



Evaluating the Nitrate to Phosphate Ratio and Other Physicochemical Characteristics of Different Water Sources in Yeghe Community, Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Water quality determination has become essential in characterising the nature of water used by humans for various purposes. This study was therefore carried out to assess the nitrate to phosphate ratio and other physical and chemical parameters influencing the quality of water used for domestic purposes in Yeghe Community, Rivers State, Nigeria. Water samples (from 3 boreholes, 3 river points and 3 wells) were collected randomly for each study period, and subjected to standard laboratory procedures to analyse for parameters such as temperature, pH, nitrate nitrogen, phosphate, total dissolved solid (TDS), dissolved oxygen (DO) and electrical conductivity, using standard procedures. Nutrient limitation in the water sources was evaluated based on critical ratios produced by Redfield, using nitrate and phosphate as limiting nutrients. The nitrate to phosphate ratios indicated that there were more of phosphate limitations in the samples, as only two of the samples showed nitrate limitation, with the well water samples showing no nitrate limitation. The study also showed that all the physico-chemical parameters were within the WHO limits, except for pH that had values below the regulatory standard. Statistical evaluation of the data showed a significant difference ($p < 0.05$) between the physicochemical parameters of the different water sources (river, tap and well), except for temperature that recorded no significant difference ($p > 0.05$). This novel study on physicochemical water quality determinants has provided baseline and

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reference data set for monitoring the pollution status of the different water sources of this rural community. Local health authorities should however regulate anthropogenic activities around these water sources to ensure the availability of safe for use water sources in this locality.

Keywords: Nitrate to phosphate ratio; physicochemical characteristics; water sources; Yeghe community.

1. INTRODUCTION

In the past decades, the provision of portable source of water was entirely the responsibility of the government. Due to increase in population, there is however a reduction in the availability of portable water. This cannot be unconnected with the increase in both industrial and agricultural activities that result in the release of pollutants into the environment resulting in both surface and underground water pollution. Its decreasing availability both in quality and quantity has been a major public health concern in Africa, particularly in Nigeria [1].

The major factors that cause reduction in water quality are related to urbanization [2], including anthropogenic activities largely caused by the poor and unhygienic living habit of people as well as the unfriendly environmental practices of factories, industries and agricultural practices, resulting in the discharge of effluents and untreated wastes [3,4].

Environmental monitoring of surface water indicated that streams and rivers in Niger delta Nigeria are showing increasing trend of water pollution due to increased population, industrialization, urbanization and exploration [5]. This has therefore led to an increase in the demand for usable water, both in the urban and rural areas. The inability of government to meet the daily demands of water for the people has forced some private individuals and communities to seek alternatives and self-help measures of providing water. In some localities, dugout wells and boreholes are the major sources of domestic water. Also, in some rural communities, untreated surface water from rivers, dams, and streams is directly used for drinking and other domestic purposes [6].

The quality of water is usually described in terms of its physicochemical and biological (bacteriological) properties. Both parameters constitute water quality indices, which are vital in communicating information on water quality trends. Physicochemical indices are based on the values of various physicochemical qualities in

a water sample. These indices play a crucial role in quality monitoring [7].

Various physicochemical parameters have been studied and reported to influence water quality. They are therefore analyzed during water quality determination to evaluate the suitability of water for a particular purpose. According to John and Mark [8], all water is made up of natural pollutants (organic and inorganic), most especially inorganic pollutants leached from the rock through which the water courses. The effect of these water quality parameters constitute their environmental and public health importance.

The pH of water is very important, as water pH below the value of 7 is considered acidic and may corrode metals. According to Jibrin et al. [9], acidic water is capable of leaching toxic trace metals from geological materials from which it has contact into the ground aquifer. Also, water with a pH above 7 is considered alkaline and may cause alteration in the taste of the water.

Electrical conductivity of water is the measure of its ability to conduct electricity. Electrical conductivity of water indicates how much of the minerals are present in water, but does not specify which element is present. High values of Electrical Conductivity mean that there are pollutants such as chloride, sodium etc. It is an indicator of water quality and soil salinity.

Temperature influences water chemistry, controls the speed of metabolic activities, influences water's ability to hold oxygen and influences other water parameters. At higher temperatures, rate of chemical reactions increase generally and more minerals from underground rocks dissolve in water. Also, High water temperature can increase the proliferation of water borne pathogenic microorganisms that can be detrimental to people who ingest it. According to Sa'eed and Amira [10], Rise in temperature may increase problems of odor and taste.

Oxygen is another import factor considered in water analysis. Both Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) emphasize on the role of oxygen as a

water quality variable. According to Bashir [11], biochemical oxygen demand is the amount of oxygen needed to dissolve organic matter present in water using aerobic bacteria. Chemical Oxygen Demand is the quantity of oxygen dissolved in water that can oxidize (chemical oxidation) both inorganic and organic compounds in water. It is done to determine the amount of these compounds available in water. Also, Dissolved oxygen (DO) is very crucial for survival of aquatic organisms and it is also used to evaluate the degree of freshness of a river [12].

Nitrates and phosphates are important elements by which plants needs for their growth. They can be generated from the soil by the plants and made available to man through diets. These anions exist as metallic salts and supplied as polyphosphates, zinc sulphate, potassium chloride or potassium nitrate or as mixed fertilizer [3]. When a water body is polluted by nitrates it becomes a threat because it can lead to methemoglobinemia in children which may also cause mental retardation if the child survives. Also, excess concentration of nitrate and phosphate ions in shallow water bodies gives rise to enrichment of nutrient salt leading to the production of algal bloom, a process called eutrophication: dissolved oxygen in the water body are highly used up by the organisms thereby leading to the suffocation and death of aquatic plants and animals. The dead plants and animals decay, creating deterioration of water quality [13,14]. According to World Health Organization (WHO) standard, the guideline limit of nitrate and phosphate in surface water are 50 mg/L and 5 mg/L respectively [1].

Several studies have reported on the surface water physicochemical parameters and pollution indices of various water bodies and their sediments in River states and Niger delta [15]. However, only a few study [16] have probed into

the nutrient status of these various water bodies. Due to this paucity of information, with regards to nitrate and phosphate limitations in the water bodies, this study was therefore, aimed at determining, as a novel study, the physicochemical quality of the different sources of domestic water and as well assess the pattern of nitrate and phosphate limitations in the various sources of water.

2. MATERIALS AND METHODS

2.1 Study Area Duration

The study was carried out in Yeghe Community in Gokana Local Government Area of Rivers State, within 4°40'60" N and 7°21'0" E in DMS (Degrees Minutes Seconds). The study was conducted at monthly interval for a period of three months (January – March 2021), following WHO guidelines.

2.2 Sample Collection

The samples were collected in triplicates from three different water sources (well, tap and stream).

Sample from the borehole was allowed to run freely for a while before collection. The samples were placed in ice packs and transported aseptically, in icepacks, to Rivers State University, Department of Microbiology Laboratory for analysis.

2.3 Description of Sample Collection Points

The water samples were collected randomly from the various sites using sterile bottles. The sampling points involved three samples each from Yeghe River (Upstream, midstream and downstream), Tap 1, 2 and 3 in Yeghe Community, and Well 1, 2 and 3, as presented in the Table 1.

Table 1. Sample collection points and coordinates

Sample ID	Sample Description	Coordinates (DMS)
RU	River upstream	4°40'65" N and 7°20'0" E
RM	River midstream	4°40'55" N and 7°18'0" E
RD	Rivers downstream	4°40'60" N and 7°15'0" E
T ₁	TAP 1	4°40'50" N and 7°11'0" E
T ₂	TAP 2	4°40'67" N and 7°28'0" E
T ₃	TAP 3	4°40'70" N and 7°24'0" E
W ₁	WELL 1	4°40'66" N and 7°23'0" E
W ₂	WELL 2	4°40'58" N and 7°31'0" E
W ₃	WELL 3	4°40'75" N and 7°22'0" E

2.4 Determination of the Physico-chemical Properties of the Water Samples

Parameters such as temperature, pH, nitrate nitrogen, phosphate, conductivity, dissolved oxygen, and total dissolved solid were determined using the methods from APHA [7].

2.5 Assessing the Nitrate: Phosphate Ratios of the Water Sources

The nitrate to phosphate ratio was used to study nutrient limiting pattern in the water bodies. It was determined by dividing the concentration of nitrate, C_N by that of phosphate, C_P .

The result was interpretation based on the Redfield ratio, as $N: P \text{ ratio} < 16 = \text{Nitrate limitation}$, while $N: P \text{ ratio} > 16 = \text{Phosphate limitation}$.

2.6 Statistical Methods

A One-way Analysis of Variance (ANOVA) was used to check for significant difference between each of the different samples. The mean separation was analysed using Tukey High significant difference (HSD).

3. RESULTS

The result of the physicochemical parameters as presented in Table 2 showed that the highest temperature was recorded at RD (River downstream) with a value of 28.9°C . While the lowest temperature (27.1°C) was recorded at W3 (Well 3).

The pH of the water samples varied between 4.6 ± 0.1 and 6.3 ± 0.01 with the highest at the RD (River downstream) sample, with the least pH obtained from T1 (Tap 1) sample.

The least amount of Total Dissolved Solid (TDS) $7.3 \pm 1.5 \text{ mg/L}$ was obtained at RM (River midstream) and RU (River upstream) with the highest at W3 (Well 3) having a value of $56.7 \pm 1.5 \text{ mg/L}$.

The least electrical conductivity of $15 \pm 0.5 \mu\text{scm}$ was obtained at RM (River Midstream) with W3 (Well 3) having the highest electrical conductivity of $113 \pm 1.0 \mu\text{scm}$.

The result of the analysis for nitrate nitrogen had the least value of $1.1 \pm 0.01 \text{ mg/L}$ obtained from RD (River Downstream), while W3 (Well 3) had the highest value of $3.45 \pm 0.03 \text{ mg/L}$.

The amount of phosphate varied between 0.02 mg/L and 0.23 mg/L with the least obtained from W3 (Well 3), while the highest was obtained from RM (River Midstream).

The amount of dissolved oxygen varied between 5.60 and 7.31 with RD (River Downstream) and T3 (Tap3) having the least values and T1 (Tap 1) having the highest value.

Table 3 presents the result for the comparative analysis of the mean physicochemical parameters of the water sources, and it shows that the river water samples were less acidic ($6.0 \pm 0.$) than the underground water sources (well and tape water samples), which were within the acidic range of 4.7 and 4.8 for tap water and well water, respectively. For total dissolved solid (TDS), river water recorded the least value (8.2 ± 1.5) while well water had the highest mean TDS value of $40.4 \pm 12.3 \text{ mg/l}$.

Similar trend was observed for the other parameters with the river water having the least value, and well water having the highest, as the readings for tap water were always lower than the value for well water but higher than river water.

However, with respect to temperature, tap water samples had the highest mean value (27.9 ± 0.42) for the three months sampled, followed by river water (27.5 ± 0.71), with well water recording the least temperature (27.4 ± 0.31).

Statistical analysis using a one-way analysis of variance showed that there was a significant difference ($p < 0.05$) between the values of the physicochemical properties studied, except for temperature and dissolved oxygen, that showed no significant difference ($p > 0.05$).

A comparison with regulatory standards (WHO) showed that all the parameters evaluated were within the limits required, except for pH that had values below the regulatory limits ($6.5 - 8.5$).

The result of the Nitrate to Phosphate Ratio showed that W3 (Well 3) had the highest value of 171.5 while the least value was obtained from Rm (River Midstream) with a value of 5.52 .

However, based on RedField ratio, two of the water sources (River midstream and Tap 3) showed a nitrate limiting condition (low nitrate concentration), as their $N: P$ ratios were all less than 16 ($N: P \text{ ratio} < 16$), while the rest showed a phosphate limiting condition since they all had $N: P$ ratios > 16 .

Table 2. Mean physicochemical parameters of the different sample stations in Yeghe community

Parameter	Rd	Rm	Ru	T1	T2	T3	W1	W2	W3	P-value
Temperature (°C)	28.9±1.1 ^a	27.3±0.7 ^a	27.2±0.1 ^a	27.9±0.2 ^a	27.5±0.3 ^a	28.4±0.3 ^a	27.4±0.3 ^a	27.7±0.2 ^a	27.1±0.1 ^a	0.4690
pH	6.3±0.01 ^a	5.9±0.1 ^b	5.9±0.02 ^b	4.6±0.1 ^e	4.8±0 ^d	4.9±0 ^c	4.7±0.1 ^d	4.7±0.1 ^d	4.9±0.01 ^c	<0.0001*
TDS (mg/l)	9.3±1.5 ^e	7.3±1.5 ^e	8.0±1.0 ^e	21.0±1.0 ^c	31±2.6 ^b	15±1.0 ^d	33.7±2.5 ^b	31±1.0 ^b	56.7±1.5 ^a	<0.0001*
EC (us/cm)	17.2±0.8 [†]	15±0.5 [†]	16±1.0 [†]	42±1.0 ^d	61.3±1.5 ^c	32±1.0 ^e	68±1.0 ^b	63±0.5 ^c	113±1.0 ^a	<0.0001*
Nitrate (mg/l)	1.1±0.01 ^g	1.3±0.01 ^f	1.31±0.02 ^f	1.76±0.02 ^e	2.22±0.02 ^d	1.75±0.05 ^e	2.41±0.01 ^b	2.32±0.02 ^c	3.45±0.03 ^a	<0.0001*
Phosphate (mg/l)	0.1±0.01 ^{bc}	0.23±0.03 ^a	0.03±0.02 ^{bc}	0.03±0.02 ^{bc}	0.03±0.01 ^{bc}	0.18±0.01 ^a	0.05±0.01 ^{bc}	0.07±0.02 ^b	0.02±0.01 ^c	<0.0001*
DO (mg/l)	5.6±0.06 ^c	7.2±0.06 ^a	7.23±0.06 ^a	7.31±0.06 ^a	7.17±0.06 ^a	5.57±0.06 ^c	7.23±0.06 ^a	7.21±0.02 ^a	6.83±0.05 ^b	<0.0001*

*Pair of means with different superscript in each row are significantly different while same superscript are not significantly different.

NB: Rd – River downstream; Rm – River midstream; Ru – River upstream; T – Tape water; W – Well water

Table 3. Mean physicochemical properties of the major water sources in Yeghe Community

Parameter	River water	Tap water	Well water	P-value
Temperature (0C)	27.5±0.71 ^a	27.9±0.42 ^a	27.4±0.31 ^a	0.0657
pH	6.0±0.2 ^a	4.7±0.2 ^b	4.8±0.1 ^b	<0.0001*
TDS (mg/l)	8.2±1.5 ^c	22.3±7.2 ^b	40.4±12.3 ^a	<0.0001*
EC (us/cm)	15.7±1.3 ^c	45.1±13 ^b	81.3±23.9 ^a	<0.0001*
Nitrate (mg/l)	1.24±0.08 ^c	1.91±0.23 ^b	2.73±0.55 ^a	<0.0001*
Phosphate (mg/l)	0.1±0.09 ^a	0.08±0.08 ^a	0.05±0.02 ^a	<0.0001*
DO (mg/l)	6.66±0.82 ^a	6.68±0.84 ^a	7.09±0.2 ^a	0.3398

*Pair of means with different superscript in each row are significantly different

NB: Rd – River downstream; Rm – River midstream; Ru – River upstream; T – Tape water; W – Well water.

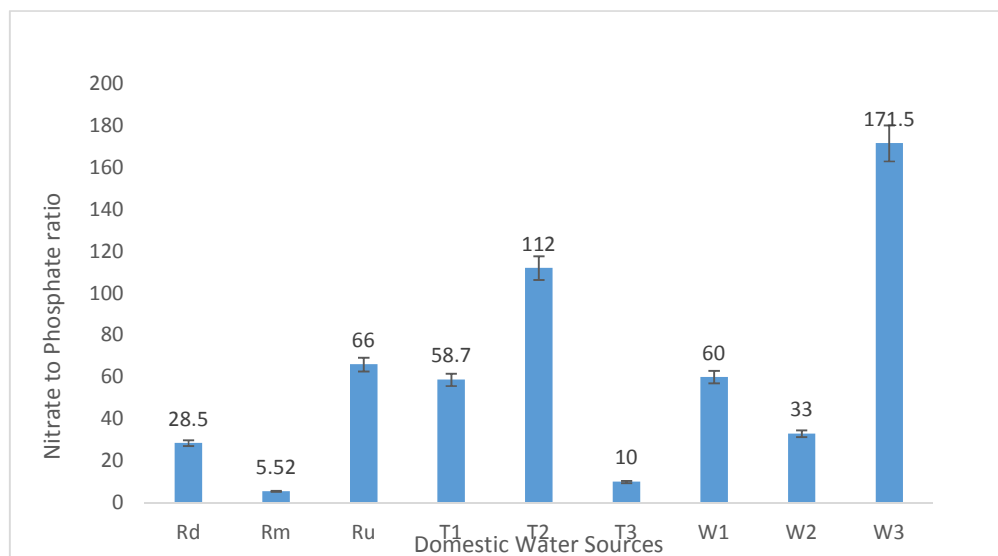


Fig. 1. Pattern of nitrate and phosphate limitation in the various water sources

NB: Rd – River downstream; Rm – River midstream; Ru – River upstream; T – Tape water; W – Well water

4. DISCUSSION

The physicochemical properties influencing water quality was investigated and the result showed that most of the parameters were within the WHO recommended limit except for pH that had limits below the recommended value. This implies that water, based on the physicochemical parameters is safe for use except for that of pH alone.

Based on World Health Organization [17] recommended limit, the pH should be between the levels of 6.5 to 8.5. The implications of pH have been reported [9]. Acidic pH ranges of water is capable of leaching toxic trace metals from geological materials from which it has contact into the ground water aquifer. Acidic water can also leach metals from plumbing systems, which can cause leakage in pipes. It was further observed that the pH values of all the

water sources were within the acidic range, and that of the river water samples being significantly higher than the well and tap water sources. Different factors are known to influence the pH of water, including manmade and natural conditions. The natural influences include carbonate materials and limestone present in soil. On the other hand the manmade influences are associated with pollutions resulting from agricultural runoffs, industrial and domestic waste discharges. In other words, the pH influences may be regarded as internal and external factors and may include variations in temperature, chlorination, presence of soluble iron and manganese in water. Outside influences can affect pH such as the release of hydrocarbons from poly or storage water tanks made with plastics, as rises in pH can occur when water is stored in tanks. Also, petrochemical activity may affect pH. Magnetic water treatment will cause shifts in pH in either

direction, depending on the make-up of the water. In this study the reason behind river water having pH values higher than that of well and tap water is attributable to lithological factors. Another possible reason could be as result of the storage conditions of the tap water sources, as plastic storage tanks may affect the pH of the water. Furthermore, the difference in nitrate concentration could account for the difference in pH levels, as higher nitrate concentration reduces the pH of water samples. From this study it was observed that the river water samples had lower nitrate concentrations and higher pH values than the other water sources. Also, an increase in temperature results in decrease in pH of water. This phenomena was observed in Table 3 and could possibly account for the difference in pH between the river water and the well water as well as the difference between the well water and tap water samples. This was however not the case for the river and tap water sources. This implies that other factors other than temperature could be responsible for this variation.

Statistical analysis showed that there was a significant difference ($p < 0.05$) in the mean physicochemical parameters across the samples, except for temperature and dissolved oxygen. While other studies on water quality in the Niger Delta region had indicated the implications of bacterial contamination of domestic sources [18,19], this present study has shown that water sources have different physical and chemical properties, and this dynamics may play a critical role in the health impact analysis and indices.

The findings from this study is line with that of previous researchers within the Niger Delta region of Nigeria, including Gokana Local Government area of River State [20,21].

Redfield ratio or Stoichiometry is the consistent atomic ratio of carbon, nitrogen and phosphorus found in marine phytoplankton and throughout the deep oceans. The term was named for an American oceanographer Alfred C. Redfield who in 1934 first described the relatively consistent ratio of nutrients in marine biomass samples collected across several voyages on board the research vessel *Atlantis*, and empirically found the ratio to be C:N:P = 106:16:1 [22]. They also help in determining which nutrients are limiting in a localized system, if there is a limiting nutrient. The ratio can also be used to understand the formation of phytoplankton blooms and subsequently hypoxia by comparing the ratio between different regions, such as a comparison

of the Redfield Ratio of the Mississippi River to the ratio of the northern Gulf of Mexico [23]. Controlling N:P could be a means for sustainable reservoir management [24].

The result of the Nitrate to Phosphate Ratio in this study showed that W3 (Well 3) had the highest value of 171.5 while the least value was obtained from Rm (River Midstream) with a value of 5.52. However, based on the RedField ratio, two of the water sources (River midstream and Tap 3) showed a nitrate limiting condition (low nitrate concentration), as their N: P ratios were all less than 16 (N: P ratio < 16), while the rest showed a phosphate limiting condition since they all had N: P ratios > 16 .

The implication of this finding shows that there may be an exogenous source of contamination as most of the samples had higher nitrate to phosphate ratio, compared to the RedFields ratio of 16. In nitrate limitation (low nitrate concentration), denitrification and other nitrate removal process are factors responsible. Another possible cause of nitrate limitation could be tied to phosphate addition (due to possible pollution from different sources) processes occurring in the aquatic system. Phosphate limitation (low phosphate) on the other hand implies more of nitrate, less phosphate addition and an associated less risk of eutrophication.

Nitrate and phosphate concentration are important factors in the eutrophication of water, as excessive concentrations, mostly in shallow water bodies, usually results in overgrowth of water plants leading to the formation of algal bloom. This in turn causes a high consumption of dissolved oxygen in the water, leading to the suffocation and death of aquatic plants and animals, and an associated deterioration of water quality [13,14]. Anthropogenic sources include; fertilizers, wastewater and septic system effluent, animal wastes, detergents, industrial discharge, phosphate mining, drinking water treatment, forest fires, synthetic material development surface [25,26].

Due to the public health environmental concerns associated with nitrate and phosphate pollution, regular monitoring of water quality is critical to ensure that these values are maintained within permissible limits. This can be achieved by controlling human activities within and around these water bodies. This will involve the prohibition of waste disposal into the aquatic systems, as well as monitoring other anthropogenic factors contributing to water pollution.

5. CONCLUSION

The study on the major domestic water sources in Yeghe Community has revealed that the physical and chemical parameters influencing water quality, except for pH, are within the limits of WHO guideline values. The findings from this study therefore makes the need for regular monitoring very critical as this will help to regulate and main the quality of the water sources within regulatory limits.

From the analysis involving the nitrate to phosphate ratio, it can be inferred that most of the water sources are influenced by phosphate limiting conditions, with associated less risk of eutrophication than nitrate limitation, showing higher risk of eutrophication.

This study has therefore established the physicochemical characteristics of the various water types used for domestic purposes in Yeghe Community and have provide important reference date for future research and health policy formulation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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