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Impact of dumpsite leachate on ground water quality in Ibarapa East Local Government Eruwa, Oyo State, Nigeria

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ABSTRACT
This study evaluates the impact of solid waste disposal on groundwater quality in Ibarapa East Local Government, Eruwa, Nigeria, using physical, chemical, and biological assessments, alongside the DRASTIC modeling approach. The research highlights uncontrolled dumpsites as a significant source of groundwater contamination, particularly near water sources. Detailed analyses of water samples revealed high variability in bacterial counts, including elevated levels of Escherichia Coli, as well as concerning concentrations of heavy metals exceeding WHO standards. Key findings include the identification of vulnerable settlements and the creation of a groundwater vulnerability map. The study's recommendations encompass waste management policy reevaluation, regulatory enforcement, community engagement, and continuous monitoring. The pressing need for intervention is underscored to ensure safe groundwater for the growing population. This research offers critical insights for policymakers to safeguard groundwater resources and addresses the broader implications for public health and ecosystem sustainability.
Keywords: groundwater contamination, solid waste disposal, groundwater vulnerability, bacterial counts, heavy metals, DRASTIC model.

I. INTRODUCTION

Water is essential to life and human survival, forming about 70% of our body fluids and covering 70% of the earth's surface. Water shortages or pollution can severely impact productivity and health (Garba et al., 2010). Ensuring access to clean water is crucial for prosperous communities.

Contaminated water consumption leads to significant health disasters, highlighting the need for proper treatment and distribution infrastructure (Mahananda et al., 2010). Municipal solid waste (MSW) can leach toxic substances into the environment, necessitating proper disposal to avoid pollution and health issues (Lateef et al., 2015). Many urban disposal sites, near water bodies and communities, lead to groundwater contamination (Akinola, 2016). Unorganized dumpsites, common near communities and wetlands, release pollutants into nearby water bodies and air (Abduls-Salam et al., 2011).

This study aims to assess groundwater vulnerability to contamination from dumpsites in Ibarapa East Local Government, Eruwa town. Objectives include identifying the proximity of dumpsites to groundwater sources, analyzing water and leachate samples, and using the DRASTIC model to assess groundwater vulnerability. Groundwater, a crucial resource for over 50% of the world's population, is often invisible and vulnerable to undetected contamination (WHO, 2017; Foster and Chilton, 2003). Dumpsites pose a significant risk by producing leachate that can render groundwater toxic (Christensen et al., 2001). Addressing this issue is essential for ensuring safe and sustainable groundwater resources

II. METHODOLOGY

Ibarapa East Local Government, Eruwa, located in southwestern Nigeria, has a population of 167,500 (NPC, 2022). Situated in the grass savannah with several streams and many hills, its topography is undulating with elevations ranging from 500m to 1,219m. The area experiences distinct dry and wet seasons. The local economy is primarily agricultural, including farming, fishing, hunting, and animal husbandry, along with manufacturing and trading.

A reconnaissance survey identified the location of wells and proximity to dumpsites. Inventories of water wells, dumpsites, and sewage disposal systems were taken. Suitable locations for collecting water and leachate samples were identified, considering background information, pollution sources, and human influences. Water samples were collected from 10 locations early in the morning to avoid temperature increases. Each 1L sample was collected in sterilized plastic bottles, labeled, and stored in containers. Leachate samples were collected from dumpsites using appropriate containers to prevent contamination, labeled, and transported to the laboratory for analysis. The sampling was conducted during the dry season in April 2023.

Water and leachate samples underwent physical, chemical, and bacteriological analyses in the laboratory.

The DRASTIC model, developed by the U.S. EPA, evaluates groundwater vulnerability to contamination based on seven parameters: Depth to Water Table, Net Recharge, Aquifer Media, Soil Media, Topography, Impact of Vadose Zone, and Conductivity. Each factor is assigned a score to develop a vulnerability assessment map. Higher DRASTIC scores indicate areas more vulnerable to contamination, aiding in land use planning, environmental management, and groundwater protection.

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III. RESULT AND DISCUSSION

Location of Wells and Dumpsites

Ten well locationpoints and dumpsites sampling points within the study area were visitedfor sample collection and testing as shown in Tables 1 and 2, respectively. The static water level of the wells ranged from 1.58 – 5.57m.

Table 1: Well Point Locations

S/N	NAME/LOCATION	LONGITUDE	LATITUDE	STATIC WATER LEVEL
1	ISABA	E 3° 24’ 59’’	N 7° 31’ 52’’	1.58m
2	ISALE ELESIN	E 3° 25’ 02’’	N 7° 31’ 55’’	2.77m
3	BABALEJE	E 3° 25’ 03’’	N 7° 31’ 53’’	2.24m
4	OWODE	E 3° 25’ 02’’	N 7° 31’ 50’’	2.26m
5	AKINTARO	E 3° 25’ 08’’	N 7° 31’ 54’’	2.92m
6	AROWOLO	E 3° 25’ 12’’	N 7° 31’ 59’’	2.79m
7	CENTRAL MOSQUE ALAYANDE	E 3° 25’ 12’’	N 7° 32’ 16’’	2.34m
8	GAA ROAD	E 3° 25’ 27’’	N 7° 32’ 55’’	3.51m
9	ORITA SAW MILL	E 3° 26’ 23’’	N 7° 33’ 09’’	5.57m
10	OKE OJA NEW IBARAPA EAST LOCAL GOVERNMENT, ERUWA	E 3° 26’ 29’’	N 7° 33’ 02’’	2.82m (No Water)

Table 2: Dumpsites Sampling Points

S/N	NAME/SAMPLING POINTS	LONGITUDE	LATITUDE
1	ISABA	E 3° 25’ 00’’	N 7° 31’ 51’’
2	ISALE ELESIN	E 3° 25’ 00’’	N 7° 31’ 51’’
3	BABALEJE	E 3° 25’ 02’’	N 7° 31’ 52’’
4	OWODE	E 3° 25’ 02’’	N 7° 31’ 50’’

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5	AKINTARO	E 3° 25' 08''	N 7° 31' 55''
6	AROWOLO	E 3° 25' 13''	N 7° 31' 58''
7	CENTRAL MOSQUE ALAYANDE	E 3° 25' 12''	N 7° 32' 18''
8	GAA ROAD	E 3° 25' 33''	N 7° 32' 51''
9	ORITA SAW MILL	E 3° 26' 23''	N 7° 33' 13''
10	OKE OJA NEW IBARAPA EAST LOCAL GOVERNMENT, ERUWA	E 3° 26' 29''	N 7° 33' 03''

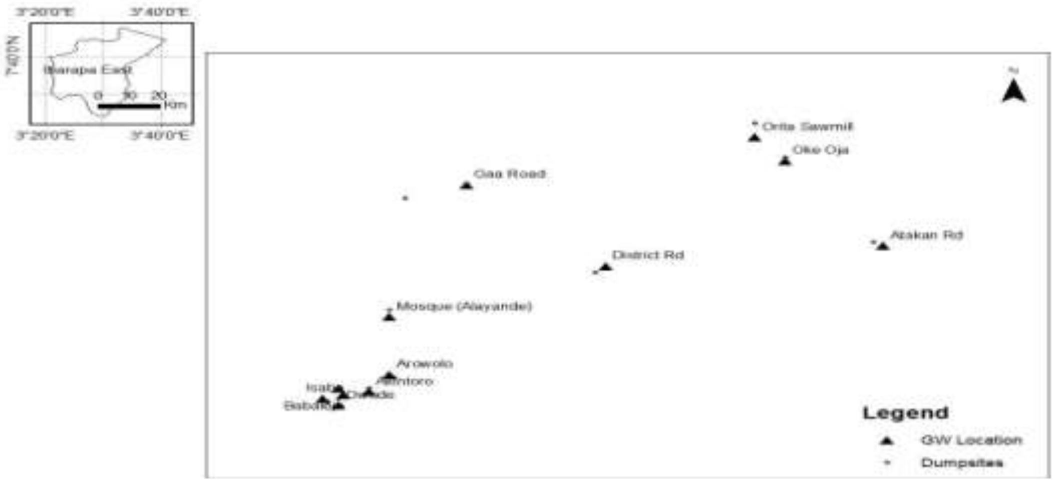

Fig. 1. Map of Ibarapa East Local Government, Eruwa showing sampling points

Physio-Chemical Characteristics of Water Samples

The analysis of physio-chemical parameters for the water samples, detailed in Tables 3 and 4, reveals a comprehensive comparison with the World Health Organization (WHO) standards. Turbidity, measured at an average of 0.151 NTU, is significantly lower than the WHO standard of 5-25 NTU, indicating clear water free of suspended particles.

The average pH value of 7.127 falls within the WHO range of 6.8-8.5, with variations indicating slightly acidic to slightly alkaline water, which is safer for human health and aquatic life. Temperature readings averaged 27.67°C, well within the WHO range of 24.5-39.7°C, suitable for various uses. Total alkalinity averaged 149.82 mg/L, signifying moderate acid-neutralizing capacity.

Total hardness, at an average of 48.563 mg/L, is much lower than the WHO standard of 500 mg/L, indicating soft water less likely to cause scaling or soap scum. Total Dissolved Solids (TDS) and Electrical Conductivity, averaging 447.8 mg/L and 471.2 µS/cm respectively, are well below WHO limits, reflecting fewer dissolved solids and ions.

Metal concentrations in the water samples, including Zinc, Copper, Nickel, Manganese, Iron, Chromium, Cadmium, and Lead, are below WHO standards, indicating minimal contamination. However, even low levels of certain metals can be harmful over long-term exposure.

Finally, the average concentrations of Calcium and Sulfate are 71.36 mg/L and 6.2481 mg/L, respectively. The calcium level is generally safe, and the sulfate concentration is significantly lower than the WHO standard of 400 mg/L. Overall, the water samples meet WHO standards for most parameters, indicating good water quality. However, the cumulative effect of multiple contaminants can still pose health risks, underscoring the need for regular monitoring to ensure continued compliance with safety standards..

Table 3: Actual Value for the water samples characterized

Parameters	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	WHO (2017) Standard
Turbidity	0.0	0.0	0.0	0.0	0.0	0.15	0.25	0.37	0.37	0.37	5 – 25
PH	6.90	6.42	6.45	6.90	7.10	8.20	7.1	8.2	7.1	6.9	6.8 – 8.5
Temperature	29.6^0	28.5^0	27.3^0	28.5^0	28.6^0	26.5^0	28.3^0	26.1^0	26.4^0	26.9^0	24.5 – 39.7
Color	Light Brown	Clear Colorless	Light Brown	Light Brown	Clear Colorless	Clear Colorless	Clear Colorless	Light Brown	Clear Colorless	Light Brown	Clear Color
Total Alkalinity	120	232	174.168	152	224	112	144	105	110	125	
Total Hardness	42.7	39.6	46.9	58.5	41	52	64	51.12	22.11	67.70	500
Total Dissolved Solid	434	556	640	143	194	208	118	500	840	845	1000
Electrical Conductivity	436	919	165	238	332	344	195	600	607	876	1500
Zinc (Zn)	0.247	0.311	0.326	0.253	0.416	0.183	0.154	1.4	2.20	4.0	4.0
Copper (Cu)	0.246	0.171	0.218	0.029	0.191	0.377	0.412	0.205	0.190	0.270	1.5
Nickel (Ni)	0.003	0.007	0.002	0.003	0.003	0.003	0.005	0.007	0.002	0.003	
Manganese (Mn)	0.14	0.13	0.17	0.17	0.22	0.26	0.31	0.27	0.13	0.17	1.0
Iron (Fe)	0.177	0.213	0.191	0.122	0.185	0.503	0.37	0.5	0.75	1.5	1.0
Chromium (Cr)	0.042	0.033	0.036	0.031	0.033	0.015	0.007	0.033	0.033	0.031	
Cadmium (Cd)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	

Lead (Pb)	0.031	0.021	0.025	0.017	0.009	0.001	0.001	0.001	0.021	0.024	1.05
Ca	35.8	291	43.7	51.2	37	66.2	72.1	45.6	41.5	29.5	
SO_4^{2-}	5.38	6.204	4.362	5.075	4.3	26	3.56	1.75	1.88	3.97	400

Note: ALL parameters in mg/l except pH and turbidity in NTU

Table 4: Average Valuefor the water samples characterized

Parameters	Average score per reading	WHO(2017) Standard
Turbidity	0.151	5-25
Ph	7.127	6.8-8.5
Temperature	27.67	24.5-39.7
Total Alkalinity	149.8168	
Total Hardness	48.563	500
Total Dissolved Solid	447.8	1000
Electrical Conductivity	471.2	1500
Zinc (Zn)	0.949	4
Copper (Cu)	0.2309	1.5
Nickel (Ni)	0.0038	
Manganese (Mn)	0.197	1
Iron (Fe)	0.4511	1
Chromium (Cr)	0.0294	
Cadmium (Cd)	0.001	
Lead (Pb)	0.0151	1.05
Ca	71.36	
SO_4^{2-}	6.2481	400

Note: ALL parameters in mg/l except pH and turbidity in NTU

Bacteriological Characteristics of Water Samples

The bacteriological analysis of water samples, shown in Tables 4.5 and 4.6, reveals moderate to high variability in bacterial counts across different sites. Total Coliform count averages 11.4 CFu/100ml, with a range from 0 to 30 CFu/100ml and a standard deviation of 8.69. Escherichia Coli counts show significant variability, averaging 16.3 CFu/100ml with a standard deviation of 47.35 and counts ranging from 0 to 151 CFu/100ml. Total Heterotrophic Bacterial count averages 96.7 CFu/100ml, with a standard deviation of 82.15 and a range from 4 to 210 CFu/100ml. These results indicate substantial contamination, with some improvement compared to previous studies but also highlight areas with elevated bacterial counts. This underscores the importance of regular monitoring to ensure water intended for domestic use remains free from bacteriological contamination.

Table 5: Actual Value of Bacteriological Parameters of Water Samples

Location	Total Coliform (cfu/100ml)	Escherichia Coli (cfu/100ml)	Total Heterotrophic Bacterial (cfu/100ml)
1	2	0	4
2	9	1	75
3	14	1	87
4	18	5	210
5	30	1	206
6	5	1	11
7	0	0	10
8	12	2	203
9	9	151	73
10	15	1	88

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Table 6: Average Value of Bacteriological Parametersof Water Sample

Index	Total Coliform (cfu/100ml)	Escherichia Coli (cfu/100ml)	Total Heterotrophic Bacterial (cfu/100ml)
count	10	10	10
mean	11.4	16.3	96.7
std	8.69483	47.3499	82.1517
min	0	0	4
25%	6	1	26.5
50%	10.5	1	81
75%	14.75	1.75	174.25
max	30	151	210

Physio-Chemical Characteristics of Leachate Samples

The physio-chemical analysis of leachate samples reveals a mean pH value of 7.45, within the WHO's recommended range of 6.8 to 8.5, indicating the water is generally safe regarding pH levels. However, heavy metals such as Zinc (509.2 mg/L), Copper (680.2 mg/L), and Manganese (1846.6 mg/L) far exceed WHO limits, posing severe health risks. Iron levels also exceed standards with a mean of 31.144 mg/L, and Cadmium levels are alarmingly high at 42215.3 mg/L. Lead levels average 553 mg/L, much higher than the WHO standard, while Sulfate levels are safely within limits at 22.162 mg/L. These findings highlight critical contamination concerns requiring immediate intervention.

Table 7: Average value of Physico-chemical Parameters of Leachate Samples

Parameters	Mean	SD	Min	Max	WHO Standards
PH	7.45	0.521	6.9	8.2	6.8-8.5
Zinc (Zn)	509.2	314.216	148	1125	0.5- 2.0
Copper (Cu)	680.2	356.571	127	1401	1.5
Nickel (Ni)	657.4	325.403	138	1053	
Manganese (Mn)	1846.6	778.007	909	3771	0.4
Iron (Fe)	31.144	20.027	6.14	73.5	1.0-3.0
Chromium (Cr)	898.6	472.311	340	1814	
Cadmium (Cd)	42215.3	11034.7274	31852	59222	0.003-0.03
Lead (Pb)	553	237.298	315	1021	0.4
Ca	2242	928.742	1315	3745	
SO_4^{2-}	22.162	4.184	12.25	26.51	400

Groundwater Vulnerability Assessment Using the DRASTIC Model.

Table 8 presents the DRASTIC values for various locations in the study area, providing crucial information on factors influencing groundwater vulnerability. DRASTIC is a widely used method for assessing groundwater vulnerability, considering parameters such as Depth to Water (D), Recharge (R), Aquifer Media (A), Soil Media (S), Topography (T), Impact of the vadose zone (I), and Conductivity (C).

Here's a discussion on how elevation, water level, and other DRASTIC parameters may affect the drastic value in the context of the presented table:

Elevation and Water Level: Higher elevations generally contribute to increased vulnerability due to greater potential for downward movement of contaminants. However, this depends on the specific hydrogeological conditions.

Locations with higher water levels may experience increased vulnerability, as it implies a shorter distance for contaminants to reach the water table.

Table 8: DRASTIC Values of the Study Area

location	x_coordinates	y_coordinates	elevation (m)	water level (m)	drastic value	vulnerability
ISABA	3.416389	7.531111	180	1.58	154	High
ISALE ELESIN	3.417222	7.531944	183	2.77	139	Low
AKINTARO	3.418889	7.531667	176	2.92	154	High
AROWOLO	3.42	7.533056	175	2.79	135	Low
CENTRAL MOSQUE ALAYANDE	3.42	7.537778	170	2.34	150	Medium
GAA ROAD	3.424167	7.548611	186	3.51	150	Medium
ORITA SAW MILL	3.439722	7.5525	167	5.57	138	Low
OKE OJA NEW ERUWA	3.441389	7.550556	160	2.82	154	High
ATAKAN RD., OLD IB. RD.	3.446667	7.543611	170	0.21	155	Very High
DISTRICT ROAD	3.431667	7.541944	178	1.13	138	Low
MOBERUAGBA	3.43	7.541111	168	2.3	154	High
ERUWA TITUN	3.455278	7.545278	182	1.6	148	Medium
ABORERIN	3.423889	7.528889	184	4.2	150	Medium
POLY	3.425833	7.523333	180	3.02	135	Low

Vulnerability Map

Figure 3 illustrates the vulnerability of settlements within Ibarapa East Local Government, Eruwa, to leachate contamination. Settlements such as Alayande, Akintaro, Aboderin, Gaa Road, Atakan Road, and Oke-Oja are highly vulnerable, while Eruwa Titun has high vulnerability, and Moberuagba, Isala, Arowolo, Orita-Sawmill, and Poly have low vulnerability. This study identifies areas at high risk of groundwater contamination due to urbanization, industrial activities, and landfills. The consistency between this study and past findings underscores the need for targeted interventions and ongoing monitoring to mitigate contamination risks in these vulnerable areas.

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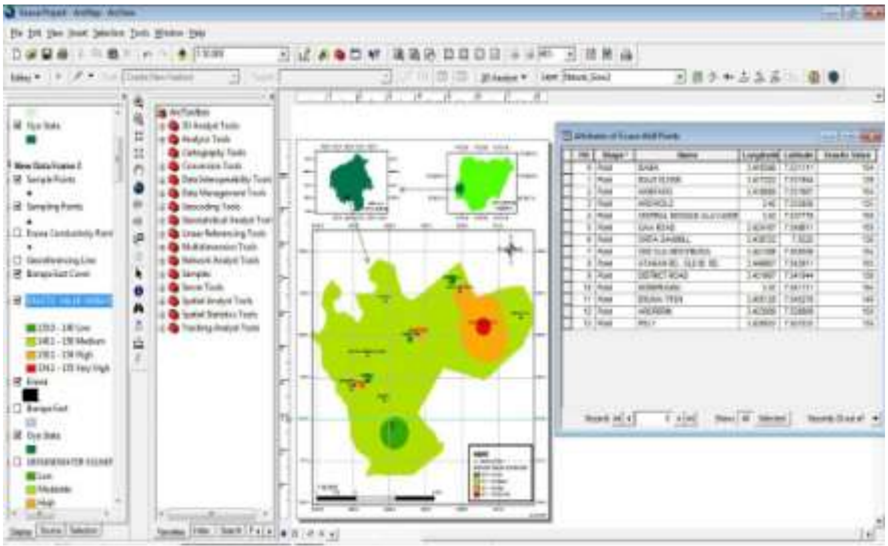

Fig 2: Groundwater Vulnerability map interface of Ibarapa East Local Government, Eruwa

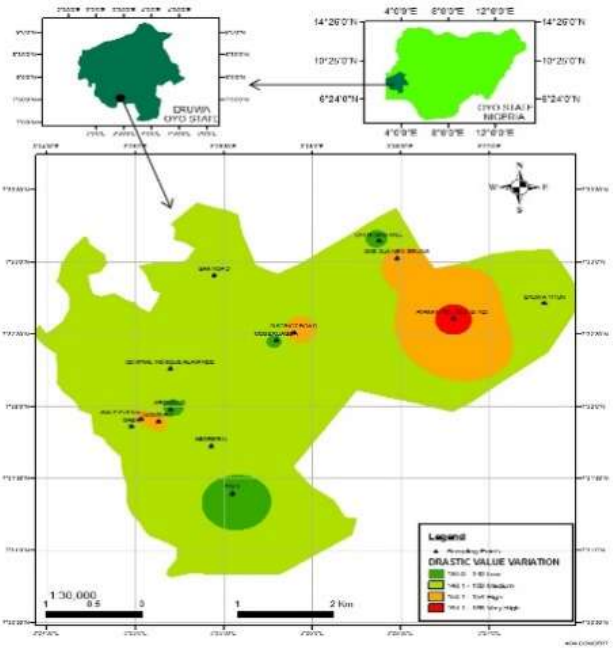

Fig 3: Groundwater vulnerability map of Ibarapa East Local Government, Eruwa

Strategies for Remediation

To effectively address groundwater contamination in Ibarapa East Local Government, Eruwa, several strategies are proposed. First, developing and enforcing waste management policies that emphasize proper hazardous waste disposal and waste segregation is essential. Additionally, stringent site selection criteria for dumpsites should ensure they are distanced from groundwater sources and environmentally suitable. Establishing on-site leachate treatment facilities will manage contamination before discharge, while regular groundwater monitoring programs will enable early detection and prompt action. Remediation measures like constructing containment barriers and using pump-and-treat systems will address contaminated areas. Compliance with waste disposal regulations must be enforced, and public awareness efforts should educate communities about contamination risks. Exploring innovative technologies like bioremediation and phytoremediation, assessing the long-term impact of contamination, and investigating emerging contaminants are also crucial. Evaluating the effectiveness of current policies and conducting health impact assessments will support the development of comprehensive strategies to protect groundwater resources. These approaches will inform decision-making and guide effective water treatment and pollution control measures.

IV. CONCLUSION

The analysis conducted in the Ibarapa East Local Government area, Eruwa, Nigeria, highlights significant groundwater contamination from dumpsites. Unregulated waste disposal, especially in developing countries, poses serious risks to health and environmental stability. Many wells in Eruwa are located near dumpsites due to population growth and suburban expansion, resulting in physicochemical and microbiological parameters in water exceeding WHO permissible limits. Using the DRASTIC model and community-engaged approaches, the study calls for immediate reevaluation of waste management policies, emphasizing robust waste-handling frameworks, regulatory enforcement, and community participation. Identifying vulnerable areas underscores the need for targeted interventions and sustainable practices to protect groundwater resources.

Key recommendations include strengthening waste management policies, enforcing disposal regulations, increasing community education, and using the DRASTIC model for continuous monitoring to guide interventions. Developing sustainable practices like recycling and composting is essential for long-term preservation. A multi-faceted approach integrating regulation, education, technology, and community engagement is vital for health and environmental resilience. Further research should include models like GOD and SINTACS for comparison, assess surface water vulnerability, and continuously monitor water quality for contaminants. This study contributes by determining groundwater quality and vulnerability, and developing a vulnerability map for Ibarapa East.

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