Epublic Health Significance of Nutrients, Heavy Metal and Total Heterotrophic Bacteria Interaction in Water Bodies in Port Harcourt and Its Environs

[1] **Bibiye, A.A.S and [2] Eddeh-Adjugah, O.G.**

1. Rivers State College of Health Science and Management Technology, School of Environmental Health Technology
2. Institute of Geosciences and Environmental Management, Rivers State University

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ABSTRACT: *Water is an essential commodity for all living things. It is an inorganic compound that can exist in solid, liquid and gaseous state under normal condition. The quality of any water body depends on certain factors such as the absence and or very neglectable amount of Total Heterotrophic bacteria count, heavy metal including physicochemical parameters among others. This study was carried during the dry season of 2021, and accounts for groundwater, surface and well water in Abuloma, Borikiri, Eagle-Island, Fimie, Macoba-Isaka, Ruekini and Rumuokoro respectively. Water samples were collected in 10ml sterile containers and labeled appropriately. Sample for the River was collected at the pelegial level stoppered while submerged. Sample from the boreholes and hand-dogged wells were collected in line with the American Public Health Association (APHA, 2107). The samples for the determination of heavy metal contents were fixed with 2 drops of concentrated trioxonitrate (V) acid (HNO_3) while that for microbial analysis were preserved in ice chests to inhibit the activity of microbes and were sent to the laboratory for further analysis. Results indicated that the nutrients (NO_3^-, SO_4^{3-} and PO_4^{2-}) values appeared insignificant (i.e., values are within the acceptable levels) when compared with European Union guidelines for water consumption except PO_4^{2-} for well water at Rumuekini and Rumuokoro respectively. The THBC factor was high in Abuloma for all the nutrients in surface water. Also, in well water, at Eagle-Island, Pb appeared elevated above the European Union standard for drinking water quality. Thus, it is recommended that well water from Eagle-Island be treated (i.e., the removal of Pb) to ensure it quality and safety for human consumption.*

KEY WORDS: Toal heterotrophic bacteria, nutrients, heavy metal, public health

INTRODUCTION

Every living being depend on water in one way or the other. Water is an essential commodity for humans and other living creatures [1]. It is the only inorganic compound existing in its solid, liquid and gaseous physical state under normal conditions [2]. Water typologies include groundwater (well, borehole, spring etc.) and surface water (streams, river, lake etc.) [3]. Groundwater has been one of the most valuable natural resources that support human health, economy development and ecological diversity. Seventy percent (70%) of the earth surface is covered by water and sixty-five percent (65%) of the human body is made up of water [3] [4]. Out of the total water been consumed by human beings, more than fifty percent 50% is consumed for industrial purposes. However, only a small portion is consumed for drinking [5]. Thus, good water quality for drinking is needed for man to maintain sound health and prevent diseases [6]. Both ground and surface water geologically are linked with the recharge and discharge phenomenon of the hydrological cycle.

Water must be available, acceptable, affordable and accessible by all. In public and environmental health dimension, the acceptability of water is an explicit function of its quality or wholesomeness [7]. Water quality simply means and include the chemical, physical, and biological characteristics of water based on the standards of its usage [8]. It is most frequently used by reference to a set of standards against which compliance, generally achieved through treatment of the water, can be assessed [9]. The most common standards used to monitor and assess water quality convey the health of ecosystems [10] [8]. Water quality mostly for drinking can be inhibited by the excess presence of heavy metals and physicochemical parameters including microbial load. In this scenario, its acceptability can be impaired. Right from the days of old, water has been a vehicle for the transmission of various diseases like Cholera, Typhoid, Dracunculiasis, Giardiasis, Dysentery, etc. [11] [12]. Microorganisms are highly sensitive to heavy metal pollution and play an important role in the material cycling, energy flow and water quality of the ecosystem. The Heterotrophic bacteria are bacteria that use organic nutrients for growth. These bacteria are universally present in all types of water, food, soil, vegetation, and air [13]. They can be anaerobic or aerobic, and could be dangerous to human health [14] [15] [16]. The amount of Total Heterotrophic Bacteria (THBC) in water body mostly for human consumption (drinking) also influences the quality of such water.

Albeit, metals are substances that has high electrical conductivity, malleability, and luster, which readily loses electrons to form a positive ion [17]. However, there is no one widely agree criterium-based definition for heavy metal. In metallurgy, it is define based on density [18], in physics it might be atomic number [19], while in biologist or chemist define it based on chemical behaviours [20]. Density criteria range from above 3.5 gcm^{-3} to above 7 gcm^{-3} [21]. In most cases, a density of more than 5 gcm^{-3} is sometimes mentioned as a common heavy metal defining factor [22]. Some of these heavy metals (Cu, Zn, Fe etc.) play an essential role in the biochemistry of living organisms while at excess concentration may become inimical not only to the surrounding of the organism but the organism(s) itself [23] [24]. For example, copper (Cu) in water could improve digestive system, boost metabolism, help fight obesity, stimulate brain and improves its functioning, boost immunity and promotes overall well-being [25] whereas excess utilization can cause liver and kidney toxicity amongst others [24]. It has been observed that heavy metal pollution has become one of the foremost worries of human beings since it is associated with hidden, persistent, and irreversible variables [26] [27]. Furthermore, Pb exerts both physical and behavioural effect on children, infants, and foetuses even at lower exposure level than adult, mostly the vulnerable children [28]. Heavy metal interference in water bodies is an inhibition of water quality for human consumption [29] [30] [31].

MATERIAL AND METHOD

Study Area

The geographical coordinate of Port Harcourt has Latitude 4°49′27.0012″N and Longitude 7° 2′0.9996″ E respectively. The city a tropical climate, significant rainfall pattern in most months of the year with a short dry season that has little effect and lies 9 meter above sea level. The area is overwhelmed with multinational company most of whom are oil-based industries. This has given rise to the daily increase of people into the city. The variance in precipitation between the driest month and the wettest month is 378 mm or 15 inches [52].

Collection of Water Samples

Water samples for laboratory analysis were collected with the aid of 10ml sterile containers from running tap, river and hand dogged wells. The samples were labeled according to the source and location, respectively. Samples for the determination of heavy metal contents were fixed with 2 drops of concentrated trioxonitrate (V) acid (HNO_3). Water sample for the microbial analysis were preserved in ice chests to inhibit the activity of microbes.

Sampling Locations

Groundwater, surface water and hand dogged well water were established in Obio/Akpor and Port Harcourt City Local Government Areas of Rivers State. Out of the seven sampling points, Rumuekini was used as the control.

Laboratory Analysis

All the water quality parameter measured was expressed in mg/L and samples were analyzed in line with the experimental procedure of the American Public Health Association [32]. Details of the experimental methods and equipment used are given elsewhere [33] [34].

RESULT

Physicochemical Properties and THBC Interaction in Groundwater The concentration of Nitrate (NO_3^-) and the Total Heterotrophic Bacteria Count (THBC) across the sampling stations was $2.85x10^{-1}$ mg/L and $6.50x10^{-1}$cfu/ml (Abuloma), $2.55x10^{-1}$mg/L and $6.00x10^{-1}$cfu/ml (Borikiri), $5.70x10^{-1}$ mg/L and $10.25x10^{1}$cfu/ml (Eagle-Island), $2.45x10^{-1}$mg/L and $2.00x10^{-1}$cfu/ml (Fimie), $2.35x10^{-1}$ mg/L and $6.00x10^{-1}$cfu/ml (Macoba-Isaka), $2.75x10^{-1}$ mg/L and $4.80x10^{1}$ cfu/ml (Rumuekini), and $2.95x10^{-1}$mg/L and $1.25x10^{1}$cfu/ml respectively. Concentration of SO_4^{3-} and THBC across the sampling locations were $5.00x10^{-1}$ mg/L and $6.50x10^{-1}$ cfu/ml (Abuloma), $2.00x10^{1}$mg/L and $6.00x10^{-1}$ cfu/ml (Borikiri), $8.50x10^{1}$ mg/L and $10.25x10^{1}$ cfu/ml (Eagle-Island), $2.00x10^{1}$ mg/L and $2.00x10^{-1}$cfu/ml (Fimie), $4.50x10^{1}$ mg/L and $6.00x10^{-1}$ cfu/ml (Macoba-Isaka), $2.50x10^{1}$mg/L and $4.80x10^{1}$ cfu/ml (Rumuekini), and $2.50x10^{1}$ mg/L and $1.25x10^{1}$ cfu/ml (Rumuokoro) correspondingly while the concentration of phosphate (PO_4^{2-}) and the THBC values were $2.95x10^{-1}$ mg/L and $6.50x10^{-1}$ cfu/ml (Abuloma), $2.20x10^{-1}$ mg/L and $6.00x10^{-1}$ cfu/ml (Borikiri), $2.24x10^{1}$ mg/L and $10.25x10^{1}$cfu/ml (Eagle-Island), $3.30x10^{-1}$ mg/L and 2.00x10^{-1}cfu/ml (Fimie), 2.60x10^{-1}mg/L and 6.00x10^{-1}cfu/ml (Macoba-Isaka), 1.15x10^{-1}mg/L and 4.80x10^{1}cfu/ml (Rumuekini), and 4.50x10^{-1} mg/L and 1.25x10^{1} cfu/ml (Rumuokoro) respectively (Table 1).

The THCB variables down the Table 1 shows unique variant across sampling locations. For example, at Abuloma, the THBC exhibited 6.50x10^{-1}cfu/ml for Nitrate, Sulphate and Phosphate respectively which slightly varied with that of Borikiri, 6.00x10^{-1}cfu/ml, Eagle-Island (10.25x10^{1}) cfu/ml, Fimie (2.00x10^{-1}) cfu/ml, Macoba-Isaka (6.00x10^{-1})cfu/ml, Rumuekini (4.80x10^{1})cfu/ml and Rumuokoro (1.25x10^{1})cfu/ml for Nitrate, Sulphate and Phosphate. This difference is clearly observed across the other locations. The highest THBC value of Nitrate, Sulphate and Phosphate was in Eagle-Island (10.25x10^{1}) cfu/ml while the corresponding minimum (1.25x10^{1}) cfu/ml value was recorded in Rumokoro (Table 1).

Table 1: Groundwater (Borehole) THBC (cfu/ml) for the Physicochemical Properties

Physical Properties	**Conc. / THBC**	**ABU**	**BOR**	**EAI**	**FIM**	**MAC**	**RUM**	**ROM**
NO_3^- (mg/L)	Conc.	2.85x10^{-1}	2.55x10^{-1}	5.70x10^{-1}	2.45x10^{-1}	2.35x10^{-1}	2.75x10^{-1}	2.95x10^{-1}
	THBC	6.50x10^{-1}	6.00x10^{-1}	10.25x10^{1}	2.00x10^{-1}	6.00x10^{-1}	4.80x10^{1}	1.25x10^{1}
SO_4^{3-} (mg/L)	Conc.	5.00x10^{-1}	2.00x10^{1}	8.50x10^{1}	2.00x10^{1}	4.50x10^{1}	2.50x10^{1}	2.50x10^{1}
	THBC	6.50x10^{-1}	6.00x10^{-1}	10.25x10^{1}	2.00x10^{-1}	6.00x10^{-1}	4.80x10^{1}	1.25x10^{1}
PO_4^{2-} (mg/L)	Conc.	2.95x10^{-1}	2.20x10^{-1}	2.24x10^{1}	3.30x10^{-1}	2.60x10^{-1}	1.15x10^{-1}	4.50x10^{-1}
	THBC	6.50x10^{-1}	6.00x10^{-1}	10.25x10^{1}	2.00x10^{-1}	6.00x10^{-1}	4.80x10^{1}	1.25x10^{1}

Phys.=Physicochemical Properties, Conc.=Concentration, THBC=Total Heterotrophic Bacteria Count, ABU=Abuloma, BOR=Borikiri, EAI=Eagle-Island, FIM=Fimie, MAC=Macoba-Isaka, RUM=Rumuekini, ROM=Rumokoro.

Physicochemical Properties and THBC Interaction in Surface water

The physicochemical variables (Nitrate, sulphate and phosphate) and the Heterotrophic Bacteria interaction in surface water (River) shows that that the concentration NO_3^- and THBC was 1.95x10^{-1} mg/L and 21.50x10^{1} cfu/ml (Abuloma), 4.20x10^{-1} mg/L and 4.20x10^{1}cfu/ml (Borikiri), 2.10x10^{1} mg/L and 7.20x10^{-1} cfu/ml (Eagle-Island), 3.00x10^{-1} mg/L and 2.00x10^{-1} cfu/ml (Fimie), 1.33x10^{-1} mg/L and 8.40x10^{-1}cfu/ml (Macoba-Isaka), 7.30x10^{-1} mg/L and 2.25x10^{1} cfu/ml (Rumuekini), and $2.60x10^{-1}$mg/L and $9.10x10^{1}$ cfu/ml (Rumuokoro). SO_4^{3-} has $3.00x10^{-1}$ mg/L and $21.95x10^{1}$ cfu/ml (Abuloma), $2.76x10^{-1}$ mg/L and $4.20x10^{1}$cfu/ml (Borikiri), $1.43x10^{-1}$ and $7.20x10^{1}$ cfu/ml (Eagle-Island), $2.97x10^{1}$ mg/L and $2.00x10^{-1}$cfu/ml (Fimie), $20.50x10^{1}$cmg/L and $8.40x10^{1}$ cfu/ml (Macoba-Isaka), $2.97x10^{-1}$ mg/L and $2.25x10^{1}$ cfu/ml (Rumuekini), and $7.50x10^{1}$ mg/L and $9.10x10^{1}$cfu/ml (Rumuokoro) (Table 2). PO_4^{2-} had $6.75x10^{-1}$ mg/L and $21.95x10^{1}$ cfu/ml (Abuloma), $2.60x10^{-1}$ mg/L and $4.20x10^{1}$ cfu/ml (Borikiri), $6.95x10^{-1}$ mg/L and $7.20x10^{1}$ cfu/ml (Eagle-Island), $6.80x10^{-1}$ mg/L and $2.00x10^{-1}$ cfu/m;l (Fimie), $1.80x10^{-1}$ mg/L and $8.40x10^{1}$cfu/ml (Maciba-Isaka), $8.25x10^{-1}$ mg/L and $2.25x10^{1}$ cfu/ml (Rumuekini), and $1.30x10^{-1}$mg/L and $9.1x10^{1}$ cfu/ml (Rmuokoro) respectively (Table 2). The THBC factor for Nitrate, Sulphate and Phosphate in Abuloma showed dissimilarities. THBC for Nitrate was $21.50x10^{1}$cfu/ml while that for Sulphate and Phosphate was $21.95x10^{1}$cfu/ml respectively. Borikiri had $4.20x10^{1}$cfu/ml, Eagle-Island had $7.20x10^{-1}$ cfu/ml, Fimie had $2.00x10^{-1}$ cfu/ml, Macoba-Isaka had $8.40x10^{1}$ cfu/ml while Rumuekini was $8.40x10^{1}$cfu/ml and Rumuokoro was $9.1x10^{1}$ cfu/ml. Maximum THBC was recorded in Abuloma ($21.95x10^{1}$ cfu/ml) while the minimum value was recorded in Fimie ($2.00x10^{-1}$cfu/ml) (Table 2).

Table 2: Surface water (River) THBC (cfu/ml) for the Physicochemical Properties

Physical Properties	Conc. / THBC	ABU	BOR	EAI	FIM	MAC	RUM	ROM
NO_3^- (mg/L)	Conc.	$1.95x10^{-1}$	$4.20x10^{-1}$	$2.10x10^{1}$	$3.00x10^{-1}$	$1.33x10^{-1}$	$7.30x10^{-1}$	$2.60x10^{-1}$
	THBC	$21.50x10^{1}$	$4.20x10^{1}$	$7.20x10^{-1}$	$2.00x10^{-1}$	$8.40x10^{-1}$	$2.25x10^{1}$	$9.10x10^{1}$
SO_4^{3-} (mg/L)	Conc.	$3.00x10^{-1}$	$2.76x10^{-1}$	$1.43x10^{-1}$	$2.97x10^{1}$	$20.50x10^{1}$	$2.97x10^{-1}$	$7.50x10^{1}$
	THBC	$21.95x10^{1}$	$4.20x10^{1}$	$7.20x10^{-1}$	$2.00x10^{-1}$	$8.40x10^{-1}$	$2.25x10^{1}$	$9.10x10^{1}$
PO_4^{2-} (mg/L)	Conc.	$6.75x10^{-1}$	$2.60x10^{-1}$	$6.95x10^{-1}$	$6.80x10^{-1}$	$1.80x10^{-1}$	$8.25x10^{-1}$	$1.30x10^{-1}$
	THBC	$21.95x10^{1}$	$4.20x10^{1}$	$7.20x10^{-1}$	$2.00x10^{-1}$	$8.40x10^{-1}$	$2.25x10^{1}$	$9.1x10^{1}$

Phys.=Physicochemical Properties, Conc.=Concentration, THBC=Total Heterotrophic Bacteria Count, ABU=Abuloma, BOR=Borikiri, EAI=Eagle-Island, FIM=Fimie, MAC=Macoba-Isaka, RUM=Rumuekini, ROM=Rumokoro.

Physicochemical Properties and THBC Interaction in Well water

The concentration of Nitrate in Abuloma was $3.35x10^{-1}$ mg/L, Borikiri ($3.40x10^{-1}$) mg/L, Eagle-Island ($5.6x10^{-1}$) mg/L, Fimie ($2.45x10^{-1}$) mg/L, Macoba-Isaka ($1.05x10^{-1}$) mg/L, Rumuekini ($4.80x10^{-1}$) mg/L and Rumuokoro ($4.00x10^{-1}$) mg/L. The minimum concentration of Nitrate was located at Macoba-Isaka ($1.05x10^{-1}$) mg/L while the maximum concentration was located at Eagle-

Island ($5.6x10^{-1}$) mg/L. Maximum THBC was located at Eagle-Island ($9.40x10^{1}$) cfu/ml while the minimum value was located at Borikiri ($1.15x10^{1}$) cfu/ml (Table 3). Abuloma had $4.65x10^{1}$ cfu/ml, Fimie ($7.00x10^{-1}$) cfu/ml, Macoba-Isaka ($3.30x10^{1}$) cfu/ml, Rumuekini ($2.25x10^{1}$) cfu/ml, and Ruomoro ($7.10x10^{-1}$) cfu/ml (Table 3). At Abuloma, Borikiri, Eagle-Island and Fimie, the concentration of sulphate was $5.00x10^{1}$cfu/ml, $14.50x10^{1}$cfu/ml, $23.50x10^{1}$cfu/ml, and $4.50x10^{1}$ cfu/ml correspondingly while $12.00x10^{1}$ cfu/ml, $2.50x10^{1}$ cfu/ml and $13.50x10^{1}$ cfu/ml were values for Macoba-Isaka, Rumuekini, and Rumuokoro respectively. Maximum THBC for sulphate was recorded in Rumuekini ($18.05x10^{1}$) cfu/ml while its minimum value was recorded in Borikiri ($1.65x10^{1}$) cfu/ml. Abuloma had $4.65x10^{1}$ cfu/ml, Eagle- Island ($10.25x10^{1}$) cfu/ml, Fimie ($4.40x10^{1}$), Macoba-Isaka ($9.00x10^{-1}$) cfu/ml, and Rumuokoro ($8.60x10^{1}$) cfu/ml (Table 3). The minimum concentration of Phosphate was recorded in Borikiri ($1.95x10^{-1}$) mg/L while its maximum concentration was recorded in Eagle-Island ($7.05x10^{-1}$) mg/L. Abuloma had ($3.40x10^{-1}$) mg/L, Fimie ($3.55x10^{-1}$) mg/L, Macoba-Isaka ($4.75x10^{-1}$) mg/L, Rumuekini ($5.85x10^{-1}$) mg/L and Rumuokoro ($5.30x10^{-1}$) mg/L respectively. Minimum THBC was recorded in Rumuokoro ($5.1x10^{-1}$) cfu/ml whereas the maximum value of THBC was recorded in Eagle-Island ($9.40x10^{1}$) cfu/ml. Also, Abuloma had ($4.65x10^{1}$) cfu/ml, Borikiri ($1.15x10^{1}$) cfu/ml, Fimie ($7.00x10^{-1}$) cfu/ml, Macoba-Isaka ($3.30x10^{1}$) cfu/ml and Rumuekini ($2.25x10^{1}$) cfu/ml respectively (Table 3).

Table 3: Well water THBC (cfu/ml) for the Physicochemical Properties

Physical Properties	Conc. / THBC	ABU	BOR	EAI	FIM	MAC	RUM	ROM
NO_3^- (mg/L)	Conc.	$3.35x10^{-1}$	$3.40x10^{-1}$	$5.6x10^{-1}$	$2.45x10^{-1}$	$1.05x10^{-1}$	$4.80x10^{-1}$	$4.00x10^{-1}$
	THBC	$4.65x10^{1}$	$1.15x10^{1}$	$9.40x10^{1}$	$7.00x10^{-1}$	$3.30x10^{1}$	$2.25x10^{1}$	$7.10x10^{-1}$
SO_4^{3-} (mg/L)	Conc.	$5.00x10^{1}$	$14.50x10^{1}$	$23.50x10^{1}$	$4.50x10^{1}$	$12.00x10^{1}$	$2.50x10^{1}$	$13.50x10^{1}$
	THBC	$4.65x10^{1}$	$1.65x10^{1}$	$10.25x10^{1}$	$9.00x10^{-1}$	$4.40x10^{1}$	$18.05x10^{1}$	$8.60x10^{1}$
PO_4^{2-} mg/L)	Conc.	$3.40x10^{-1}$	$1.95x10^{-1}$	$7.05x10^{-1}$	$3.55x10^{-1}$	$4.75x10^{-1}$	$5.85x10^{-1}$	$5.30x10^{-1}$
	THBC	$4.65x10^{1}$	$1.15x10^{1}$	$9.40x10^{1}$	$7.00x10^{-1}$	$3.30x10^{1}$	$2.25x10^{1}$	$5.1x10^{-1}$

Phys.=Physicochemical Properties, Conc.=Concentration, THBC=Total Heterotrophic Bacteria Count, ABU=Abuloma, BOR=Borikiri, EAI=Eagle-Island, FIM=Fimie, MAC=Macoba-Isaka, RUM=Rumuekini, ROM=Rumokoro.

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Heavy metals and THBC Interaction in Groundwater (Borehole)

The heavy metal and microbial quality of groundwater sources in Abuloma, Borikiri, Eagle-Island, Fimie, Macoba-Isaka, Rumuekini and Rumuokoro revealed that some of the groundwater sources were contaminated with heavy metal. The concentration of Zinc (Zn) and Copper (Cu) ranged from $1.00x10^{-3}$ mg/L to $3.90x10^{-2}$ mg/L while Iron (Fe) and Lead (Pb) ranged from $1.00x10^{-3}$ mg/L to $7.22x10^{-1}$ mg/L. Total Heterotrophic bacteria count (THBC) across the sampling locations ranged from $2.00x10^{-1}$ cfu/ml to $21.95x10^{1}$ cfu/ml. The highest THBC was obtained in groundwater (Fe) sample from Abuloma while the least count was obtained in Fimie (Zn), Fimie (Cu), Fimie (Fe) and Fimie (Pb) (Table 4).

Table 4: Groundwater (Borehole) THBC (cfu/ml) for Heavy Metal Concentration

Phys. Properties	Conc. / THBC	ABU	BOR	EAI	FIM	MAC	RUM	ROM
Zn (mg/L)	Conc.	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.20x10^{-2}$
	THBC	$6.50x10^{-1}$	$6.00x10^{-1}$	$10.25x10^{1}$	$2.00x10^{-1}$	$6.00x10^{-1}$	$4.80x10^{1}$	$1.25x10^{1}$
Cu (mg/L)	Conc.	$3.00x10^{-1}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$3.90x10^{-2}$	$1.00x10^{-3}$	$1.00x10^{-3}$
	THBC	$6.50x10^{-1}$	$6.0x10^{-1}$	$10.25x10^{1}$	$2.00x10^{-1}$	$6.10x10^{-1}$	$4.80x10^{1}$	$1.25x10^{1}$
Fe (mg/L)	Conc.	$1.00x10^{-3}$	$2.59x10^{-1}$	$1.62x10^{-2}$	$1.00x10^{-3}$	$7.12x10^{-1}$	$7.22x10^{-1}$	$1.20x10^{-2}$
	THBC	$21.95x10^{1}$	$4.20x10^{1}$	$7.20x10^{1}$	$2.00x10^{-1}$	$6.40x10^{1}$	$2.25x10^{1}$	$9.40x10^{1}$
Pb (mg/L)	Conc.	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$	$1.00x10^{-3}$
	THBC	$6.25x10^{-1}$	$6.00x10^{-1}$	$10.25x10^{1}$	$2.00x10^{-1}$	$6.00x10^{-1}$	$4.80x10^{1}$	$1.25x10^{1}$

Phys.=Physicochemical Properties, Conc.=Concentration, THBC=Total Heterotrophic Bacteria Count, ABU=Abuloma, BOR=Borikiri, EAI=Eagle-Island, FIM=Fimie, MAC=Macoba-Isaka, RUM=Rumuekini, ROM=Rumokoro.

Heavy metals and THBC Interaction in Surface water (River)

The heavy metal concentration and bacterial count for surface water indicated some quantum of contamination in some sampling locations. The minimum concentration levels of heavy metal were recorded in Abuloma (Cu & Pb) Borikiri (Zn & Pb), Eagle-Island (Zn, Cu, & Pb), Fimie (Zn. Cu, Fe & Pb), Macoba-Isaka (Zn & Pb), Rumuekini (Zn & Pb) and Rumuokoro (Zn) while the

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maximum concentration Borikiri (Cu), Macoba-Isaka (Cu), Rumuekini (Cu) and Rum,uokoro (Cu) (Table 5). For Iron, the maximum concentration was recorded in Macoba-Isaka and Rumuekini whereas the maximum concentration for Lead was recorded in Rumuokoro (Table 5). However, the minimum value of THBC (2.00×10^{-1}) cfu/ml across sampling locations was recorded in Fimie (Zn, Cu, Fe & Pb) while their maximum values (21.95×10^{1}) cfu/ml were recorded in Abuloma (Zn, Cu, Fe & Pb) respectively (Table 5).

Table 5: Dry Season Surface water (River) THBC (cfu/ml) for Heavy Metal Concentration

Phys. Properties	Conc. / THBC	ABU	BOR	EAI	FIM	MAC	RUM	ROM
Zn (mg/L)	Conc.	2.00×10^{-3}	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-3}
	THBC	21.95×10^{1}	4.20×10^{1}	7.20×10^{1}	2.00×10^{-1}	8.40×10^{1}	2.25×10^{1}	9.10×10^{1}
Cu (mg/L)	Conc.	1.00×10^{-3}	2.27×10^{-2}	1.00×10^{-3}	1.00×10^{-3}	2.0×10^{-2}	3.70×10^{-2}	3.70×10^{-2}
	THBC	21.95×10^{1}	4.2×10^{1}	7.20×10^{1}	2.00×10^{-1}	8.40×10^{1}	2.25×10^{1}	9.10×10^{1}
Fe (mg/L)	Conc.	1.00×10^{-3}	2.59×10^{-1}	1.62×10^{-2}	1.00×10^{-3}	7.12×10^{-1}	7.22×10^{-1}	1.20×10^{-2}
	THBC	21.95×10^{1}	4.40×10^{1}	7.20×10^{1}	2.00×10^{-1}	8.40×10^{1}	2.25×10^{1}	9.10×10^{1}
Pb (mg/L)	Conc.	1.00×10^{-3}	1.20×10^{-2}	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-3}	1.60×10^{-1}
	THBC	21.95×10^{-1}	4.20×10^{1}	7.20×10^{1}	2.00×10^{-1}	8.40×10^{-1}	2.25×10^{1}	9.10×10^{1}

Phys.=Physicochemical Properties, Conc.=Concentration, THBC=Total Heterotrophic Bacteria Count, ABU=Abuloma, BOR=Borikiri, EAI=Eagle-Island, FIM=Fimie, MAC=Macoba-Isaka, RUM=Rumuekini, ROM=Rumokoro.

Heavy metals and THBC Interaction in Well water (River)

In the well water, Zinc had concentration value of 1.00×10^{-3} mg/L across sampling locations except Abuloma (4.00×10^{-3}) mg/L and Macoba-Isaka (5.10×10^{-2}) mg/L. Copper had 1.00×10^{-3} mg/L across sampling location except Macoba-Isaka (4.60×10^{-2}) mg/L while the pattern differed from that of Iron and Lead (Table 6). For Iron and Lead concentration, Abuloma had 3.00×10^{-3} mg/L and 1.00×10^{-3}mg/L, Borikiri had 2.40×10^{-1}mg/L and 1.00×10^{-3}mg/L, Eagle-Island (1.62×10^{-2} and 7.05×10^{-1}) mg/L, Fimie (1.00×10^{-3} and 3.35×10^{-1}) mg/L, Macoba-Isaka (1.00×10^{-3} and 1.00×10^{-3}) mg/L, Rumuekini (2.20×10^{-2} and 1.00×10^{-3}) mg/L and Rmuokoro (2.61×10^{-1} and 1.00×10^{-3}) mg/L respectively (Table 6). THBC ranged from 1.15x10^{1}cfu/ml to 10.25x10^{1} cfu/ml The minimum value of THBC was located in Borkiri for copper, Iron and Lead while the maximum value was located in Eagle-Island for Zinc (Table 6).

Table 6: Well water (River) THBC (cfu/ml) for Heavy Metal Concentration

Phys. Properties	**Conc. / THBC**	**ABU**	**BOR**	**EAI**	**FIM**	**MAC**	**RUM**	**ROM**
Zn (mg/L)	Conc.	4.00x10^{-3}	1.00x10^{-3}	1.00x10^{-3}	1.00x10^{-3}	5.10x10^{-2}	1.00x10^{-3}	1.00x10^{-3}
	THBC	4.65x10^{1}	1.65x10^{1}	10.25x10^{1}	9.00x10^{-1}	4.00x10^{1}	18.05x10^{1}	8.60x10^{1}
Cu (mg/L)	Conc.	1.00x10^{-3}	1.00x10^{-3}	1.00x10^{-3}	1.00x10^{-3}	4.60x10^{-2}	1.00x10^{-2}	1.00x10^{-3}
	THBC	4.65x10^{1}	1.15x10^{1}	9.40x10^{1}	7.00x10^{-1}	3.30x10^{1}	2.25x10^{1}	7.00x10^{1}
Fe (mg/L)	Conc.	3.00x10^{-3}	2.40x10^{-1}	1.62x10^{-2}	1.00x10^{-3}	1.00x10^{-3}	2.20x10^{-2}	2.61x10^{-1}
	THBC	4.65x10^{1}	1.15x10^{1}	9.40x10^{1}	7.00x10^{-1}	3.30x10^{1}	2.25x10^{1}	7.00x10^{1}
Pb (mg/L)	Conc.	1.00x10^{-3}	1.00x10^{-3}	7.05x10^{-1}	3.35x10^{-1}	1.00x10^{-3}	1.00x10^{-3}	1.00x10^{-3}
	THBC	4.65x10^{-1}	1.15x10^{1}	9.40x10^{1}	7.00x10^{-1}	3.30x10^{1}	2.25x10^{1}	7.10x10^{1}

Phys.=Physicochemical Properties, Conc.=Concentration, THBC=Total Heterotrophic Bacteria Count, ABU=Abuloma, BOR=Borikiri, EAI=Eagle-Island, FIM=Fimie, MAC=Macoba-Isaka, RUM=Rumuekini, ROM=Rumokoro.

DISCUSSION

Nitrate, Sulphate and Phosphate ions are nutrients essential for both plan and animal including humans. They are anions. According to the [35], the maximum concentration value of Sulphate is 250mg/L. The USEPA maintained that Phosphate ion presence in water should not be higher than 0.025mg/L [36]. The safe Drinking Water Act of the USEPA set the maximum contaminant level of Nitrate as 10mg/L [37]. Nitrate is a polyatomic ion having the chemical formula NO_3^-. Salts containing this ion are called nitrate. Nitrates are component of fertilizers (because of their solubility and biodegradability) and explosives [38]. Aside leafy food, drinking water is also a source of dietary inorganic nitrate [39]. The Nitrate in this study was low and is within the acceptable range of 0-3.7mgkg^{-1}day^{-1} by the Joint FAO/WHO Expert Committee on Food Additive (JEFCA) [40].

Sulphate occurs naturally in groundwater in most part of the world. To most surface water, it occurs as a result of precipitation. At high levels concentration, sulphate can give a bitter or medicinal taste which can lead to laxative effect in man and animal mostly the vulnerable infant and calf. Sulphates as a macronutrient is the fourth abundant anion in human plasma (300 µM) [41]. It is needed for proper cell growth and development, and takes into account several biological processes, including biosynthesis and detoxification through sulphation of many endogenous and exogenous compounds [41]. Sulphate compounds regularly contain hardness ions (i.e., calcium and magnesium), and contribute to increases in the level of hardness in some groundwater systems. At very high concentration level, sulphate is considered as a secondary contaminant and a nuisance chemical [42]. This study revealed that the sulphate level in groundwater (borehole and well) and the surface water is within the allowable limit for drinking water quality in line with the European Union of 1998 for Water Quality Standard for drinking.

Also, phosphate are chemicals that contains the element phosphorous, which have the capacity to influence water quality via excessive growth of algae in water ecosystems and create imbalances, which destroy other life forms and produce harmful toxin [43]. Most phosphate enter the water way via plants and rocks. However, they can enter the waterway through anthropogenic sources *vis-à-vis* manufacturing and detergents, human sewage discharges and agricultural fertilizer run-off [44]. The current study reveals that phosphate concentration is slightly high above the normal standard in Abuloma and Fimie, while it is much higher in Rumuokoro for the groundwater (boreholes) sampled. In the surface water (River), at Abuloma, Eagle-Island, Fimie and Rumuekini, the concentration of phosphate is very much higher than the regulatory standard. For the well water, there was slight increase of phosphate in Abuloma, Fimie and Macoba-Isaka while at Eagle-Island, Rumuekini and Rumuokoro, the value of phosphate is very much higher than the regulatory standard. The high concentration value of phosphate in the surface water could be attributed to run-off, insanitary sewage disposal and industrial effluent (detergents etc.) in the river while that of the well water could be due to seepages catalyzed by precipitation and run-off. This corroborates with the views of [44] and [35].

Zinc (Zn) is a chemical element, having atomic number 30 and a slightly bristle metal at room temperature. It is the 24th most abundant element in Earth crust and has five stable isotopes. More so, it is an essential nutrient that enhances body growth and development. It helps protein and DNA production, wound healing, immune system functions [45]. However, the consumption of high-level zinc can lead to stomach cramps, nausea and vomiting. (http://www.saskh2o.ca). Literature holds that the maximum allowable limit for zinc in drinking should not exceed 5mg/L [35]. The concentration of zinc across the seven sampling locations for groundwater, surface and well water in this study indicates low concentration that fall within the allowable limit for human consumption.

Copper (Cu) is a trace element that enhance coenzyme and iron metabolism in human [45]. It occurs naturally either as in mineral deposits or, less frequently, as a metal. Copper enters water body through weathering, and human activities like mining, manufacturing and agriculture. Copper in drinking water can occur due to copper-containing pipes and fittings in distribution and plumbing systems, which is a function of chemistry of the water [46]. Copper deficiency may cause several health effects such as gastrointestinal tracks infection (diarrhea, pain and vomiting, nausea). Aesthetically, the presence of copper can affect the taste of the water, staining of laundry and plumbing features. Exposure to very high level of copper could lead to liver and kidney effects [46]. The copper concentration level in the seven sampling locations in this study reveals that there is no health-related issue (s) as the concentrations were far below the standard set by the United State National Academy of Medicine (900µg/day for adults and 340-890 µg/day for children) [46].

Iron (Fe) generally play a key role in human. As an essential mineral, it carries oxygen in the blood, muscle tissue and n energy production [47] [45]. According to [35], high level of iron in water could create negative effects on human health. For example, iron in drinking water is classified as secondary contaminant by Environmental Protection Agency, because iron carries bacteria with it that feed off the iron to survive. This small organism has the potential to harm when digested. The effect of iron cut across food and drinks, skin, clogging, discoloration, metallic taste and smell, and staining [47] [48]. The EPA limit of iron in water for human consumption is 0.3mg/L while EU is 0.2mg/L. Iron in water could occur due to broken underground pipes. Iron from surrounding soil can seep in when the soil is saturated [48]. However, in the current study, the iron level in Eagle-Island ($7.12x10^{-1}$ mg/L) and Fimie ($7.12x10^{-1}$ mg/L) for both groundwater (borehole) and surface water (River) were very much higher than the EPA and the EU standard. In the well water, Abuloma, Borikiri, Rumuekini and Rumuokoro were slightly higher than the EU standard for iron in drinking water. The slight increases observed in this study could be due to run-off (mostly for the surface water i.e., river), seepages and leakages due to broken underground pipes (mostly for the wells and boreholes). This corroborates with the study carried out by [48].

More so, Lead (Pb) is one of the heavy metals that can be found in water bodies. It enters water bodies when there are leakages in lead pipes, faucets and fixtures [49]. Much exposure to lead can cause cardiovascular effects, increased blood pressure and incidence of hypertension, reproductive problem in men and women etc., [50]. High level exposure can also have serious health effect on children. Such effects are not limited to brain and central nervous system, causing coma, convulsion including death. Children who survive severe lead poisoning may be left with intellectual disability and behavioural disorders [50]. The maximum amount of Lead in drinking water should not exceed 0.01 mg/L [50] In the groundwater (borehole) source, the amount of lead is less than the maximum allowable limit across sampling locations while in the surface water, only water from Rumuokoro ($1.60x10^{-1}$ mg/L) exceeded the [50] guideline, and at the well water source, all the lead values were within the acceptable standard for drinking water. This indicates that there is no health issue as it relates to water consumption except surface water sample location at Rumuokoro. Presence of lead in the Rumuokoro river could be as a result disposal of lead paint containers, lead pipes, run-off etc.

The microbiological quality of drinking water (mostly boreholes and hand-dogged wells) depends on several factors such as free residual chlorine etc., which minimizes or reduces bacterial recontamination and regrowth in mostly municipal water distribution system. Notwithstanding such preventive mechanism, regrowth of heterotrophic and opportunistic bacteria in bulk water and biofilms has yet to be completely controlled. The Total Heterotrophic Bacteria count (THBC) in this study varies systematically across sampling locations and across different water bodies. In the groundwater source, minimum THBC ($2.00x10^{-1}$) cfu/ml was recorded in Fimie for the nutrients while the maximum of $10.25x10^{1}$cfu/ml was recorded in in Eagle-Island. In the surface water sample for the nutrients, the minimum THBC ($2.00x10^{-1}$) cfu/ml was recorded in Fimie while the maximum was recorded in $21.95x10^{1}$ cfu/ml was recorded in Abuloma. For the well water sample (i.e., the nutrients), minimum THBC $5.3x10^{-1}$ cfu/ml was in Rumuokoro while the maximum of $23.95x10^{1}$ cfu/ml was recorded in Abuloma for sulphate. THBC interaction with the heavy metal revealed that at the groundwater source, Fimie had the minimum count of $2.00x10^{-1}$cfu/ml whereas Eagle-Island had the maximum count of $10.25x10^{1}$cfu/ml respectively. In the surface and well water sampled, Fimie had the minimum THBC of $2.00x10^{-1}$cfu/ml and $7.00x10^{-1}$ cfu/ml correspondingly with a maximum of $21.95x10^{1}$ cfu/ml (Abuloma) and 9.40x101 cfu/ml (Eagle-Island) respectively. The dynamics of bacteria growth in the various water bodies could be attributed to run-off, loosed materials, sediment and corrosion, poor waste disposal practices. This is in line with the study of [36], [51].

SUMMARY OF FINDINGS

1. The concentration gradient of Nitrate (NO^{3-}) and sulphate (SO_4^{3-}) in this study were found to be within the EU Standard for drinking water quality.
2. Phosphate (PO_4^{2-}) concentration for groundwater (Borehole) at Rumuokoro sampling location was higher than the regulatory standard set by the EU.
3. The highest phosphate concentration for surface and well water was found at Rumuekini and Eagle-Island respectively.
4. The heavy metal (Zn, Cu, Fe and Pb) and microbial (THBC) values exhibited unique pattern for groundwater, surface and well water sources, except Macoba-Isaka and Rumuokoro location for well water.
5. The overall result shows that there is no correlation between the heavy metals and microbial counts.
6. The value of lead in Eagle-Island for well water was higher than the regulatory standard set-up by the European Union.
7. The microbial (THBC) load in Eagle-Island for groundwater, Abuloma for surface water and Fimie in well water exert the highest count.

CONCLUSION

The presence of heavy metal, nutrients (NO_3^-, SO_4^{3-} and PO_4^{2-}) and Total Heterotrophic Bacteria Count (THBC) in water bodies is significant in public health as it reveals the degree of quality of such water body for human consumption, aesthetics and or for recreational purposes. The heavy metal (Pb) for well water in Eagle-Island appears to be much higher than the regulatory standard. This calls for public health attention to ensure water safety for public consumption.

RECOMMENDATION

1. Surface and well water sources from Eagle-Island and Rumuokoro be treated specifically for phosphate removal.
2. At the Eagle-Island sample location for well water, there should be treat against lead to Pb) (i.e., removal of Pb in the water source to encourage quality).
3. Government agencies saddled with monitoring and supervision of water quality should ensure periodic monitoring of all water sources for public consumption.
4. Indiscriminate effluent disposal should be checked and control by the relevant government agency.

COMPETING INTEREST

Authors have declared that no competing interest exist.

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