Unizik Journal of Educational Research, Science and Vocational Studies (UJERSVOCS)
Volume 3 (1); Sept.-December, 2025; https://unilaws.org/ujervs
E-ISSN (Online): 1595-6199 ISSN (Print): 1595-6202

PHYSICO-CHEMICAL AND HEAVY METAL ANALYSIS OF BOREHOLE WATER AS AN ENHANCEMENT OF PROPERTY VALUE IN NNEWI NORTH, SOUTH-EASTERN NIGERIA

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ABSTRACT
This study assessed the physico-chemical and heavy metal quality of borehole and surface water sources in Nnewi North, Anambra State, with a focus on implications for public health and property value enhancement. Ten sampling points were selected: Ezekwabo Uruagu (SLA), Miri Eze Stream (SLB), Evo Eatery (SLC), Maria Regina School (SLD), NAUTH (SLE), Ojiofor Specialist Hospital (SLF), Okongwu Memorial Grammar School (SLG), Hope Specialist Hospital (SLH), Chidera Hospital and Maternity (SLI), and Immaculate Heart Hospital and Maternity (SLJ). Water samples were analysed for key physico-chemical indicators, pH, temperature, turbidity, total dissolved solids (TDS), electrical conductivity (EC), alkalinity, and hardness alongside heavy metals including iron (Fe), lead (Pb), zinc (Zn), cadmium (Cd), copper (Cu), and mercury (Hg). Results were benchmarked against WHO and NSDWQ drinking water standards. Most physico-chemical parameters were within acceptable limits; however, elevated turbidity was recorded in several locations, particularly SLB and SLC. Among heavy metals, mercury exceeded permissible limits in all sites except SLG, while iron and cadmium surpassed guideline values in multiple locations, indicating potential geogenic and anthropogenic contamination. These exceedances pose significant health risks, such as kidney toxicity, neurological impairment, and gastrointestinal disturbances. Furthermore, deteriorating water quality was found to negatively influence property desirability, increasing treatment costs and lowering market value in affected communities. The study recommends strengthened groundwater protection policies, routine monitoring, public awareness campaigns, and adoption of affordable purification technologies to safeguard health and support sustainable property value growth in Nnewi North.

Keywords: Heavy Metal, Groundwater, Borehole, Contaminant

Introduction
Access to clean and safe water is a fundamental requirement for public health, economic development, and social well-being. In many developing regions, including Southeast Nigeria, borehole water serves as a primary source of domestic and industrial water supply due to inadequacies in public water infrastructure. Nnewi, a fast-developing commercial and industrial hub in Anambra State, has witnessed a significant rise in urbanization, population growth, and property development. This rapid expansion has placed increasing the demand on groundwater resources, especially boreholes, making their quality and safety a subject of growing concern. Effluents coming from different industrial and commercial establishment pose a serious threat to the environment, particularly in urban and semi-urban areas. It becomes the source of pollution to soil, ground water and surface water (Lakhimi, 2010). Heavy metal contamination of urban topsoil, is usually deduced from man-made source such as emissions from automobile exhaust waste incineration, land disposal of wastes, agricultural activities, emission from industrial processes and wet or dry atmospheric deposits. Industries are the source of all major pollution including air, water and land (Sarker, 2014).

The physicochemical and heavy metal analysis of borehole water is an essential scientific method for assessing the portability and safety of water sources. Physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), temperature, turbidity, and hardness offer insight into the water's basic chemical composition and suitability for consumption or other uses. Equally important is the evaluation of heavy metals such as lead (Pb), cadmium (Cd), copper (Cu) iron (Fe), and zinc (Zn), which, even in trace concentrations, can pose serious health hazards if not properly monitored.

In the context of Nnewi, these analyses carry further implications beyond public health, they play a significant role in enhancing property values. Access to clean, tested, and reliable borehole water directly influences the desirability and marketability of residential and commercial properties.

Real estate developers and potential property buyers are increasingly aware of the environmental and health risks associated with poor water quality, thereby making water quality assessment a factor in land valuation and property investment decisions. Furthermore, governmental and environmental regulations are beginning to mandate water quality certification as part of property development and urban planning standards. However, Industrial wastes are peculiar to individual industries as each sector produces its own particular combination of pollutants, for example, waste from plastic industries contains Cadmium and Chromium. Untreated or partially treated industrial waste water contains algae materials, non-biodegradable organic matters, heavy metals and other toxicants that deteriorate the environment and the receiving water bodies (Akarinwo and Gwin, 2006). Water pollution is a serious problem globally.

This study, therefore, investigates the physicochemical properties and concentrations of heavy metals in borehole water across various locations in Nnewi, with the goal of evaluating its safety for human use and its implications for real estate development. By identifying contamination levels and assessing the spatial variation in water quality, the study aims to contribute to informed decision-making for residents, developers, investors, and policymakers. Ultimately, the findings are expected to reinforce the role of water quality as a determinant of property value and urban sustainability in Southeast Nigeria.

Aim of the study
To determine the physico-chemical and heavy metal quality of borehole water as an enhancement to urban liveability, and real estate investment attractiveness and property value in Nnewi North, Anambra State.

Objectives of the study
i. To evaluate the physico-chemical and heavy metal parameters of selected borehole and surface water sources.
ii. To assess the compliance of results with WHO and NSDWQ drinking water standards.
iii. To examine the relationship between water quality and property values in the area.
iv. To recommend strategies for the improvement groundwater quality to support public health and property value appreciation in Nnewi north.

Study Area

Nnewi North is a major commercial and industrial hub in South-Eastern Nigeria, known for automobile manufacturing and medical facilities. The town depends largely on groundwater via boreholes.

Sample Locations

Ten sampling sites were selected and coded as follows:

SLA – Ezekwabo Uruagu, SLB – Miri Eze Stream, SLC – Evo Eatery, SLD – Maria Regina School, SLE – NAUTH, SLF – Ojiofor Specialist Hospital, SLG – Okongwu Memorial Grammar School, SLH – Hope Specialist Hospital, SLI – Chidera Hospital and Maternity, SLJ – Immaculate Heart Hospital and Maternity. Before collecting the samples from the taps, the mouth of the taps was first cleaned and the water was allowed to run for about two-three minutes before the midpoint was collected to avoid collecting rust from the pipe walls. The plastic bottles used for collecting the samples were to be rinse thoroughly with the Sample water to ensure that it is free from contamination.

Methods For Analysing Heavy Metal Analysis

Heavy metal analysis was conducted using Varian AAS 240 atomic absorption spectrometers according to the method of APHA 1995 [American public Health Association]

Working principle: Atomic absorption spectrometer working principle is based on the sample being aspirated, into the flame and atomized when the AAS' light beam directed through the flame into the monochromator and into the detector that measures the amount of light beam absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a Source Lamp composed to that element is used. Making the method relatively free from spectral or radiation interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

Results

Physical and Chemical Parameters of Water

The table below shows the physical and chemical characteristics of the water samples as tested. Represented with values obtained from the laboratory analysis expressed in Mg/L against the WHO and NSDWQ for drinking Water.

Parameters for physical and chemical analysis of surface and borehole water in Nnewi North and environs.

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Table 1: Physical and Chemical Parameters

Parameters	SL A	SL B	SL C	SL D	SL E	SL F	SL G	SL H	SL I	SL J	WHO	NSDWQ
Ph	6.80	6.20	5.90	5.60	6.50	5.70	5.80	6.40	6.20	5.90	6.5-8.5	6.5-8.5
Hardness	44	52	50	30	60	64	56	48	45	50	500	500
Temperature	22 C	21.10C	23C	20 C	15 C	29 C	18 C	25 C	24 C	19 C		
Turbidity	13.40 NTU	13. 30 NTU	94.10 NTU	27.30 NTU	54.00 NTU	42.10 NTU	51.20 NTU	60.30 NTU	54.10 NTU	36.60 NTU	5.0	5.0
Alkalinity	24	8	28	22	17	26	48	63	32	56	100	100
Total Dissolved Solid (TDS)	7.60	16.10	86.30	4.69	58.15	61.30	65.60	75.40	41.60	34.60	500-1000	500-1000
Electricity Conductivity	11.S	16.40	23.50	23.50	50.10	30.30	30.60	23.70	45.50	39.80	200	200

Table 2: Heavy Metal Analysis

Parameters	SL A	SL B	SL C	SL D	SL E	SL F	SL G	SL H	SL I	SL J	MEAN VALUE	WHO	NSDWQ
Cadmium	0.259	0.069	0.028	0.013	0.070	0.130	O.222	0.312	0.400	0.300	0.1803	0.003	0.003
Lead	0.004	0.000	0.000	0.005	0.096	0.05O	0.O70	0.000	0.05O	0.010	0.024	0.01	0.01
Copper	0.018	0.004	0.005	0.000	O.054	0.148	0.118	0.210	0.110	0.500	0.1167	2.0	1.0
Iron	0.114	0.000	0.857	0.000	0.673	0.574	0.201	0.512	0.630	0.560	0.4121	0.03	0.03
Mercury	0.320	0.200	0.170	0.280	0.375	0.141	0.006	0.030	0.112	0.201	0.1835	0.01	0.01
ZINC	O.OO	0.000	0.000	0.000	0.120	0.003	0.030	0.210	0.000	0.100	0.0463	3.0	3.0

pH

The pH values of the analysed water samples ranged from 5.60 to 6.80, indicating that some of the water sources fall below the WHO permissible range of 6.5–8.5 for drinking water. Values below 6.5 reflect slight acidity, which may not pose an immediate health hazard but can have important implications for water quality, infrastructure, and the mobilization of contaminants. Water with pH between 5.60 and 6.40 is considered moderately acidic. Such acidity in borehole water may arise from several factors including the geological composition, industrial and vehicular emissions and runoff or poor waste disposal.

Hardness:

The total hardness of the samples ranged from 45 to 64 mg/L, placing them well below the WHO maximum limit of 500 mg/L. Hardness is caused mainly by the presence of calcium and magnesium ions, which are natural minerals found in water.

1. Values in this range indicate soft to moderately soft water. Such water is desirable because:
2. It does not cause scaling in pipes, kettles, or boilers.
3. It improves soap lathering and reduces detergent use.

4. It is generally pleasant for drinking and household activities.
Since the values are far below the upper limit, there is no risk of adverse effects such as taste alteration, excessive mineral load, or pipe encrustation. The results confirm that the water is safe, palatable, and suitable for domestic and drinking purposes.

Temperature:
The recorded temperature values for the water samples ranged from 19°C to 25°C, which fall within the WHO recommended limit of less than 30°C for drinking water. This temperature range is generally considered acceptable and typical of groundwater sources in tropical regions such as Nnewi North. Although temperature is not a direct health-related parameter, it plays an important role in determining the overall physico-chemical stability, taste, and biological characteristics of water by having effect on the influence on microbial growth, effects on dissolved oxygen and chemical demand and influence on taste and palatability.

Turbidity:
Turbidity refers to the cloudiness or lack of clarity in water caused by the presence of suspended particles such as clay, silt, organic matter, microorganisms, and industrial or domestic pollutants. According to WHO standards, turbidity should not exceed 5 NTU for drinking water, because higher values compromise both safety and aesthetic quality.
In this study, several water samples particularly SL,B (Miri Eze Stream) and SL,E (NAUTH) recorded turbidity values above the acceptable limit, indicating the presence of significant suspended particles. This raises important concerns about the source, quality, and safety of the water in these locations.

Alkalinity:
The alkalinity of the water samples ranged from 0 to 75 mg/L, which falls within acceptable limits for drinking water. Alkalinity represents the water's ability to neutralize acids, primarily due to the presence of bicarbonates, carbonates, and, to a lesser extent, hydroxides.
The values in this range indicate that the water has low to moderate buffering capacity. This means the water can resist sudden changes in pH, helping maintain a stable and safe acidity level. Samples at the lower end (close to 0 mg/L) may have very low buffering strength, but they still pose no direct health risk. Samples up to 75 mg/L reflect naturally occurring bicarbonates, which are typical of groundwater and surface water.
Overall, these alkalinity levels show that the water is chemically balanced, non-corrosive, and suitable for consumption.

Total Dissolved Solids (TDS):
The TDS values for the water samples ranged from 161 mg/L to 760 mg/L, which means all samples fall within the WHO and Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limit of 1000 mg/L. This indicates that the concentrations of dissolved inorganic salts and small amounts of organic matter in the water are still at acceptable levels for human consumption.

Although TDS levels vary across the samples, the values do not pose any immediate health concern. Samples with values on the higher side (closer to 760 mg/L) may have slightly more mineral content, which can affect taste or palatability, but they remain safe and compliant. Overall, the TDS results suggest that the water sources have a moderate mineral load and do not show signs of excessive contamination from dissolved solids.

Electrical Conductivity (EC):
The electrical conductivity of the analysed water samples ranged from 111 to 640 µS/cm, which places all samples well within the WHO and NSDWQ permissible limit of 1000 µS/cm. EC is an important indicator of the water's ability to conduct electrical current, which is directly related to the concentration of dissolved ions such as calcium, magnesium, sodium, chloride, and sulfates. The values obtained suggest that the water sources contain moderate levels of ionic minerals, indicating neither excessive dissolution of salts nor significant contamination from industrial or agricultural runoff. Samples with EC values closer to the upper end (around 640 µS/cm) simply reflect a higher mineral content but still fall within acceptable limits and pose no health risk. Overall, the EC results show that the water quality is chemically stable, with ion concentrations at safe and tolerable levels for drinking and domestic use.

Iron (Fe):
Some borehole samples recorded iron concentrations as high as 0.857 mg/L, clearly exceeding the WHO permissible limit of 0.3 mg/L. Although iron is not highly toxic, high levels cause brownish discoloration, metallic taste, staining of laundry, and can promote iron-related bacteria that form slime in pipes.

Lead (Pb):
Lead concentrations ranged from 0.000 to 0.010 mg/L, generally within the WHO and NSDWQ limit of 0.01 mg/L. from the heavy metal table above, the concentration of lead are relatively high in SLE, SLF, SLG, and SLI with 0.096, 0.050, 0.070, and 0.050 respectively. Even though these values are low, lead is a highly toxic metal with no safe exposure threshold, especially for children. Possible sources include: old plumbing materials, industrial residues from metal workshops or battery activities (common in the Nnewi area), soil leaching from waste disposal sites.

Cadmium (Cd):
Cadmium concentrations ranges from 0.259, 0,069, 0.028, 0.013, 0.070, 0.130, 0.222, 0.312, 0.400, 0.300 in SLA, SLB, SLC, SLD, SLE, SLF, SLG, SLH, SLI, SLJ respectively in mg/L in both ground and boreholes water are far above the WHO and NSDWQ limit of 0.003 mg/L. Cadmium is extremely dangerous even at trace levels and is linked to: kidney damage, bone deformities, cancer (carcinogenic), and reproductive system issues. Likely sources include: battery manufacturing and disposal (very common in Nnewi), metal plating workshops, contaminated industrial waste, and weathering of cadmium-containing rocks.

Copper (Cu):
Copper levels were below the 1.0 mg/L WHO and NSDWQ limit in all sampled sites. Copper is an essential micronutrient and typically enters water through: corrosion of copper pipes, geological sources. Within permissible limits, copper does not pose health risks and may even contribute trace nutritional value.

Mercury (Hg) the concentration of mercury was above the limit of WHO and NSDWQ of 0.01 mg/l at site location SLA, SLB, SLC, SLD, SLE, SLE, SLF, SLI and SLJ with 0.320, 0.200, 0.170,

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0.280, 0.375, 0.141, 0.112, and 0.201 respectively. This shows extremely high levels of mercury with the mean value of 0.1835mg/l. its potentials may result from industrial activities, medicine waste, burning of waste materials and poor disposals of fluorescent bulbs. Mercury contamination is especially dangerous because it bioaccumulates and biomagnifies, becoming more concentrated in the body over time.

Zinc (Zn):

Zinc concentrations were below the WHO limit of 3.0 mg/L at all sites. Zinc is generally non-toxic at low concentrations and contributes to metabolic functions in the body. Its presence in groundwater usually results from: natural rock dissolution, and mild corrosion of galvanized pipes. Acceptable zinc levels indicate that the water is safe from zinc-related taste or health issues and that industrial or domestic runoff is not significantly impacting zinc concentrations. This enhances confidence in the chemical safety of the water supply.

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Discussion

The physico-chemical analysis of borehole water in Nnewi North provides important insights into the quality, safety, and usability of water consumed in this rapidly urbanizing area. The parameters evaluated are pH, temperature, turbidity, TDS, electrical conductivity, alkalinity, and hardness reflect the chemical and physical condition of groundwater, and they collectively indicate the suitability of water for domestic, industrial, and health-related applications. The findings suggest that while the water is generally acceptable for consumption, certain parameters reveal environmental influences and potential risks that require attention.

Turbidity concentration maybe as a result of surface contamination, soil disturbance, or runoff pollution, especially in areas with high human activity. It signals the need for filtration or sediment removal before consumption.

The TDS values confirm that mineral-rich soils and rock formations contribute to groundwater composition. Higher values in certain boreholes may indicate influence from industrial waste or urban runoff but remain within safe limits. EC confirms that groundwater in the region is chemically stable and not influenced by saline intrusion, industrial chemicals, or sewage infiltration at significant levels. Soft water reduces maintenance costs for households, improves soap lathering, and minimizes pipe blockage. However, extremely soft water can slightly increase corrosion, contributing to the low pH observed. Most parameters met WHO and NSDWQ safety standards, indicating that the water is largely suitable for drinking.

Heavy Metal

The study revealed that cadmium and iron concentrations exceeded WHO and NSDWQ permissible limits in several sampling locations. The presence of these metals in groundwater is an indication of both geogenic (natural) and anthropogenic (human-driven) influences. The high cadmium levels are closely linked to the industrial profile of Nnewi, a known centre for battery production and disposal, Automobile spare parts manufacturing and recycling, Metal welding and electroplating workshops, Improper disposal of industrial effluents, Dumping of electronic waste (e-waste).

Many aquifers in South-eastern Nigeria are iron-rich due to the presence of ferruginous lateritic soils and iron-bearing minerals. Acidic water ($pH < 6.5$) accelerates corrosion, which releases iron into the columns. Many factors may lead to high rate of iron concentration such as the natural geological formations, Corroded borehole casings and distribution pipes, and poorly constructed or old boreholes. Although iron is not highly toxic, elevated levels affect water quality and causes brown or reddish staining of sinks, toilets, and laundry, gives an unpleasant metallic taste, promotes growth of iron bacteria, which form slime and clog pipes, high intake may cause stomach discomfort in sensitive individuals etc.

Mercury concentration is critically high and far above the safe limit of drinking water. The water is not safe for drinking or domestic use and should be treated. When borehole water is already certified safe, tenants avoid these extra costs. Landlords can therefore justify higher rent because the property eliminates monthly water expenses. A property with independently verified safe borehole water is significantly more attractive to tenants, buyers, and investors. In Nnewi north area, an industrial city with documented risks of metal contamination, the tenants prefer properties where health risks are reduced. Thus, water-quality reports create, higher demand for the property, lower hesitation during negotiation, quicker occupancy rates Real-estate investors entering Nnewi (especially developers in Otolo, Uruagu, Umudim, and Nnewichi) often require environmental and water assessments. A scientifically validated water report may reduce the risk of future lawsuits, simplifies environmental approval, ensures predictable water supply for tenants and encourages high-density housing or commercial use.

Conclusion

The analysis of water samples from the study area reveals a significant presence of heavy metal contamination, particularly with respect to lead (Pb) and cadmium (Cd), both of which exceeded the WHO and NSDWQ permissible limits by large margins across multiple sampling locations. Mercury (Hg), previously analysed, also exceeded safe limits at all sites, indicating widespread contamination. Iron (Fe) levels exceeded the acceptable limit in some locations, suggesting possible corrosion of borehole infrastructure or natural geological enrichment. While zinc (Zn) and copper (Cu) remained within safe limits, their presence indicates minor contributions from household plumbing, metallic waste, or industrial activities.

The elevated concentrations of toxic metals such as lead, cadmium, and mercury pose serious public health risks, including neurotoxicity, kidney damage, and increased cancer potential. The uniform exceedance of thresholds in several zones suggests that the contamination is not localized but widespread, likely resulting from poor waste management practices, industrial effluents, metal workshops, battery disposal, and leaching of contaminants into groundwater. The results indicate that the water sources in the studied area are unsafe for drinking and domestic use without adequate treatment. Immediate intervention is required to prevent chronic exposure, health complications, and long-term environmental degradation.

Physicochemical and heavy-metal analysis of borehole water is a powerful economic tool in Nnewi's real estate market. It influences: Rent charged, buyer willingness, land valuation, market competition, development potential and public health outcomes. Where results show safe water, property and land values increase significantly because buyers and tenants prefer health-secure, cost-effective, and reliable water sources. But where contamination exists, properties lose value unless remediation measures are taken. Thus, regular scientific water testing is a practical way to enhance property values and investment attractiveness in Nnewi.

Recommendations

1. Immediate Public Health Measures: Inform residents that the affected water sources are unsafe for consumption also provide alternative safe water sources (treated boreholes, sachet/bottled water, communal purification units).

2. Regular Monitoring: Implement monthly or quarterly water quality monitoring by local authorities and track heavy metal trends to detect worsening contamination early.

3. Industrial and Waste Management Control: Regulate industries in the area, especially those involving in batteries, metal plating, and electronics waste should enforce proper waste disposal legislation and ban dumping of industrial waste in open land or drainage systems.

4. Treatment of Contaminated Water: Use appropriate treatment methods like, activated carbon filtration, reverse osmosis, Ion exchange systems, coagulation flocculation for metal removal. They are effective in removing heavy metals like Pb, Cd, Hg, and Fe.

5. Replace Corroded Infrastructure: Replace or rehabilitate of rusted borehole pipes, contaminated storage tanks and introduce PVC or stainless-steel pipes to prevent iron leaching.

6. Environmental Remediation: clean up polluted soils around industrial zones, establish controlled landfill sites for hazardous waste, promote recycling of batteries, electronics, and scrap metals.

7. Community Education, train residents on the dangers of heavy metals, and encourage proper disposal of batteries, electronics, and metal scraps.

8. Government and Policy Involvement: strengthen enforcement of National Environmental Regulations, support research institutions to conduct periodic environmental audits. And provide subsidies or tax incentives for industries adopting eco-friendly practices.

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