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Assessment of Groundwater Quality by Heavy Metal Pollution Index in Ijare Rural Community and Alagbaka Urban Area in Ondo State, Nigeria

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ABSTRACT: Groundwater is becoming an essential source of water supply in many locations, and assessment of groundwater quality is essential to trace out the major groundwater contaminants. In this study, Ijare represents a rural land use and Alagbaka representing the urban land use. The objective of this paper is to assess the groundwater quality by heavy metal pollution index (HMPI) in Ijare rural community and Alagbaka urban area in Ondo State, Nigeria using a 210VGP atomic absorption spectrophotometer. Data obtained reveals that, the concentration of iron in wells ranged between 0.1335 and 0.2715mg/L, Chromium in the study areas had levels ranging from 0.056 to 0.1615mg/L, while the levels of manganese ranged between 0.0775 and 0.1725mg/L and that of Lead had levels was between 0.01 to 0.11mg/L. This study thus reveals that the concentration of iron was within the WHO drinking water standard limit of 0.3mg/L, chromium in the study areas had levels above the WHO drinking water standard limit of 0.05mg/L, manganese levels within the WHO drinking water standard limit of 0.4mg/L and Lead had levels above the recommended limit.

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Water is an essential and widely distributed component of life. All living things in the world require water to survive. On the other hand, water could be an issue if it is not available under the right circumstances (Olabanji *et al.*, 2021). Water that runs underground is referred to as groundwater. Groundwater is an essential supply of water for agriculture, industry, and is primarily used a potable water in many places. However, in recent years, the availability of clean and drinkable water has emerged as one of the most critical developmental issues in many parts of Nigeria. As a result, determining the potability of water before it is utilized for human consumption is a must (Kumar *et al.*, 2018) and assessment of groundwater health is essential to trace out the major groundwater contaminants (Ganiyu *et al.*, 2018). Changes in land use and land cover above the ground are having a substantial impact on groundwater recharge as groundwater extraction grows around the world. The lowering of the water table is the overall effect of the accelerating population growth, urban development, industrialization, and over-utilization of groundwater for agricultural purposes (Megdal, 2018; Wang *et al.*, 2018). This decrease in the total volume of available groundwater resources increases the concentration of contaminants, therefore, not only reducing the number of water resources available for use but also reducing the quality of groundwater resources. Groundwater quality evaluation, when combined with GIS, can be a very strong tool for generating solutions for water quality assessment, water resource challenges, water availability determination, and water resource management on a local or regional scale (Ketata *et al.*, 2011). Geographic Information System (GIS) is a software program that enables users to design interactive

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queries, examines spatial data, modify data and maps, and display the outcomes of these actions (Madurika and Hemakumara, 2017). Water quality indices are one of the most efficient methods for communicating information about the condition of any water body (Singh *et al.*, 2013). The heavy metal pollution index (HMPI) is a rating technique that assesses the overall quality of water in terms of heavy metals. Therefore, the objective of this study is to assess the groundwater quality by heavy metal pollution index (HMPI) in Ijare rural community and Alagbaka urban area in Ondo State, Nigeria.

MATERIALS AND METHODS

Study Area: The study was carried out in Alagbaka (urban) and Ijare (rural), both located in Ondo state. Alagbaka is located in Akure south Local Government Area (L.G.A.) of Akure, Ondo State as shown in Figure 1. Akure is the capital city of Ondo state, located in the South-western region of Nigeria. The geographical location of the city is latitude 7^0 15' 0" North and longitude 5^0 12' 0" East (Ojo, 2022). Ijare on the other hand is a town located in Ifedore L.G.A of Ondo State. The town is located at latitude 7^0 22' 0" North and longitude 5^0 10' 0" East and it is situated at about 10.3km North of Akure (Oladapo, 2013). Ijare is the study area representing the rural land use in Ondo state. Alagbaka on the other hand is the study area representing the urban land use.

Sampling and analysis: Water samples were collected from a total of ten (10) wells at different locations within Alagbaka and Ijare. Five (5) groundwater samples were collected from Alagbaka representing urban land use, while the other five (5) samples were collected from Ijare representing rural land use. The sample collection points were chosen randomly. The coordinates of the groundwater wells are presented in table 1. The geographical coordinates of each well location were gotten using the Google Map mobile app. At sample collection points, the water from wells were collected using a clean fetcher. The well water was first agitated before water was fetched to ensure that settled particles within the water can rise and become suspended in order to improve integrity of water quality test. The groundwater samples were collected in clean, well-labelled 1.5L capacity sampling bottles which were properly rinsed with distilled water before sample collection. The bottles with their caps were rinsed three times with the water to be sampled. After collection, the bottles were well-corked, stored in a cooler and transported to the laboratory within 4 hours in order to preserve the integrity of the water samples (Ojo, 2022). Heavy metals such as Iron (Fe), Manganese (Mg), Lead (Pb), and Chromium (Cr) were analysed by using a 210VGP atomic absorption spectrophotometer. ArcGIS software was used in mapping the study areas. The maps of Alagbaka and Ijare were first generated with the aid of the software.

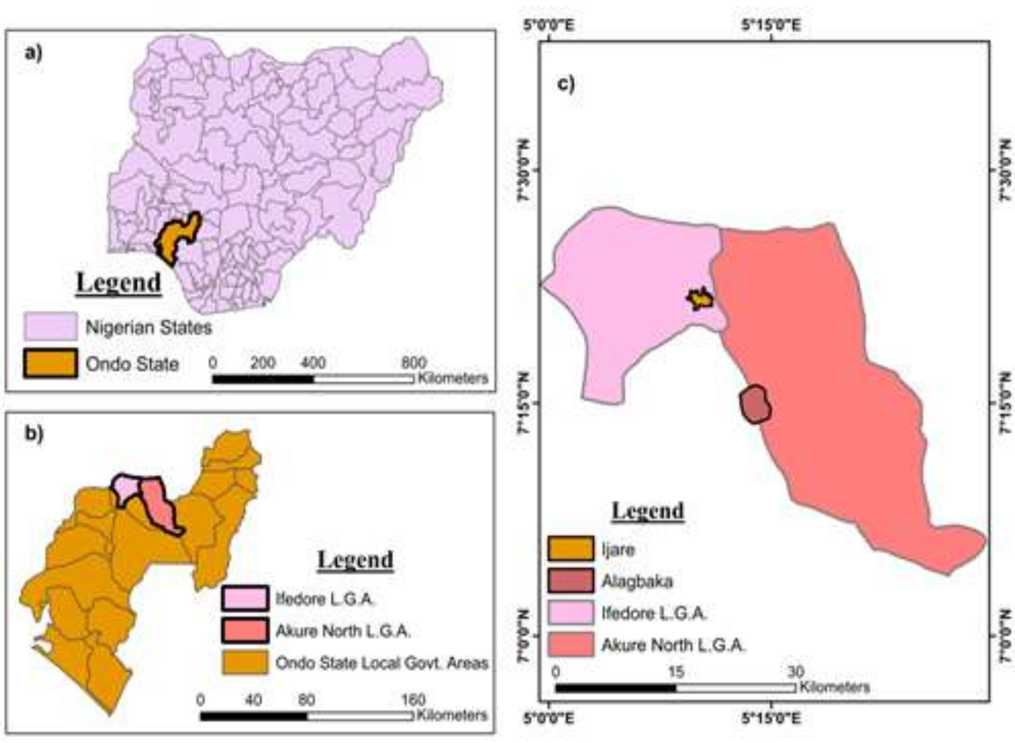

Fig. 1: Location of the study areas in Ondo state, Nigeria

Table 1: Coordinates of sampled groundwater wells

Groundwater	Latitude	Longitude
U1	7.255014	5.219304
U2	7.255454	5.220446
U3	7.253524	5.218707
U4	7.251192	5.218291
U5	7.248972	5.218363
R1	7.359262	5.169494
R2	7.358603	5.167156
R3	7.358599	5.167161
R4	7.358065	5.169643
R5	7.357530	5.172125

U1 to U5 are sampled groundwater wells in Alagbaka (Urban); R1 to R5 are sampled groundwater wells in Ijare (Rural)

Heavy Metal Pollution Index (HMPI): The Heavy Metal Pollution Index (HMPI) is a tool used to evaluate the level of heavy metal contamination in water bodies (Wang *et al.,* 2018). The index considers the concentrations of various heavy metals in water and their corresponding toxicity levels. This method considered the maximum acceptable limit and maximum permissible limit of each heavy metal for water quality classification. The HMPI technique was created by assigning a rating or weightage (W_i) to each parameter. The rating is an arbitrary figure between zero and one that represents the relative relevance of individual quality factor. The WHO standards for drinking water were utilized in this study to determine the concentration limit (i.e the highest permissible value for water supply, S_i). Heavy metal pollution index (HMPI) for the study areas was calculated using equation 1 (Mohan *et al.,* 1996).

$$HMPI = \frac{\sum_{i=1}^{n} SI_i \times W_i}{\sum_{i=1}^{n} W_i} \qquad 1$$

Where: SI_i is the sub-index of the *i*th parameter; W_i is the unit weight of the *i*th parameter; n is the number of parameters considered.

The sub-index (SI_i) of each parameter were determined using equation 2 (Mohan *et al.,* 1996).

$$SI_i = \frac{|M_i - I_i|}{|S_i - I_i|} \times 100 \qquad 2$$

Where: Mi is the monitored value of heavy metal of the *i*th parameter; I_i is the ideal value of the *i*th parameter; S_i is the standard limit of *i*th parameter as recommended by WHO drinking water standard.

The individual unit weights, ideal values and standard limits of the heavy metals considered for computing the HMPI of groundwater samples are presented in Table 2. A value of HMPI below 100 represents low pollution of heavy metals, while 100 is the threshold value at which harmful health consequences are probable. An HMPI value greater than 100 indicates the water is unsuitable for consumption (Kumar *et al.,* 2019).

Table 2: Heavy metals, their unit weights, ideal values and standard permissible limits in drinking Water Source: WHO, 2011; Mahato *et al.,* 2017

Parameters	Unit Weight (W_i)	Ideal value (I_i)	Standard Permissible limit (S_i)
Chromium	0.0200	0.0	0.05
Iron	0.0033	0.0	0.3
Manganese	0.0033	0.1	0.4
Lead	0.1000	0.0	0.01

RESULTS AND DISCUSSION

Heavy metal concentration analysis: The heavy metals evaluated in the water samples are iron (Fe), chromium (Cr), Manganese (Mn) and lead (Pb). The WHO standards limit for drinking water quality were used to analyse the results. Table 3 shows a summary of descriptive statistics of the metal concentrations in the groundwater samples (mg/L). By comparing the arithmetic mean of the concentrations of the parameters in urban groundwater wells with that of rural ground water wells, the groundwater quality of urban and rural land uses was compared. The concentration of iron in the sampled wells ranged between 0.1335 and 0.2715mg/L and were within the WHO drinking water standard limit of 0.3mg/L as shown in figure 2. Chromium in the study areas had levels ranging from 0.056 to 0.1615mg/L, which are all above the WHO drinking water standard limit of 0.05mg/L as presented in figure 3. The levels of manganese ranged between 0.0775 and 0.1725mg/L in study wells and all the wells had manganese levels within the WHO drinking water standard limit of 0.4mg/L as presented in figure 4. Lead had levels in the study areas ranging from 0.01 to 0.11mg/L and while only 20% of the sampled wells had levels above the recommended limit as shown in figure 5.

Table 3: Descriptive statistics of groundwater quality in urban and rural study areas.

Parameters	Mean ± S.D for urban land use	Mean ± S.D for rural land use	P-value
Cr^{2+}	0.1439 ± 0.01534	0.0891 ± 0.02194	0.000
Fe^{2+}	0.2207 ± 0.06185	0.1700 ± 0.02763	0.007
Mn	0.1469 ± 0.01837	0.0962 ± 0.01942	0.000
Pb	0.0864 ± 0.01843	0.0384 ± 0.03148	0.000

S.D = Standard Deviation

Elevated quantities of Chromium in potable water can cause nausea, gastrointestinal distress, kidney, lungs and liver damage as well as reproductive problems (Ojo, 2022). Exposure to lead is associated with a wide range of effects, including various neurodevelopmental effects, cardiovascular diseases, impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes (WHO, 2011).

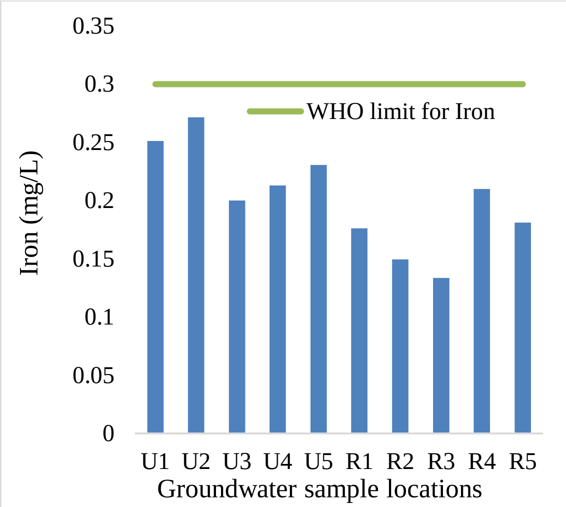

Fig. 2: Variation of Iron with WHO in urban and rural study wells with WHO standard

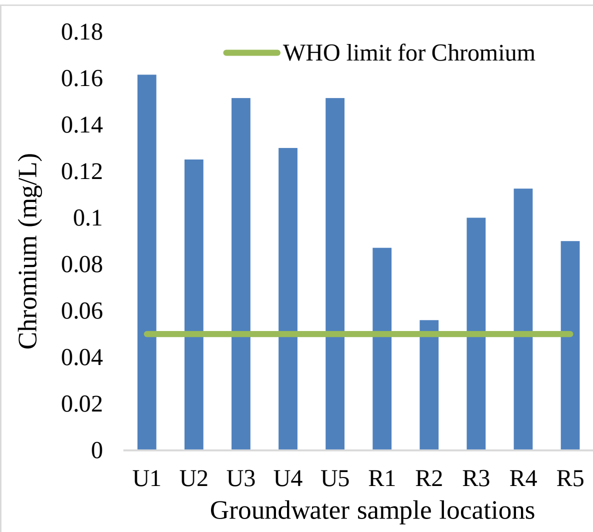

Fig. 3: Variation of Chromium in urban and rural study wells with WHO standard

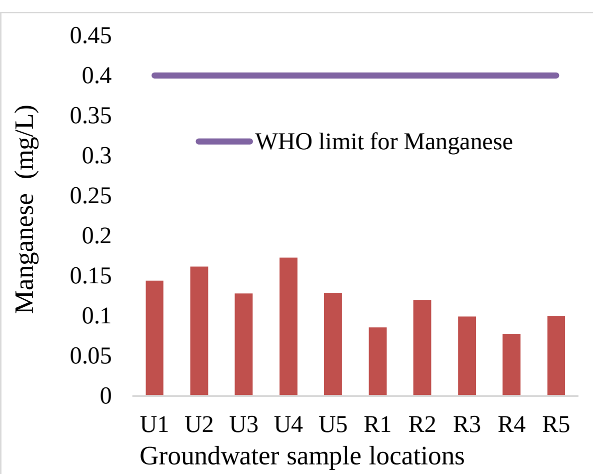

Fig. 4: Variation of Manganese in urban and rural study wells with WHO standard

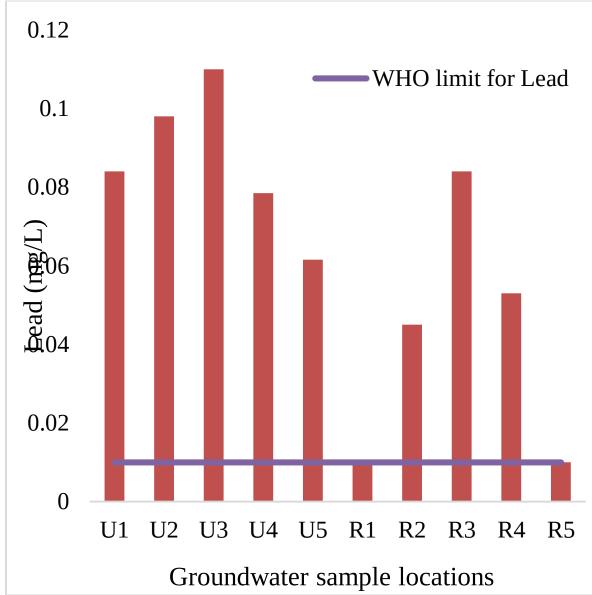

Fig. 5: Variation of Lead in urban and rural study wells with WHO standard

Analysis of heavy metal pollution index (HMPI): The heavy metals evaluated for heavy metal pollution indices (HMPIs) are Chromium, Iron, Manganese and Lead. Table 4 shows the HPIs for each groundwater well sampled. The HMPIs of sampled groundwater wells in the urban study area range from 547.91 to 919.21, with a mean of 736.85, whereas those in the rural study area range from 107.74 to 704.17, with a mean of 340.72. This demonstrates that the level of heavy metal pollution in the groundwater sources in the urban study area is significantly higher than in the rural area. This condition could be attributed to the artificial sealing of natural soil with concrete and asphalt pavement, as well as the channeling of runoffs into large water bodies via drainages that characterize the urban area (Bhaskar *et al.*, 2016; Han *et al.*, 2017). This prevents rain and surface water from infiltrating into the soil, preventing appropriate groundwater recharge, which is required to reduce the concentration of groundwater contaminants (Liaqat *et al.*, 2021; Obiora-Okeke *et al.*, 2021). Other factors, such as industrialization, urbanization, and population growth, agricultural activities, and municipal wastewater discharge may also be responsible for the relatively high heavy metal pollution of urban groundwater wells, as shown in table 4. Heavy metals accumulate in living organisms and cause health problems, such as cancer, neurological disorders, and reproductive problems. It was also discovered as shown in table 4, that while urban land use had higher pollution indices than rural land use, all sampled wells in both urban and rural areas had HMPI values greater than 100 according to the HMPI classification. A value of HMPI below 100 represents low pollution of heavy metals, while 100 is the threshold value at which harmful health consequences are probable. An HMPI value greater than 100 indicates the water is unsuitable for consumption (Kumar *et al.,* 2019). Therefore, the value of index indicates that the water is unfit for drinking purpose and not free from heavy metal pollution.

Table 4: HMPIs of sampled groundwater wells in urban and rural study areas and classification of heavy metal pollution level according to HMPI (Kumar *et al.,* 2019)

Sampled groundwater wells	Heavy Metal Pollution Index (H.M.P.I)
U1	724.84
U2	832.62
U3	919.21
U4	659.68
U5	547.91
R1	107.81
R2	335.43
R3	704.17
R4	448.46
R5	107.74

HPI value	Pollution level
<100	Low pollution level: Suitable for consumption
>100	High pollution level: Unsuitable for consumption

R = Rural, U = Urban

Conclusion: Based on the analysis carried out on the two land use types, groundwater in both study areas is polluted by heavy metals and could be more susceptible to contamination in urban areas. This necessitates adequate steps to properly protect and remediate polluted groundwater for safety purposes. An efficient, safe and effective sewage system for disposal of sewage, wastes water and control of runoff should be developed to improve groundwater quality in the study areas.

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