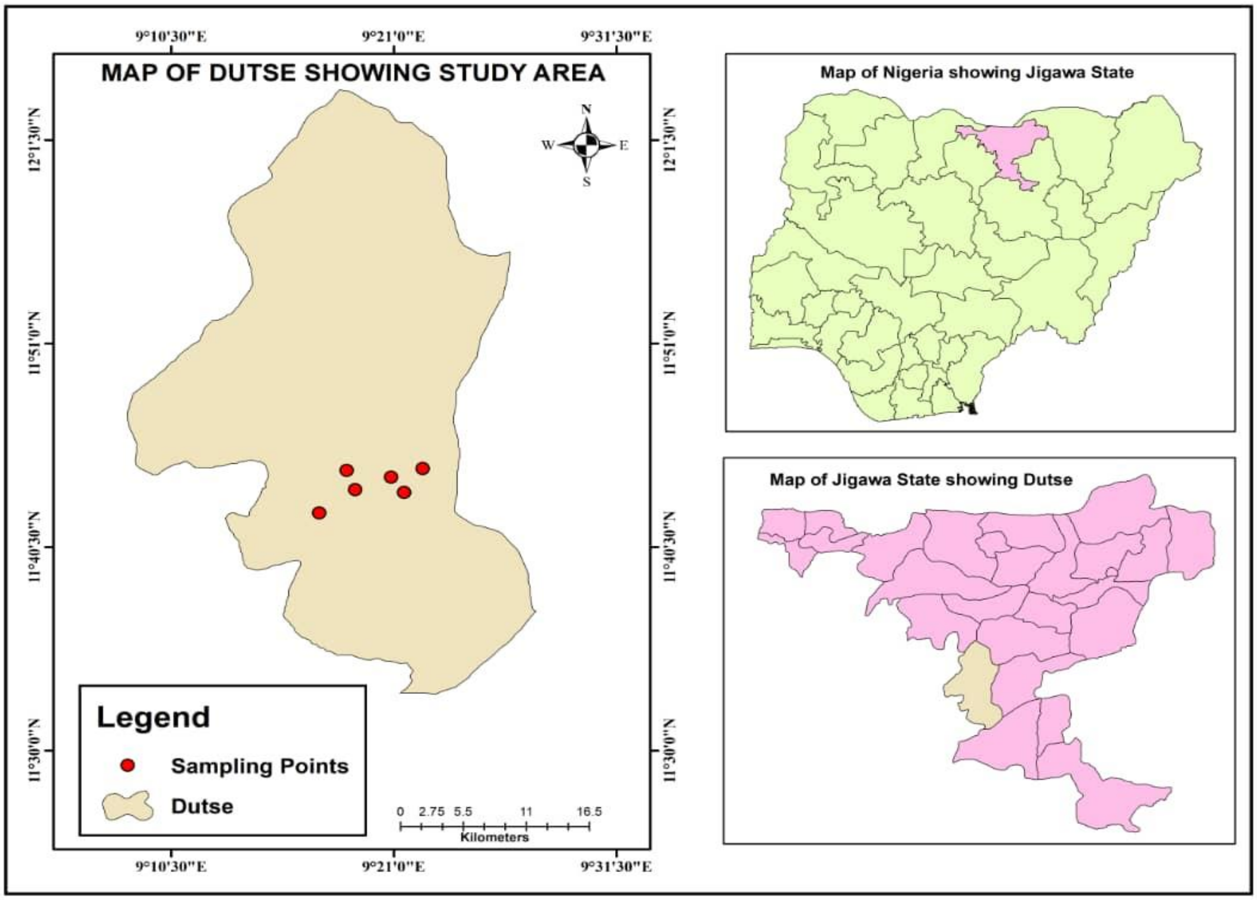

Figure 1: Map of the study area with the sampling points for groundwater analysis

Land Use Change Detection

The data (satellite images) for land use and land cover (LULC) change detection in this study were primarily from Landsat TM (Thematic Mapper) imagery obtained from the United States Geological Survey (www.earthexplorer.usgs.gov). The images with 30m spatial resolution were collected for 2015 and 2025, respectively. The dataset was selected based on seasonal climate considerations; thus, imagery snaps taken during the summer, when the sky is clearer, were prioritised. This is to minimise the effect of cloud cover and associated reflectance. The choice of Landsat data for this study was informed by their public availability and consistent global coverage. Moreover, the medium-resolution spatial (30m) of the Landsat data makes it suitable for a study of this nature; thus, Landsat data has been and remains the most frequently used data in land-use change detection studies (Pushpalatha et al., 2025).

Before analysing and interpreting the imagery, atmospheric correction was conducted using geometric rectification. The maps were first geo-referenced in the UTM Zone 50 projection and then projected with the WGS 84 datum into UTM Zone 50 to match the satellite image datum. The image classification method used to identify land use and land cover modifications in this research was supervised maximum likelihood classification (MLC) in the TerraSet software (Gu & Zeng, 2024). The Maximum Likelihood Classification (MLC) was selected for this study because it is the most widely used, has been tested, and is recognised as the best technique for land-use classification and change detection (Belay et al., 2024). It is also operationally simple, easily applicable, and robust. Additionally, the researcher has prior knowledge of the region, which is crucial for successfully generating the final LULC classes using this image classification technique (Belay et al., 2024; Ghalehteimouri et al., 2024). The LULC categories of Dutse town were successfully classified into built-up area, water body, vegetation, agricultural land, and bare land for the two time slices (Field exercise 2024). The classified images were vectorised using ERDAS Imagine 9.1 image analysis software within ArcMap 10.4 in the GIS environment. Temporal changes in LULC between periods were quantified to enable comparison across the time series.

Water sampling and analysis

Four water samples were collected from three boreholes and one well using polythene bottles. The selection of only four groundwater samples was informed by the unavailability of any other groundwater sources, leaving no option but to use the available four. Parameters with low stability, such as pH and temperature, were measured in situ at each sampling event. The sampling containers were rinsed with borehole water, and each borehole was allowed to operate for at least 3 minutes before sample collection. All samples were collected in pre-cleaned one-litre polythene plastic bottles and acidified with analytical-grade concentrated nitric acid to a pH of approximately 2.0, except for samples that were collected separately and not acidified for nitrate determination (Tukur et al., 2020; (Ali et al., 2025). Samples were labelled according to the sampling points and transported to the laboratory in a cooler containing ice blocks for analysis. Sampling locations were indicated in Table 1, with coordinates derived from a Global Positioning System (GPS) device (Umar et al., 2019). The sampling points were meticulously selected, with consideration given to their proximity to the open dumpsite, which is susceptible to pollution. This will help fill a gap overlooked by previous researchers regarding the influence of proximity to groundwater sources, such as boreholes and wells.

Table 1: Sampling points, elevation, and coordinates

Sampling points	Elevation (above sea level)	latitude	longitude
Dumpsite A	455m	0537402	1292563
Dumpsite B	457m	0537390	1292594
Point A (Borehole)	446m	0537328	1292669
Point B(Well)	450m	0537412	1292773
Point C (Borehole)	454m	0537502	1292715
Point D (Borehole)	453m	0537624	1292431

Source: GPS, 2025

The working conditions of all field meters and equipment were checked, and they were calibrated in accordance with the manufacturer's specifications. Blank samples made with deionised water were also passed between every three measurements of the sample as a check for possible contamination and equipment malfunction (Kizil et al., 2025). A Flame photometer is used to determine the concentrations of selected heavy metals, such as zinc, copper, iron, cadmium, lead, and manganese, in the samples.

Statistical Analysis

To correlate the selected heavy metals, SPSS 20 was employed. Additionally, charts showing the average values of the parameters collected over three sampling intervals for the sampled boreholes were presented to the WHO (Organisation, 2024) and NSDWQ (Nneka, 2024) standards for drinking water.

RESULTS AND DISCUSSION

The results of the land use/cover changes revealed that the dominant land use types in Dutse town were agriculture and built-up areas (Figure 1a and 1 b, Table 1), accounting for more than 80% of the total area. There were two main trends in land-use changes from 2015 to 2025: increases in built-up areas, vegetation, and bare land; however, agricultural land and water bodies decreased. The increases in built-up areas, vegetation, and bare land were 28.0540%, 1.4710%, and 5515.1914%, respectively. At the same time, the decreases in agricultural land and water bodies were 5,515.1914% and 0.0088%, respectively. This indicates that Dutse town is sprawling, expanding from its 2015 state to its current state (Figure 1, Table 2). Thus, the built-up areas have been consuming the close-settled zone agricultural land and the existing water bodies in the vicinity of the town. Surprisingly, however, vegetation increases; this might not be unrelated to the government's commitment to township tree planting, especially in Dutse town, the state capital (Jigawa State).

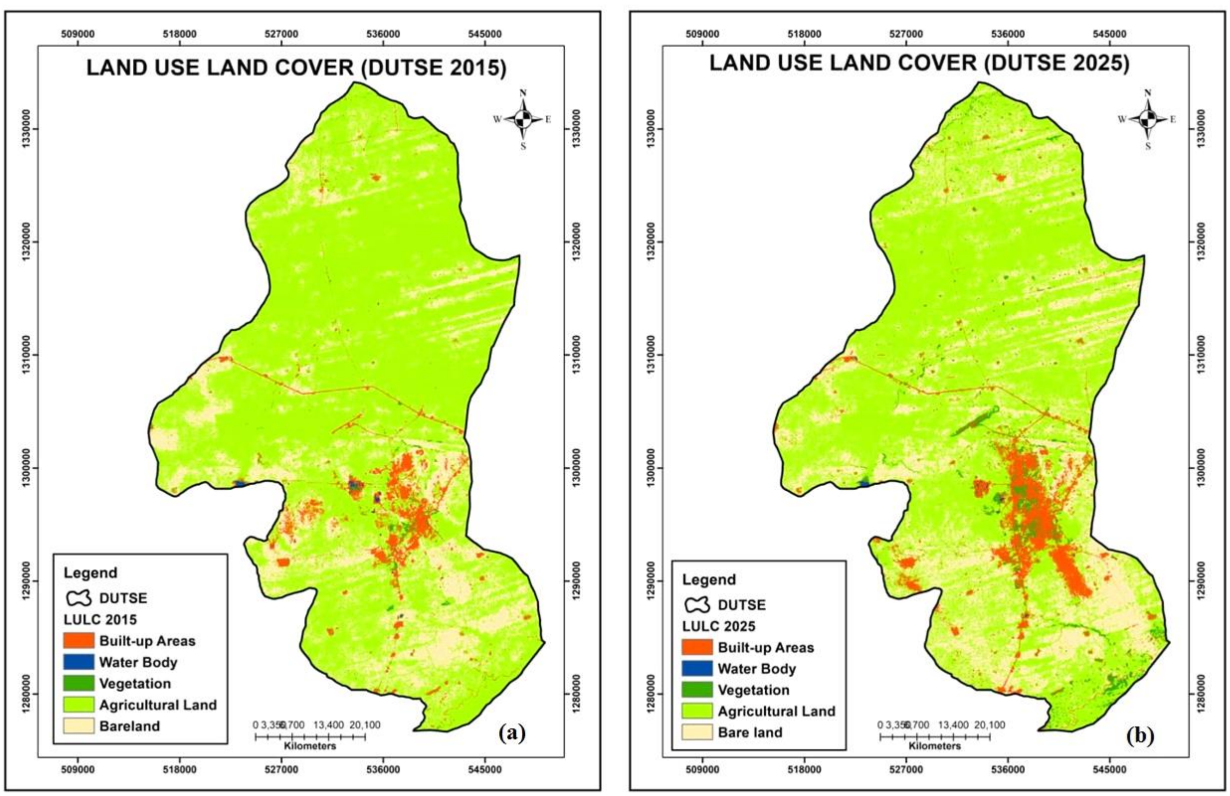

Figure 1: Land use and Land cover change (a) 2015 (b) 2025

Table 2: Description of land use types and their area coverage

Land use	2015 Area (Km^2)	2025 Area (Km^2)	% Change 2015-2025
Build-up Areas	41.93	66.91	28.05
Water Body	1.05	0.83	0.01
Vegetation	5.88	25.03	1.47
Agricultural Land	797.86	691.36	5515.19
Bare Land	251.99	314.58	792.73

The results of the groundwater analysis for the selected heavy metals via boreholes and wells within Dutse Town are presented in Tables 3 and 4. In Table 3, only the results for the analysed heavy metals, compared with the WHO and NSDWQ drinking water quality standards, were reported.

Table 3: Heavy metals assessed and their average values

Heavy metals → Sample points ↓	Iron(Fe) (mg/L)	Cadmium(Cd) (mg/L)	Lead(Pb) (mg/L)	Copper(Cu) (mg/L)	Zinc(Zn) (mg/L)	Manganese(Mn) (mg/L)
A (Borehole)	0.112	-0.018	-0.880	0.090	0.111	0.349
B (Well)	0.046	-0.019	-0.097	0.088	0.034	0.203
C (Borehole)	0.012	-0.017	-1.164	0.106	0.046	0.277
D (Borehole)	0.047	-0.015	-1.270	0.119	0.043	0.181
Mean	0.054	-0.017	-1.078	0.101	0.059	0.253

Source: Laboratory Analysis (2025)

However, Table 3 reported the results of heavy metal analysis in Dutse town in 2015 and 2025, accounting for land-use changes that indicated evidence of urban sprawl in the town. The heavy metals chosen for this study were within the maximum permissible concentrations in both 2015 and 2025, except for manganese, which exceeded the maximum permissible level in both 2015 and 2025, and iron in 2015. The elevated manganese concentration in both 2015 and 2025 is a source of concern, and possible causes of the increase in manganese concentration in groundwater include anthropogenic activities such as mining and industrialisation, as well as leaching from dumpsites/landfills (Tytkowska-Owerko et al., 2025). All these sources were found at varying levels around Dutse town (Muhammad et al., 2024).

Rock mining for various purposes is evident within and around Dutse town; there is expansion and an increase in small and large industries within the study area. Additionally, the possibility of increased leaching of manganese via dumpsites and landfills is greater, as the fact that an increase in waste generation is intensifying day by day, as Dutse town, the capital city of Jigawa state, is grossly sprawling from both sides, and strangers are trooping in due to relative peace and security within and around the city. Thus, the increase in manganese in the study area corresponds to activities that result in high manganese concentrations in drinking water worldwide (Awoyemi, 2024). Exceeding the permissible manganese limit in our drinking water can cause serious health effects, including neurological and behavioural problems, as well as deficits in memory, attention, and motor skills.

The manganese concentration has decreased from 0.273 in 2015 to 0.23 in 2025; therefore, it is crucial for those responsible for ensuring safe drinking water to take the necessary steps to reduce manganese levels in Dutse town's drinking water drastically. This is because, still at present, it is above the permissible limit (Table 3). This agrees with some previous studies conducted in Dutse town. Furthermore, Table 3 also indicates an increase in iron concentration above the permissible limit in 2015. However, the narrative was changed in 2025, where it dropped below the permissible limit (Table 4). Both natural and artificial factors can contribute to elevated iron levels in groundwater. Naturally, many subterranean rock formations contain iron, which dissolves in groundwater as it seeps through them (Mukherjee & Bairwa, 2025). The breakdown of iron from rocks and minerals can also be accelerated by low oxygen levels or acidic groundwater (Basharat et al., 2025). Iron can also enter groundwater through anthropogenic processes such as inappropriate waste disposal, agricultural runoff, and industrial discharges (Awoyemi, 2024).

Thus, it was reported that in 2015, the urban sprawl and concretisation of urban surfaces in Dutse town, driven by developmental projects, were minimal (Muhammad et al., 2024) compared to 2025, as shown by land-use and land-cover changes (Figure 1a & b).

The anthropogenic factors aggravating high iron concentration in groundwater, such as inappropriate waste disposal and agricultural runoff in particular, were reduced in their effects in 2025, because some measures to manage indiscriminate waste disposal have been taken; for example, waste disposal infrastructures were increased, but consideration for their proximity to sources of groundwater has not been duly observed. Additionally, the agricultural runoff that injects pollutants into the groundwater system via municipal close-settlement agricultural runoff was tempered by surface concretisation via urban development; thus, this agricultural runoff can no longer leach the contaminant within the vicinity of Dutse town, as was the case before (Amoo et al., 2025). These are some of the reasons for the reduced iron concentration below the permissible limit in 2025 (Table 4)

Table 4: Heavy metals of interest and their average mean values (2015 & 2025).

S/N	Elements	Mean 2015	Mean 2025	Max. Permissible Conc. WHO and NSDWQ	Remark
1	Iron(Fe) (mg/L)	**1.824**	0.054	0.3	APL/BPL
2	Cadmium(Cd) (mg/L)	0.003	-0.017	0.005	BPL
3	Lead(Pb) (mg/L)	0.0147	-1.078	0.015	BPL
4	Copper(Cu) (mg/L)	0.015	0.101	1.3	BPL
5	Zinc(Zn) (mg/L)	0.0695	0.059	0.2	BPL
6	Manganese(Mn)	**0.273**	**0.253**	0.05	APL

As shown in Table 4, iron concentration from the borehole water ranged from 0.012 -0.112mg/l, designated A, C, and D. The minimum value from the borehole samples is 0.012mg/l, designated as sample point C, while the maximum value is 0.112mg/l, designated as sample point A. The mean concentration value is 0.054mg/l. The fact that WHO's highest desirable standard for iron is 0.1 mg/l and the maximum permissible limit is 1 mg/l. Borehole A (0.112 mg/l) has exceeded the highest desirable level, while all other sampled points were below the desirable and maximum WHO standards. The table also indicates the Cadmium concentration, which ranged from -0.015 to 0.019 mg/L (Table 3). The minimum concentration (-0.015mg/l) was from borehole D, while the maximum

(-0.019mg/l) was from the well water designated as sample point B, and the mean concentration is -0.017mg/l. The maximum permissible limit of Cadmium recommended by WHO and NSDWQ is 0.005 mg/L and 0.003 mg/L, respectively. Thus, Cadmium concentrations are below the permissible limits set by both the WHO and the NSDWQ. Similar results were reported. (Ogunbodet al., 2025)

Moreover, Table 3 shows Lead concentrations; the range is from -0.097 to 1.270 mg/L (Table 4). The minimum concentration (-0.097 mg/l) is from well water designated as sample point B, while the maximum concentration (-1.270 mg/l) was from sample point D, which is a borehole-type groundwater source. The mean concentration is -1.078mg/l, being so the maximum permissible standard of lead in drinking water as permitted by WHO is 0.01mg/l, and NSDWQ is 0.01mg/l; thus, Lead concentrations from all samples (A, B, C, and D) were within the recommended standard for the two concerned water quality organisations considered in this research (WHO and NSDWQ).

Table 2, further, revealed Copper mean concentration value of 0.101mg/l, and ranges (0.088 - 0.119mg/l), minimum concentration (0.088mg/l) which was recorded from well water designated as sample point B, and the maximum concentration (0.119mg/l) which is however, from sample point D which a borehole groundwater sources D. Since, the WHO highest desirable concentration of (0.05mg/l) and the maximum permissible limit of (1.5mg/l), and the maximum permissible standard recommended by NSDWQ is 1mg/l., copper concentration from all the samples are thus, within the permissible standards of both WHO and NSDWQ as reported by. (Ghalehteimouri et al., 2024)
The concentration of Zinc ranges from 0.034 - 0.111mg/l (Table 4). The minimum zinc concentration of 0.034 mg/L was obtained from one of the well groundwater sources designated as sample B. In comparison, the maximum value is 0.111 mg/L, recorded at sample point A, a borehole-type groundwater source.

The mean concentration is 0.059 mg/L, and the highest desirable zinc concentration in drinking water ascribed by WHO is 5 mg/L. However, the maximum permissible limits set by WHO and NSDWQ are 15 mg/L and 3.0 mg/L, respectively. Thus, all samples taken were within the desirable limits.

The last heavy metal concentration reported from Table 4 is Manganese, with concentrations ranging from 0.181- 0.349mg/l (Table 4). The minimum concentration is 0.181 mg/L, obtained at sample point D, a borehole-type groundwater source, while the maximum concentration is 0.349 mg/L, recorded at sample point A, also a borehole-type groundwater source. The mean concentration obtained is 0.253 mg/L, while the highest desirable level recommended by WHO is 0.05 mg/L, and the maximum permissible limit is 0.5 mg/L. Thus, these water sources have elevated concentrations above the desirable level recommended by WHO but remain within the maximum permissible standard. Hence, regular analysis is advisable in these areas as recommended by some previous studies (Xu et al., 2012; Sellami et al., 2014; Ibrahim et al., 2015)

Additionally, results from a One-way ANOVA indicated variation in heavy metal parameters between the four sampling points: Borehole A, Well B, Bore C, and D (Table 5).

Table 5: Results of the heavy metals concentration by using Analysis of Variance (ANOVA)

Treatment →	A	B	C	D	Pooled Total
observations N	6	6	6	6	24
sum ∑xi∑xi	-0.2360	0.2550	-0.7400	-0.8950	-1.6160
mean ¯xx¯	-0.0393	0.0425	-0.1233	-0.1492	-0.0673

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sum of squares ∑x2i∑xi2	0.9295	0.0620	1.4454	1.6641	4.1010
sample variance s2s2	0.1840	0.0102	0.2708	0.3061	0.1736
Sample std. Dev. Ss	0.4290	0.1012	0.5204	0.5533	0.4166
td. dev. of mean SE¯x	0.1751	0.0413	0.2125	0.2259	0.0850

The Analysis of Variance (ANOVA) results indicated a mean square of **0.0454**. The sum of squares of **3.9922of 3.9922**, while the p-value (0.8707) corresponding to the F-statistic (0.2353) of one-way (Table 6) ANOVA is higher than 0.05, suggesting that the treatments did not differ significantly between the sample points at the chosen significant level.

Table 6: Analysis of Variance Test on the mean of sample points

source	sum of squares SS	degrees of freedom νν	mean square MS	F statistic	p-value
treatment	0.1361	3	0.0454	0.2353	0.8707
error	3.8561	20	0.1928		
total	3.9922	23			

CONCLUSION AND RECOMMENDATIONS

The effects of urban sprawl and the proximity of dumpsites on groundwater contamination have been investigated. The results indicate urban sprawl through changes in land-use and land-cover between 2015 and 2025. The changes in land use were concentrated in built-up areas, indicating urban expansion and a concomitant increase in waste generation, particularly around commercial centres (e.g., Dutse Ultra-Modern Market). However, little or no consideration is given to groundwater sources during the siting of waste disposal sites; some sites were located near wells and boreholes. Thus, both urban sprawl and the proximity of dumpsites to groundwater sources have affected the concentration of heavy metals in groundwater in the study area. In 2015, for example, iron concentration was above the permissible limit. However, in 2025, it fell below the permissible limit due to changes in land use toward more built-up areas, which reduced the leaching of agricultural runoff into the groundwater system. Although the growth and development of towns and cities are always welcome, consideration should be given to changes in land use and their impacts on vital resources, such as groundwater, since urban sprawl has led to increased waste and pollution as the human population grows. Moreover, when siting waste dumpsites, consideration should be given to wells and boreholes in the vicinity (proximity considerations), ensuring that no waste dumpsites are located near groundwater sources, because it has been identified that consideration for their proximity to groundwater sources has not been duly observed, and increased public awareness to educate people on the effects of indiscriminate waste disposal. Further treatment of water is advised after collection from boreholes and wells near waste dumpsites, mainly when elevated concentrations of dangerous heavy metals are observed. The public should be educated on domestic water treatment processes.

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