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NITRATE, NITRITE CONCENTRATIONS IN DRINKING WATER FROM DIFFERENT GROUNDWATER SOURCES IN LAGOS STATE, NIGERIA

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ABSTRACT

The quality of drinking water is of significant concern, particularly in urban areas affected by industrial and agricultural activities. This study evaluated nitrate and nitrite concentrations in different drinking water sources, specifically well water and borehole water, across various soil types (clayey and sandy soils) in Lagos, Nigeria. Elevated nitrate and nitrite levels pose health risks such as methemoglobinemia, hypertension, cancers, congenital malformations, and spontaneous abortions. Water samples from wells and boreholes were collected across residential, agricultural, and industrial zones in Ijanikin and Okota areas of Lagos, Nigeria. Soil samples from predominant clayey and sandy soils were also analysed. Nitrate and nitrite concentrations were determined using spectrophotometric method. Results indicated that borehole water generally exhibited higher nitrate (ranging from 0.01 to 0.15 mg/L), and nitrite (ranging from 0.10 to 0.23 mg/L) levels than well water. Additionally, water from sandy soil sources had higher nitrate and nitrite concentrations than those from clayey soil. Specifically, nitrate levels in sandy soil ranged from 0.10 to 0.15 mg/L, while nitrite levels ranged from 0.11 to 0.23 mg/L. For clayey soil, nitrate levels ranged from 0.00 to 0.10 mg/L, and nitrite levels ranged from 0.07 to 0.120 mg/L. This study also revealed that nitrate and nitrite levels were predominantly higher in borehole water than in well water in Lagos metropolis. In addition, water from sandy soil sources had higher nitrate and nitrite concentrations than water from clayey soil. The higher nitrate and nitrite levels observed in borehole water than well water in Lagos metropolis could be attributed to the differences in the depth and protection of the water sources from human and industrial activities. Boreholes typically access deeper groundwater, which may be more susceptible to contamination from agricultural runoff or other sources of nitrates and nitrites due to its closer connection with the broader underground water table. In contrast, well water, being shallower, might be impacted by natural filtration processes through the soil. These results highlight the need for targeted public health interventions, including improved agricultural practices, enhanced waste management, regular monitoring of water quality to ensure safe drinking water in Lagos and mitigate associated health risks.

Key words: Nitrates, Nitrites, sandy soil, clayey soil, underground water quality

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INTRODUCTION

The quality of drinking water is of great importance, particularly in urban areas where industrial and agricultural activities can significantly impact water quality [1]. Lagos, Nigeria, a rapidly growing metropolis, faces challenges in ensuring the safety of its drinking water. The study focused on nitrate and nitrite concentrations in ground water from well and borehole water located in areas of sandy soils (coarse textured) vs those located on clay soils (fine textured).

The presence of nitrate and nitrite in drinking water is a major concern due to their potential health risks, including methemoglobinemia, commonly known as "blue baby syndrome," and other adverse health effects [2]. Nitrate poses a threat in drinking water at levels greater than 10 mg/L. High nitrate levels in water are generally associated with adverse health effects in humans and other species, ranging from infant methemoglobinemia and hypertension to cancers and other adverse effects such as birth defects (congenital malformations) and spontaneous abortions [3]. The regulatory limit for nitrate in public drinking water supplies was set to protect against infant methemoglobinemia, but other health effects are also being discovered. For instance, risks of specific cancers and birth defects may be increased when nitrate is ingested under conditions that increase the formation of N-nitroso compounds [4].

Well water in Lagos often shows elevated levels of nitrate and nitrite due to agricultural runoff (fertilizers and animal waste), sewage leakage and improper waste disposal which can leak into groundwater [3]. The concentration of nitrates and nitrites in well water can vary significantly based on proximity to agricultural areas, industrial sites, and urban runoff [5]. Studies have shown that well water can contain elevated levels of nitrates and nitrites due to the leaching of fertilizers and waste products into the groundwater [6]. A comprehensive study conducted in Lagos revealed that nitrate levels in well water samples ranged from 10 to 50 mg/L, with some areas exceeding the World Health Organization (WHO) guideline limit of 50 mg/L for nitrates in drinking water [1, 8]. Nitrite levels were generally lower, typically ranging from 0.1 to 1.0 mg/L, but still of concern in areas with poor sanitation practices [7]. A related study on dug wells in Lagos Island, Southwestern Nigeria, revealed that nitrate concentrations often surpassed safe thresholds, posing serious health risks to the local population. The findings underscore the potential for well water on Lagos Island to become an environmental hazard if effective mitigation strategies are not implemented [9].

In Lagos and many other parts of Nigeria, borehole water serves as a major source of drinking water and is often regarded as safer than well water, owing to its deeper extraction from underground aquifers [10]. Borehole water though deeper may still be affected by widespread contamination of the water table, while shallow wells are more directly impacted by surface-level pollution and inadequate sanitation. Water infiltration is higher on sandy soils than in clay soil. However, borehole water is not immune to nitrate and nitrite contamination. The geological composition and human activities and soil texture near borehole sites can influence nitrate and nitrite levels [10]. Research indicates that borehole water in Lagos has nitrate concentrations ranging from 5 to 30 mg/L, with occasional spikes in areas close to agricultural fields or waste disposal sites. Nitrite concentrations in borehole water are generally lower, often below 0.5 mg/L, but can increase due to localized contamination sources [10]. Thus, high nitrates in water supply in Nigeria have serious implications for human health, necessitating urgent attention and remedial measures [4].

Clay soils, prevalent in certain parts of Lagos, have a high capacity for nutrient retention and can also hold onto contaminants such as nitrates and nitrites [11]. Studies have found that nitrate concentrations in clay soils range from 20 to 100 mg/kg, depending on the level of fertilizer use and organic waste deposition [11,12]. Nitrite levels in clay soils are typically lower, ranging from 0.1 to 2 mg/kg, as nitrites tend to be less stable and convert to other nitrogen forms [13]. Human health risk assessment of nitrate and heavy metals in urban groundwater in Southeast Nigeria revealed significant contamination levels in clay soils, necessitating ongoing monitoring and mitigation efforts [14]. Sandy soils have lower nutrient retention capabilities, leading to higher leaching rates of nitrates and nitrites into groundwater [6]. Nitrate concentrations in sandy soils can vary widely, often ranging from 10 to 80 mg/kg, influenced by agricultural runoff and irrigation practices [11]. Nitrite levels in sandy soils are usually low, typically less than 1 mg/kg, due to rapid drainage and microbial activity that converts nitrites to other nitrogen forms [13].

Despite increasing concerns about groundwater contamination and the significant health risk associated with it, limited studies have comprehensively compared nitrate and nitrite concentrations across diverse groundwater sources and soil types in Lagos State, Nigeria, leaving gaps in understanding regional variability and potential health implications. This study aimed to provide a comprehensive analysis of these contaminants in different water and soil sources in Lagos, Nigeria. Findings from this study are expected to inform public health strategies and contribute to improving water safety in the region.

MATERIALS AND METHODS

Study Area

This study was conducted in Lagos, Nigeria, an urbanized area with extensive industrial and agricultural activities. Sampling sites were selected to represent different environmental and human impact zones, including residential, industrial, and agricultural areas. Water samples were drawn from Ijanikin and Okota area of Lagos state, Nigeria.

Sample Collection

Water Samples

Water samples were collected from well and borehole water, to assess nitrate and nitrite concentrations. Samples were collected from various sources in mainland area of Lagos from 16 different sources. Samples were stored in clean polyethylene bottles and refrigerated at 4°C until analysis to prevent any changes in nitrate and nitrite concentrations.

Well Water: Samples were collected from wells located in residential, agricultural, and industrial areas to capture variations in nitrate-nitrite levels due to proximity to potential contamination sources.

Borehole Water: Samples were taken from boreholes, considered less susceptible to surface contamination due to their deeper extraction points.

Sample Preparation

Each water sample was filtered through a 0.45μm membrane filter to remove particulate matter. The filtered samples were then subjected to nitrate and nitrite analysis using spectrophotometric method [7].

Standard Calibration Curve

To determine the nitrate-nitrite concentration, a standard calibration curve was created [15]. A stock solution was prepared as follows:

Preparation of Stock Solution

For preparation of 100.0mg L^{-1} sodium nitrite stock solution, 0.01g of sodium nitrite was dried at 110^{0}C for four hours and dissolved in distilled water in a 100mL volumetric flask. A working solution was prepared by diluting the standard stock solution to appropriate volume with distilled water whenever required [18].

Addition of Solutions

1ml of each nitrite standard solution was pipetted into a clean test tube, and the following solutions were added:

1. 0.5 ml of 0.5% sodium carbonate (Solution C)
2. 2.5 ml of sulphanilic acid (Solution A) and
3. 2.5 ml of NED (Solution B)

These were left to stand for 15 minutes, and the optical density values were measured and plotted against nitrite concentration to construct the calibration curve.

Recovery Experiment for Nitrate

Nitrate determination was initially carried out by reduction using finely divided cadmium. The resulting nitrate was then analyzed as described for nitrate standardization. To determine the percentage of nitrate recovered when passed through a cadmium column, the following procedure was used:

Procedure

A cadmium column was prepared using a burette glass column.

Prior to analysis, the column was activated by washing with 25 ml of diluted Hydrochloric acid (HCl) (0.1 N), followed by 30 ml of distilled water, and finally with 25 ml of dilute ammonia buffer.

Solutions containing 1µg, and 3 µg NaNO3-N/ml were prepared. Each solution (20 ml) was mixed with 3 ml of amino buffer, followed by 7 ml of distilled water.

100ml of the eluate was collected and analyzed for nitrite according to the method described by Baxter *et al*. [16].

Two determinations were made for each concentration (1 µg and 3 µg NO3-N), and the percentage resolved was calculated.

Sample Analysis

Nitrate Determination

10ml of nitrate stock solution was pipette into a beaker, 5ml of HCl and 2ml of Zn/NaCl granular mixture were added and allowed to stand for 30 minutes, with occasional stirring to form nitrite. Then the solutions were filtered into 100ml standard flask using Whatman No 1 filter paper and diluted up to mark. Aliquot of stock solution containing 0.26-10.7µg/ml of reduced nitrate were transferred into series of 10ml standard flask, 1ml of 0.5% sulfanilic acid 1ml of 2mol/HCl solution were added and shaken thoroughly for five minutes (Diazotization). Then, 1ml of 2mol/1 NaOH solution was added to form an azo dye. The contents were diluted to 10ml with water and the absorbance of the red colour dye was measured at 540nm against the corresponding reagent blank, using Jenway 754 UV – visible spectrophotometer [7].

Nitrite Determination

Aliquot of stock solution containing 0.2-8µg/1 of nitrite was transferred into series of 10ml calibrated flask. To each flask 1ml of 0.5% sulfanic acid and 1ml of 2mol/1 HCl solution were added, and the solution was shaken thoroughly for 5 minutes. (Diazotization reaction). Then 1ml of 0.5% methyl anthranilate and 2ml of 2mol/1 NaOH solution were added to form azo dye, and the contents were diluted with 10ml using water. Then absorbance of the red-coloured dye was measured at 540nm against the corresponding reagent black, using Jenway – UV –visible spectrophotometer [7].

Estimation of Nitrite in Water

90ml of each water sample was analyzed for nitrite as described using the method as described by Baxter TE (17).

Nitrate Analysis
Water samples were analyzed for nitrate by subtracting the original nitrite concentration from the nitrite concentration after reduction by cadmium in the sample.

Statistical Analysis
Data were analyzed using descriptive statistics to determine the mean, standard deviation, and coefficient of variation for the nitrate and nitrite measurements. An independent t-test was conducted to access the association between nitrate and nitrites in borehole and well water from different soil types in Lagos state. Analysis was done using STATA-17.

RESULTS AND DISCUSSION

The results of this study provide significant insights into the nitrate and nitrite concentrations in various drinking water sources within Lagos metropolis. The nitrite concentrations in water samples from various soil types ranged from 0.07 to 0.23 mg/ml as presented in Table 1.0 below. Well water on clayey had mean nitrite levels of 0.120 ± 0.001 mg/ml and 0.065 ± 0.026 mg/ml, while borehole water had consistent levels of 0.10 ± 0.03 mg/ml. The highest nitrite concentration was found in borehole water on sandy soil, recorded at 0.23 ± 0.04 mg/ml. Overall, nitrite levels were generally higher in sandy soil than clayey soil, and borehole water consistently exhibited higher concentrations than well water in both soil types. These findings indicate that borehole water generally exhibits higher levels of nitrate and nitrite than to well water, with sandy soils showing higher contamination levels than clayey soils. These observations are therefore crucial in understanding the impact of different environmental factors on water quality and have important public health implications.

Nitrate Concentration in Drinking Water
The nitrate concentration in drinking water from the different sources are presented in Table 2.0 and Figure 1.0 below. The nitrate concentrations in drinking water from various sources and soil types ranged from 0.00 ± 0.04 mg/L to 0.15 ± 0.07 mg/L. Generally, nitrate levels were found to be higher in sandy soil compared to clayey soil, and borehole water exhibited more variation in nitrate concentrations than well water. Sandy soils, which have higher permeability and lower nutrient retention capabilities, were found to have higher concentrations of these contaminants. This aligns with earlier research, which reported that sandy soils enhance the leaching of nitrates and nitrites into groundwater, resulting in elevated concentrations [6,12]. It also concurs with the observation that finer texture soils provide ore exchange sites and can bind pollutants better; thus, have a lesser potential for transmission. However, in contrast, coarser-textured soils have a larger transport potential and, therefore, a comparatively higher danger of contaminating ground water [19]. The

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nitrate concentrations in sandy soils, ranging from 0.01mg/L to 0.15 mg/L, and nitrite levels typically less than 0.23 mg/L, observed in this study, are within the range reported by these previous studies.

Clayey soils, on the other hand, tend to retain more nutrients and contaminants, leading to lower leaching rates. The difference between clay and sandy soils lies in the movement of water through them – very slow in clay and rapid in sandy soils. The nitrate concentrations in clay soils ranging from 20 to 100 mg/kg and nitrite levels from 0.1 to 2 mg/kg, as reported by previous studies [12, 14], are in line with the present study's findings. These soil properties help explain the lower nitrate and nitrite levels in well water from clayey soils than to sandy soils.

Moreover, sandy soils have larger particle sizes and higher permeability, allowing nitrates and nitrites from surface sources to leach more easily into the groundwater. This could explain why water from sandy soil sources shows higher concentrations of these compounds than clayey soils, which have smaller particle sizes and lower permeability, thereby acting as a better filter and reducing the leaching of contaminants into the water sources.

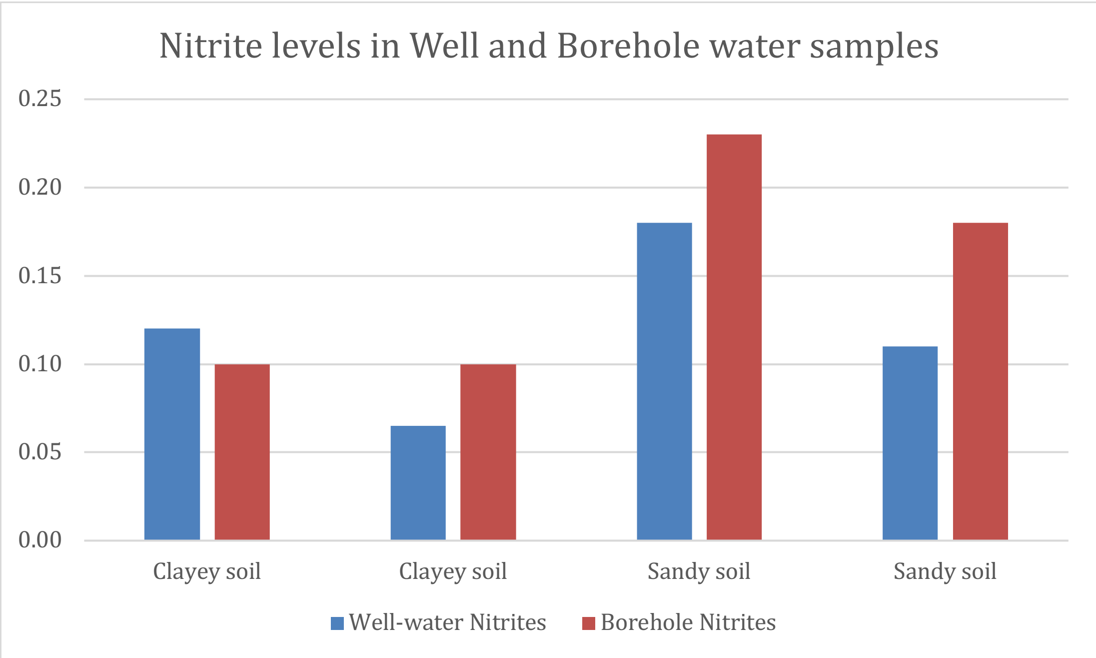

Figure 1: Nitrite levels in well and borehole water samples in Lagos Metropolis

Furthermore, the higher nitrate and nitrite levels in borehole water than to well water is consistent with findings from an earlier study which noted that borehole water, while generally safer due to deeper extraction from underground aquifers, can still be contaminated by nitrates and nitrites, particularly in areas near agricultural fields or waste disposal sites [10]. These findings of nitrate concentrations ranging from 5 to 30 mg/L and nitrite concentrations generally below 0.5 mg/L in borehole water are consistent with observations from the study.

In this study, the nitrate and nitrite concentrations detected in well water—ranging from 10 to 50 mg/L and 0.07 to 0.23 mg/mL respectively—align with findings from previous research, which similarly emphasized the influence of agricultural runoff and inadequate waste management on groundwater quality [7,8,12].

The higher nitrate and nitrite levels observed in borehole water than well water in Lagos metropolis could be attributed to the differences in the depth and protection of the water sources. Boreholes typically access deeper groundwater, which may be more susceptible to contamination from runoff from agricultural land or other sources of nitrates and nitrites due to its closer connection with the broader underground water table. In contrast, well water, being shallower, might be impacted by natural filtration processes through the soil.

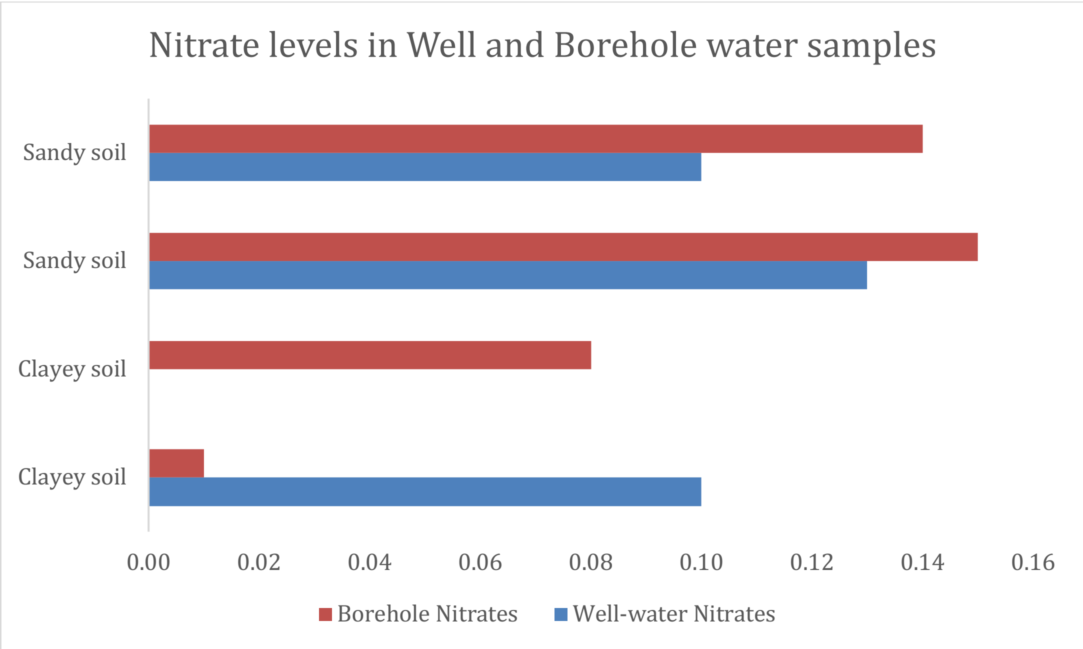

Figure 2: Nitrate levels in well and borehole water samples in Lagos Metropolis

Figures 1.0 and 2.0 above show that nitrate and nitrite levels are predominantly higher in borehole water than in well water in Lagos metropolis. Also, water from sandy soil sources had higher nitrate and nitrite concentrations than water from clayey soil sources.

The associations between nitrite and nitrate levels in soil types from borehole and well water is as presented on table 3.0 above. The highest nitrite and nitrate concentrations were found in borehole water and sandy soil; however, there exist no statistically significant association between nitrite, nitrate in borehole water and soil type; as well as between nitrite, nitrate in well water and soil type. This finding is akin to that reported in the Gaza strip where a significant correlation was found between soil type and well water nitrate level [20].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

In conclusion, this study provides vital insights into the concentrations of nitrate and nitrite in drinking water sources across different soil types within Lagos metropolis. Nitrate contamination in drinking water is associated with methemoglobinemia, or "blue baby syndrome," and other adverse health effects such as hypertension, cancers, congenital malformations, and spontaneous abortions.

It establishes that borehole water generally contains higher levels of nitrate and nitrite compared to well water, and sandy soils are associated with greater contamination levels than clayey soils due to their higher permeability and lower nutrient retention. These findings are consistent with previous research and highlight the influence of soil texture and water source depth on water quality. Although the highest nitrate and nitrite levels were recorded in borehole water from sandy soils, the associations between these contaminants and soil types were not statistically significant.

Nevertheless, the study underscores the need for regular monitoring and targeted interventions to manage water quality, especially in sandy soil regions and borehole-dependent communities, to safeguard public health from potential risks linked to nitrate and nitrite contamination.

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Table 1: Nitrite concentration in drinking water

Soil type	Location	Well (mg/L)	Borehole (mg/L)
A – Clayey soil	Ijanikin, Lagos	0.120 ± 0.001	0.10 ± 0.03
B – Clayey soil	Okota, Lagos	0.065 ± 0.026	0.10 ± 0.03
C – Sandy soil	Ijanikin, Lagos	0.180 ± 0.030	0.23 ± 0.04
D – Sandy soil	Okota, Lagos	0.110 ± 0.004	0.18 ± 0.01

Table 2: Nitrate concentration in drinking water

Source	Location	Well (mg/L)	Borehole (mg/L)
A – Clayey soil	Ijanikin, Lagos	0.10 ± 0.01	0.01 ± 0.04
B – Clayey soil	Okota, Lagos	0.00 ± 0.04	0.08 ± 0.01
C – Sandy soil	Ijanikin, Lagos	0.13 ± 0.03	0.15 ± 0.07
D – Sandy soil	Okota, Lagos	0.10 ± 0.02	0.14 ± 0.02

Table 3: Association of Nitrite and Nitrates levels in soil types from borehole and well water

Soil type	Clayey soil	Sandy soil	P-value
Borehole nitrite (mg/L)	0.10 ± 0.00	0.205± 0.03	0.15
Well nitrite (mg/L)	0.09 ± 0.04	0.145± 0.04	0.37
Borehole nitrate (mg/L)	0.05 ± 0.05	0.15 ± 0.01	0.20
Well nitrate (mg/L)	0.05 ± 0.07	0.12 ± 0.02	0.40

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