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ANALYSIS OF THE NUTRITIONAL STATUS OF SURFACE (EPIE CREEK) AND UNDERGROUND (BOREHOLES) WATER SOURCES IN YENAGOA, BAYELSA STATE.

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ABSTRACT: *The knowledge of dietary intakes of essential mineral elements from water is also important for proper assessment of the actual contribution of drinking water to daily nutrient requirements aside from food. This study aimed to explain drinking water contribution to the intakes of dietary elements and assess the overall situation in Bayelsa State. Water was sampled following analytical standards from two sources at six locations for four months in Yenagoa. Results show that all the assessed mineral elements were within the recommended dietary intakes; Na, Mg, Ca, Man, Zn, K, F and Cl were within the recommended permissible limits by WHO (2019) except for phosphorus and fluoride. Results from the innovative Drinking Water Nutritional Quality Index ranged between 12.057 - 24.41 for the Epie Creek and 16.324 - 31.131 for boreholes; scientifically described as poor. The overall comprehensive mean Drinking Water Nutritional Quality Index is 37.698; scientifically described as poor, where Ca and Fe exerted the most influence on the DWNQI scores for the studied water samples. These results represented the poor contribution of water nutrient elements for the overall human health; thus, it is a wakeup call for improvement through the provision of reliable potable water in the state.*

KEYWORDS: Surface and underground water, Epie Creek, Recommended Daily intake of water, Nutritional Water Quality Index, Hazard Quotient.

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INTRODUCTION

Water assessment has gained prominence in the environmental and ecological study with special focus on water quality and quantity, ecological health, sanitation and hygiene (WASH). This is because the key dimensions of water that are of importance for humanity are its availability, access, stability, and quality (Ringler et al., 2023) but with little attention to the nutritional quality of water for a healthy life. As part of encouraging Nigeria's 'on course' to meet one target for maternal, infant, young child and adult nutrition (MIYCAN) in the country, the knowledge of dietary intakes of essential mineral elements from water is important for proper assessment of the actual contribution of drinking water to daily nutrient requirements asides from food. Foods are mostly considered to be the predominant source of essential mineral nutrients in the diet (Ayedun, Gbadebo & Idowu, 2023; Abtahi et al., 2016), however, drinking water can also contribute to intakes of the minerals in addition to hydrating as its main function. These knowledge gaps are well articulated in the 2020 Dietary Guidelines Advisory Committee Scientific Report, which notes that "the degree to which hydration is a problem in segments of the population is an open question" and "better information about water intake is needed (Dietary Guidelines Advisory Committee Scientific Report, 2020:5). Consequently, upon this, the traditional approaches to water analysis overlook the nutritional aspects of drinking water to human health, but this study seeks to carve a niche on the nutritional quality of surface (Epie Creek) and underground (boreholes) water sources in Yenagoa, Bayelsa State using the Drinking Water Nutritional Quality Index as a way of shifting from contamination analysis to nutritional analysis. Thus, this study presents the first application of DWNQI in the Niger Delta region; as it aimed to explain drinking water contribution to the intakes of dietary elements and assess the overall situation in Bayelsa State.

MATERIALS AND METHODS

Study Area

The study was conducted in Yenagoa between June/July and November/December, 2024. Yenagoa is an industrially developing capital city of Bayelsa State, Nigeria that lies between latitude $4^0$55'N and $4^0$57'N and longitudes $6^0$15'E and $6^0$18'E in the coastal area of Nigeria at an elevation of 8 m (26 ft) above sea level (fig.1). The city is endowed with networks of creeks (Taylor, Epie and Ekole) which are mainly supplied by the Nun and Orashi River (Ebuete et al., 2019; Osaribie et al., 2023). The city has an estimated population of 524,400 persons (Wikipedia, 2022). Further details of the geology of Yenagoa and Epie Creek is documented in Amangabara and Ejenma (2012), Okiongbo and Akpofure (2012), Nwankwoala et al. (2014), Obi (2016), Oki and Akana (2016) and Ebuete et al. (2019). In Yenagoa, Koinyan, Nwankwoala and Eludoyin reported that 89.2% total required water for domestic and drinking purposes is sources from underground (private boreholes), 7.5% surface (Epie creek) and only 3.3% from rainfall (Koinyan, Nwankwoala & Eludoyin, 2013). Hence, the analysis of water contribution to the nutritional intake in humans from various water sources became necessary.

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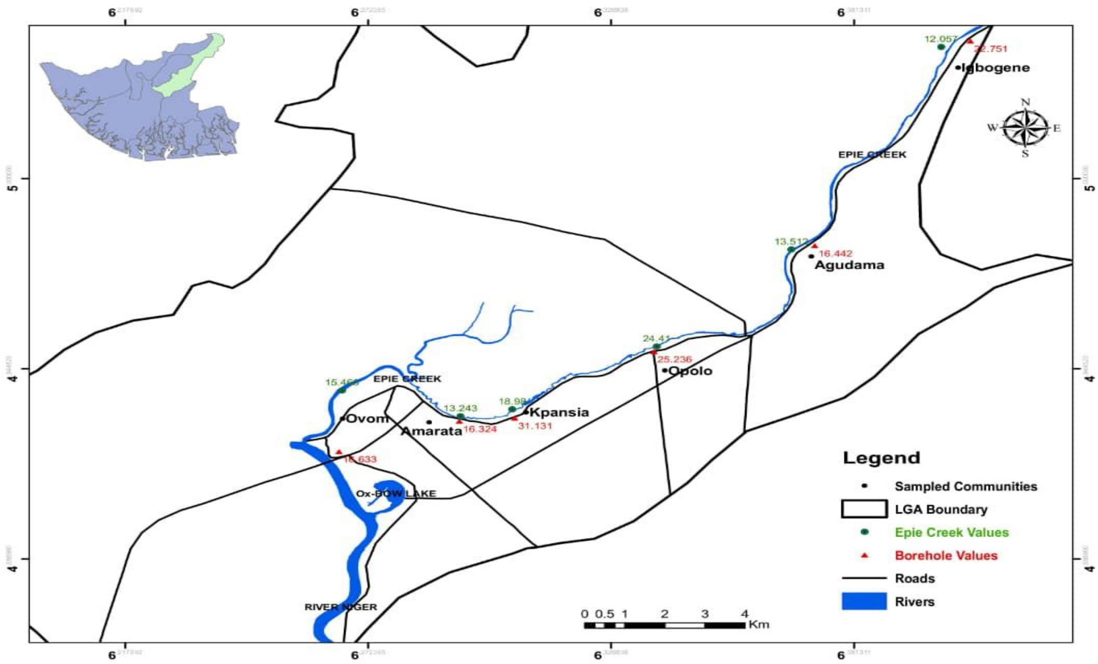

Figure 1: Map showing Water Sampled Site and Nutritional Water Quality Index in Yenagoa. **Source:** *Researcher, 2024.*

Water Sample

Water samples were purposely collected from the Epie Creek and private treated boreholes following analytical procedures by the American Public Health Association, APHA, (1998) In Oboh and Osuala (2017) for four months (June/July and November/December, 2024) from six (6) communities (Igbogene, Agudama, Opolo, Kpansia, Amarata and Ovom) (Figure 1) within the metropolis. The selection aimed to ensure comprehensive coverage of the study area to analyze for ten key nutritional elements such as Sodium (Na), magnesium (Mg), Calcium (Ca), manganese (Mn), Zinc (Zn), Iron (Fe), potassium (K), Fluoride (F), phosphorus (P) and chlorine (Cl) that play crucial roles in both human health and environmental processes.

Underground water sources: Water samples were collected from already sunken treated boreholes in a well labeled screw cap 0.75L capacity container. The tap water was allowed to run for 10 seconds to ensure a true representation of the samples; the container was pre-rinsed three times with the tap water to avoid contamination, filled while leaving sufficient air space for water expansion. On the other hand (Epie Creek), the 0.75L screw cap capacity bottle was pre-rinsed three times with water from the Epie Creek at the collection point, lower down to about 20cm, filled and cooked underwater with space for water expansion. Samples were carefully labelled, held at 4°C in ice cooler box without acid preservation for laboratory analysis. The water samples were then subjected to laboratory analyses for both cations and anions. Iron and manganese were analyzed using atomic adsorption spectrophotometer. All utilized plastics wares for this study were pre-washed with detergent water solution, rinsed and soaked for 48 hours in 50% HNO_3, then rinsed thoroughly with distilled deionized water.

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Sample Techniques

Drinking Water Nutritional Quality Index:

The analyzed water samples were processed using an innovative drinking water nutritional quality index (DWNQI) for assessing drinking water contribution for the intakes of dietary elements as detailed by Agbasi et al. (2024). According to Abtahi et al. (2016), the DWNQI was developed in five steps to reveal a concerning nutritional trend.

Daily Water Nutritional Quality Index (DWNQI) = Sum N x W .... Equ. 1

Where: N = Normalized nutritional elements; W = Assigned weighted values that is gotten through the following steps:

Step 1: Identify Nutritional Components (Minerals: Calcium, Iron, Magnesium, etc.).

Step 2: Normalizing the values of each Nutrients: N= A / B X 100 .... Equ. 2

Where: N = Unit Normalized Value; A: Mean Conc. per unit nutrient (mg/L); B: Unit Maximum permissible Limits. This step converts the absolute content into a relative scale, facilitating comparison across different nutrients.

Step 3: Assigning weight factor for each input mineral: W= A / V .... Equ. 3

Where: W=Assigned Weight (g); A= Mean concentration per unit (mg/L); V = Volume (L) of sample collection container in liters; where in this study is 0.75L. Convert values from mg/L into g/L (unit of mass).

Step 4: Describing the DWNQI scores (from 0 to 100) in five categories as poor (0–44.9), marginal (45.0–59.9), fair (60.0–69.9), good (70.0–79.9) and excellent (80.0–100).

Furthermore, elements were compared with Recommended Dietary intakes (RDIs) and WHO (2019) for mineral concentrations in drinking water and drinking water consumption. The RDIs of a nutrient is the average daily intake levels that are sufficient to meet the nutrient requirements of nearly all (97.5%) healthy individuals in the given age-sex groups (Agbasi, *et al.,* 2024).

2.3.2 Hazard Quotient (HQ)

The Hazard Quotient is a ratio used in risk assessment to evaluate the potential non-carcinogenic health risks associated with exposure to hazardous substances. It is calculated by dividing the estimated exposure level of a chemical by its reference dose (RfD) or acceptable daily intake (ADI). The formula is represented as:

HQ= CDI/RfD ....…....…... Equ. 4

Where: RfD (mg/kg^{-day}) = Oral Reference Dose for each element, basically access from the IRIS Process for Developing Human Health Assessments (EPA, 2024).

CDI is Chronic Daily intake (A x Rl / W x Y) .... Equ. 5

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Where: A = Sum means concentration of the element, RI= Required Daily Water consumption (3.53 L/day; Meinders & Meinders, 2010); W= average body weight (65kg; Akinpelu, Oyewole & Adekanla, 2015); Y= Per annual assessment (365 days; Markmanuel, Godwin & Ebuete, 2023).

Note: Any Hazard Quotient greater than one (1) indicates that the exposure level exceeds the reference dose, suggesting a potential risk to health, whereas an HQ below one (1) suggests that the exposure is within acceptable limits.

RESULTS PRESENTATION AND DISCUSSION

Result Presentation

Laboratory results of nutritional elements from the Epie Creek and boreholes are presented in tables below

Table 3.1: Mean Sampled Concentration of Nutritional Elements (mg/l)

Samples	Sour	Na	Mg	Ca	Mn	Zn	Fe	K	F	P	Cl
Igbogene	**E**	4.39	3.44	12.15	0.04	0.08	1.61	0.91	0.01	0.09	13.43
	B	6.34	4.13	10.22	0.06	0.04	2.52	1.12	0.02	0.01	16.78
Agudama	**E**	8.64	3.39	14.43	0.02	0.05	1.22	0.85	0.01	0.10	18.96
	B	5.37	4.82	18.52	0.07	0.03	0.83	1.52	0.01	0.02	27.02
Opolo	**E**	9.62	4.06	19.66	0.05	0.06	2.01	0.94	0.03	0.08	15.31
	B	6.44	4.37	15.12	0.07	0.03	2.34	2.11	0.01	0.01	24.33
Kpansia	**E**	8.55	4.42	17.54	0.04	0.01	2.25	1.34	0.02	0.11	15.25
	B	4.78	5.02	21.06	0.06	0.04	0.89	2.15	0.03	0.02	29.45
Amarata	**E**	6.75	4.51	15.67	0.03	0.02	2.40	1.32	0.02	0.09	24.84
	B	8.69	4.93	18.74	0.01	0.03	2.46	2.06	0.02	0.03	29.19
Ovom	**E**	9.13	5.09	16.10	0.03	0.04	2.47	1.40	0.02	0.10	31.13
	B	6.17	5.43	14.35	0.04	0.02	1.66	2.11	0.01	0.02	39.64
Total	**E**	**47.08**	**24.91**	**95.55**	**0.21**	**0.26**	**11.96**	**6.77**	**0.11**	**0.471**	**118.92**
	B	**37.79**	**28.7**	**98.01**	**0.31**	**0.19**	**10.72**	**11.07**	**0.1**	**0.38**	**166.41**
WHO		**200**	**50**	**25**	**0.2**	**4**	**0.3**	**20**	**1.5**	**0.05**	**200**
RDI		**2300**	**420**	**1000**	**2.3**	**11**	**18**	**3000**	**4**	**700**	**2300**

Source: *Researcher, 2024; WHO (2019) mg/l; all Recommended Daily intakes (mg/Day) were sourced from MedlinePlus (2024) website. E (Epie) and B (Boreholes)*

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Table 3.2: Analyzed Drinking Water Nutritional Quality Index (DWNQI)

Sources	Igbogene	Agudama	Opolo	Kpansia	Amarata	Ovom	Mean Total
Epie Creek	12.057	13.512	24.41	18.98	13.243	15.466	**16.278**
Boreholes	22.751	16.442	25.236	31.131	16.324	16.633	**21.420**

Source: *Researcher, 2024*

Table 3.3: Hazard Quotient of Nutritional Mineral Elements

Source	Na	Mg	Ca	Mn	Zn	Fe	K	F	P	Cl
Epie Creek	*233.50	0.82	*14.22	0.22	0.13	2.5	*201.46	0.27	3504	*176.94p
Boreholes	*186.89	0.95	*14.58	0.33	0.094	2.3	*329.42	0.25	2604	*247.60
RfD	**3^{-2}**	**4.5**	**1^{-3}**	**1.4^{-1}**	**3^{-1}**	**7^{-1}**	**5^{-3}**	**6^{-2}**	**2^{-5}**	**1^{-1}**

Source: *Researcher, 2024. All RfD values were sourced from the EPA (2024). N/B: HQ>1= suggesting a potential risk to health. * Element with potential Health risk*

DISCUSSION

Sodium (Na):

Sodium is an essential electrolyte that plays a key role in maintaining fluid balance within the body. It helps regulate blood pressure and blood volume, ensuring that bodily organs receive enough blood supply and its recommended daily intake of sodium is 2,300mg for most adults (MedlinePlus, 2024). However, sodium deficiency, or hyponatremia include nausea, headache, confusion, and in severe cases, seizures or coma (Braun & Mahowald, 2017). Records from this study show that sodium concentration ranges between 4.39-9.62mg/l and 3.39 - 5.09mg/l respectively for Epie Creek and boreholes (table 1). The values were within the recommended daily intakes of 2,300mg and 200 mg/l maximum permissible level recommended by World Health Organization (2019). Similarly, Ben-Eledo et al. (2017), Oki and Akana (2016), and Nwankwoala et al. (2014) reported similar values within the study area.

Magnesium (Mg)

Magnesium is crucial for multiple physiological functions, including enzyme activity, muscle contraction, nerve transmission, energy metabolism and protein synthesis, bowel preparation for medical procedures and served as laxative for constipation. It also contributes to proper brain function, bone health, heart and muscle activity.The maximum recommended daily dose of magnesium for adults is 420 mg for males and 350 mg for females (Alawi, Majoni & Falhammar, 2018). Magnesium deficiency causes numbness, osteoporosis, high blood pressure, clogged arteries, hereditary heart disease, diabetes, stroke, tingling, muscle contractions and cramps, seizures, personality changes, abnormal heart rhythms and coronary spasms (Witkowski, Hubert & Mazur, 2011). The mean concentration of Mg ranged between 3.39-5.09mg/l and 4.13-5.43mg/l respectively for the Epie Creek and boreholes. These values

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are within the recommended daily intake of 420mg/day and 50mg/l maximum permissible level by the World Health Organization (WHO, 2019). From the study area, magnesium presents especially from boreholes is source from dissolves minerals of feldspar and mica etc. (Nwankwoala et al., 2014). Similarly, Nwankwoala et al. (2014), Ben-Eledo et al. (2017), Oki and Akana (2016), and Egbo and Eremasi (2023) reported similar values in Bayelsa State. On the other hand, Table 3 expressed that the hazard quotient of magnesium (8.2^{-1} and 9.5^{-1}) is less than one (1) technically may not cause potential health risk hazard on users.

Calcium (Ca)

Calcium is vital for bone health, muscle function, and cardiovascular activity; hence adequate intake of calcium is essential to prevent conditions such as osteoporosis, hypertension, renal calcification, brain calcification; neurologic symptoms (e.g., depression and bipolar disorder); osteomalacia, cataracts; congestive heart failure; paresthesia; seizures; and, in rare cases, coma (Song, 2017). The recommended daily intakes of calcium is 1,000 mg/day for adults and increases to 1,200 mg/day for individuals over 70 years (MedlinePlus, 2024). The mean concentration of Ca ranges between 12.15-19.66mg/l and 10.22-21.06mg/l respectively for the Epie Creek and boreholes (table 1). These values are within the recommended daily intake of 1000 mg/day and the maximum permissible level of 25 mg/l by the World Health Organization (WHO, 2019) (Table 1). The presence of calcium in water from the study area is as a result of the dissolution of feldspars and micas in the Benin formation and the adjourning basement complex (Nwankwoala et al. 2014). Similar report in the study area were recorded by Koinyan, Nwankwoala and Eludoyin (2016), Nwankwoala et al. (2014), Oki and Akana (2016), Ben-Eledo et al. (2017) and Egbo and Eremasi (2023).

Manganese (M)

Manganese is an important trace mineral that aids bone formation, blood sugar regulation, and antioxidant defense; its role in synthesizing certain hormones and connective tissues cannot be overemphasis at a recommended daily intake of 1.8mg/day for women and 2.3mg/day for men (MedlinePlus, 2024). Manganese deficiency is relatively uncommon, but it can lead to a range of health issues such as impaired growth, skeletal abnormalities, poor wound healing, and increased oxidative stress due to a reduced antioxidant capacity (Li & Yang, 2018). The mean concentration of Mn ranges between 0.02-0.08mg/l and 0.01-0.07mg/l respectively for the Epie Creek and boreholes. This report is within the recommended daily intakes of the element of 2.3mg/day and within the maximum recommended value of 0.2mg/l by the World Health Organisation (WHO, 2019). Similar study by Oki and Akana (2016) 0-0.02mg/l; Ben-Eledo, et al. (2017) 0.016-0.188mg/l; Egbo and Eremasi (2023) 0.125mg/l - 1.032mg/l reported similar ranges of values within the study area. The values from the Analyzed Hazard Quotient of 2.2^{-1} and 3.3^{-1} are less than one (1); hence no potential hazard from the water users within the study area (table 3).

Zinc (Zn)

Zinc is integral for the functioning of over 300 enzymes and the body processes such as digestion, metabolism, and nerve function. It contributes to the immune system health by activating the T-lymphocyte (Marriott et al., 2020). Based on its importance, its daily recommended intake is 8 mg/day for women and 11 mg/day for men (MedlinePlus, 2024). Zinc deficiency in older adults causes delays in wound healing and changes in cognitive and

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psychological function (Roohani et al., 2013). The mean zinc concentration range between 0.01-0.08mg/l and 0.02-0.06mg/l respectively for the Epie Creek and boreholes (table 1) which is within the recommended daily intakes of the element 11 mg/day (table 1) and the maximum permissible limits of 4 mg/l by the World Health Organization (WHO, 2019). The Hazard Quotient of Zinc ($1.31^{-1}$and 9.4^{-2}) will not cause potential hazard on the water users (table 3). Amangabara and Ejenma (2012) reported a similar value of 0.004mg/l on the Epie Creek.

Iron (Fe)

Iron is a fundamental component of hemoglobin that is essential for the production of collagen and certain neurotransmitters, supporting overall cellular function and energy metabolism. Recommended daily intakes of Iron are 18 mg/day (women), 8mg/day (men) (MedlinePlus, 2024). Iron deficiency can lead to anemia, characterized by fatigue, weakness, and pale skin, while long-term deficiency can impair immune function and cognitive performance (Hurrell & Egli, 2010). The average iron concentration ranges between 1.22-2.47mg/l and 0.83-2.52mg/l for the Epie Creek and boreholes respectively which is within the recommended daily intakes of 18mg/day (table 1). The mobility and subsequent downward infiltration of iron through the porous and permeable formation account for the presence of iron in the water from the study area (Nwankwoala et al., 2014). Similarly, Nwankwoala et al. (2014) 0.01mg/l - 0.98mg/l; Ben-Eledo, et al. (2017) 0.32-2.52 mg/l; Oki and Akana (2016) 0.06-0.28mg/l; Nwankwoala and Eludoyin (2016) 0.001-0.073mg/l reported related range within the study area and Egbo and Eremasi (2023) 1.356mg/l and 3.120mg/l within the Kolo Creek.

Potassium (K)

Potassium plays a critical role in maintaining fluid balance, nerve transmission, and muscle contraction with a recommended daily intake of 2,500 mg to 3,000 mg/day for adults (MedlinePlus, 2024). Deficiency increases blood pressure, kidney stone risk, hypokalemia, bone turnover, hypertension, cardiovascular diseases, urinary calcium excretion, and salt sensitivity (IOM_Institute of Medicine, 2005; Hinderling, 2016). The mean concentration ranges between 0.85-1.40mg/l and 1.12-2.15mg/l respectively for the Epie Creek and boreholes, which is within the recommended daily intakes of 2,500mg/day and the recommended maximum permissible limits of 20 mg/l by the World Health Organization (WHO, 2019) (table 1). The presence of this ion could be probably resulting from the dissolution of feldspar, mica and clay minerals (Nwankwoala et al., 2014). Similarly, Nwankwoala et al. (2014) 0.20-1.62mg/l, and Oki and Akana (2016) 0.6-4.67 recorded similar values in their studies.

Fluorine (F)

Fluorine primarily contributes to dental health such as the prevention of tooth decay, however, excessive fluoride exposure can lead to dental and skeletal fluorosis (Sanou et al., 2022). The acceptable intake of fluorine is generally set around 0.05 mg/kg of body weight per day and its recommended daily intake is 3mg/day for women and 4 mg/day for men (MedlinePlus, 2024). The mean concentration of fluoride ranges between 0.01-0.03mg/l and 0.01-0.03mg/l respectively for the Epie Creek and boreholes which is within the required recommended daily intake of 4mg/day and 0.05mg/l maximum permissible level by the World Health Organisation (WHO, 2019). Similarly, Egbo and Eremasi (2023) reported a range of 0.03mg/l and 0.17mg/l

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in the Emeyal Clan of the Kolo creek. The record of $2.7^{-1}$and 2.5^{-1}respectively for the Epie Creek and boreholes indicate no potent hazard on end users (table 3).

Phosphorus (P)

Phosphorus plays a role in deoxyribonucleic acid (DNA), ribonucleic acid (RNA), adenosine diphosphate (ADP), and adenosine triphosphate (ATP) that are essential for bone health, energy production, and cellular function (Kotoski, 1997). The Recommended Dietary Allowance (RDA) for phosphorus is 700mg per day; although it varies based on age, sex, and life stage (MedlinePlus, 2024). However, some effects of hypophosphatemia include anorexia, anemia, proximal muscle weakness, skeletal effects (bone pain, rickets, and osteomalacia), increased infection risk, paresthesias, ataxia, and confusion (Erdman, Macdonald & Zeisel, 2012). The phosphorus concentration range between 0.08-0.11mg/l for the Epie Creek which is within the recommended dietary allowances of 700mg/l; also, the range of 0.01-0.03mg/l for Boreholes (table 1) is within the recommended dietary allowances of 700mg per day; although it is above the limit of 0.05mg/l by the World Health Organization. The Hazard Quotient of the element is also greater than one (1) (Table 3). The high concentrations above the limit 0.05mg/l in the Epie is linked to the decay of organic material like in sewage; for report had it that a normal adult excretes 1.3 - 1.5 g of phosphorus per day which are mostly source from the use of industrial products, such as toothpaste, detergents, pharmaceuticals, and food-treating compounds (Kotoski, 1997). (Ben-Eledo, et al. 2017, 2.06-5.26 mg/l; Ebuete, et al. (2019) 0.26-0.34 and 0.55-1.62mg/l for dry and wet season respectively.

Chlorine (Cl)

Chloride is the second most abundant electrolyte in the body with recommended daily intake of 2,300 mg/day for adults (MedlinePlus, 2024) that is crucial for maintaining osmotic balance, component of gastric acid, aiding in digestion (Toxicological Profile for Chlorine Atlanta (GA), 2010). Chlorine deficiency in human causes Electrolyte Imbalance, Acid-Base Imbalance, Dehydration, Digestive Issues, resulting to Fatigue, Muscle Cramps and Weakness, Digestive Disturbances, Dry Skin, Mucous Membranes, Increased Blood Pressure that may lead to hypertension (Signorelli et al., 2020). The mean concentration of chlorine ranges between 13.43-31.13mg/l and 16.78-39.64mg/l for the Epie Creek and boreholes respectively (table 1). These records are within the recommended daily intakes of the element and also within the recommended permissible limits by the World Health Organization of 200mg/ (WHO, 2019) (table 1); an indication that no salt water encroachment into water surfaces. Similar report was recorded by Koinyan, Nwankwoala and Eludoyin (2017) 1.5-4.3; Oki and Akana (2016) 8-47mg/l; Nwankwoala et al. (2014) 6.25-12.67mg/l within the study area.

Drinking Water Nutritional Quality Index (DWNQI)

The proper assessment of the actual contribution of drinking water to daily nutrient requirements using the drinking water nutritional quality index revealed a range of 12.057 - 24.41 for the Epie Creek and 16.324 - 31.131 in boreholes (table 2) which literally classified as poor. Inspite of the poor water nutrient contribution to human health in the study area, the borehole contributed about 56.82% while the Epie Creek is 43.18%. Beside the little water treatment given to the underground water sources to improved quality; boreholes supply over 89.2% total domestic and drinking water of the inhabitant in the study area and only 7.5% on the Epie creek.

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Summarily, the introduced Drinking Water Nutritional Quality Index (DWNQI) in Yenagoa presents its first application in the Niger Delta region. The ten key mineral elements in water play crucial roles in human health and served as nutritional transition, which includes a change from consumption of traditional to modern diets that feature high-energy density and low nutrient diversity such as edibles food, fruits, meat, fish etc while presenting a proper assessment of the actual contribution of drinking water in the Niger Delta to daily nutrient requirements. Therefore, this study provided a new perspective of water quality and environmental sustainability for policy decisions.

CONCLUSION

The study presents the importance of water elements to the total amount of nutrients one should get each day. The study shows that all the ten nutritional elements from surface and underground water sources fall within the Recommended Daily intakes (RDI) and of the total elements in this study, eight were within the recommended permissible limits by WHO (2019) except for phosphorus and fluoride. Following the analysis of hazard quotient of the elements, Mg, Mn, Zn and F cause no potential health risk hazard on end users while Na, Ca, K and Cl possess potent risk on the health of users. Results from the innovative Drinking Water Nutritional Quality Index ranged between 12.057 - 24.41 for the Epie Creek and 16.324 - 31.131 for boreholes, scientifically described as poor. This further shows that underground water sources provided and contributed slightly better nutritional elements to end users. At a 5% statistical level, the difference concerning water sources is significant (F-*ratio* 15.882>6.61); this was also applicable with the differences concerning sampled communities (F-*ratio* 32.920>5.05). The overall comprehensive mean of the Drinking Water Nutritional Quality Index is 37.698, scientifically described as poor; while the sensitivity analysis revealed Ca and Fe to have exerted most influence on the DWNQI scores for the studied water samples.

RECOMMENDATIONS

Based on the above findings, the study therefore recommended that:

i. Government should provide reliable water sources to improved nutritional intake via water

ii. Public health initiatives to address potential mineral deficiencies should be developed.

iii. Coordinating water with nutrition and health interventions

iv. Improving agricultural water management for better diets for all.

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