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PARASITIC CONTAMINATION: PREVALENCE AND LOAD IN RELATION TO WATER QUALITY OF AHI RIVER IN UMUAHIA, ABIA STATE

*[1]Emeka Donald Anyanwu, [1]Ozioma Prisca Irole-Eze, [2]Chioma Ada Ihemanma, [1]Ananda Chisom Hilary and [1]Amarachi Grace Stephen

[1]Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Umudike, Nigeria.
[2]Department of Biology/Microbiology, Ogbonaya Onu Polytechnic, Aba, Nigeria.

*Corresponding authors' email: ekadon@yahoo.com

ABSTRACT

Water is an essential resource needed by humans for most of their activities. However, human activities have resulted in the contamination of surface water bodies with chemical and biological agents. Prevalence, parasitic load and some physicochemical parameters of a rural water source in Ohiya Community, Umuahia, Abia State was assessed. The parameters were determined with standard analytical procedures. Grab and composite filtration methods were used for parasite sample collection and sedimentation method for the analysis. Some pH (33.3%) and dissolved oxygen (94.4%) values did not conform to regulatory limits out of nine (9) parameters evaluated. The study recorded 8 parasites (including helminths and protozoa) of public health significance. The overall parasitic contamination prevalence was 75.0%, 77.8% (grab method) and 72.2% (composite filtration method). The most prevalent parasite was *Entamoeba coli* (41.7%) and the least was *Balantidium coli* (2.8%). Station 2 had the maximum prevalence (91.7%) and parasitic load (84) while station 3 had the least prevalence (58.3%) and load (22). May and June 2023 had the maximum prevalence (100%) while the maximum parasitic load (74) was recorded in May 2023. On the other hand, July and August 2023 had the minimum prevalence (50.0%) while the minimum parasitic load (6) was recorded in July 2023. The composition, prevalence and parasitic load were highly influenced by physicochemical parameters, sampling method, anthropogenic-related stressors and rainfall. Based on the findings of this study, treatment of the water is required before usage. Solid wastes disposal and discharge of effluents around the river should be prohibited.

Keywords: River, Contamination, Parasite, Physicochemical parameters, Rainfall, Public Health

INTRODUCTION

Every human being uses water daily because it is a necessary resource for life (Kiliç, 2020); but it can serve as source of contamination and infection if mismanaged (Anyanwu *et al*., 2018; Bayhan *et al*., 2020). Water supplies for domestic purposes must be free from disease-carrying pathogens and other chemical contaminants to be suitable for human consumption (Bayhan *et al*., 2020). Parasites are essential components of ecosystems with strong association with their free-living members; however, they are often neglected in most biodiversity studies (Gordy *et al*., 2020). Human actions and inactions are currently ravaging the environment across the world with dire consequences on the prevalence of parasites and host-parasite relationships (Budria and Candolin, 2014). Globally, one of the major health challenges especially in developing or low-income countries are waterborne diseases (Elmonir *et al*., 2020). Over half of global diarrhoeal disease outbreaks have been attributed to consumption of unsafe drinking water (WHO, 2023). It has also been estimated by the World Health Organization that about 2 billion people are now using water from contaminated water sources (WHO, 2019). Consequently, parasitic infections that can be transmitted via water are considered as public health risk, particularly in less developed countries (Simon-Oke *et al*., 2020). The majority of urban and rural communities in developing nations lack safe and hygienic methods of domestic and human wastes disposal; many residents indiscriminately defecate and dispose solid wastes around their homes and into surface water bodies (Ejike *et al*., 2021). Surface waters have been identified as an important rallying point for humans and animals especially during the dry season and in water-stressed regions (Titcomb *et al*., 2021); where they serve as ready source of water for most purposes. However, these doubtful water sources could be contaminated with various pathogens, including parasites. The burden of waterborne diseases is quite enormous. For example, accessibility to water that is better and safe as well as improved sanitary and hygienic environments could result in preventable 1.4 million deaths (WHO, 2023; Wolf *et al*., 2023). In less developed regions of the world including Nigeria, there is no routine monitoring programme for assessing waterborne parasites especially protozoa (Nemati *et al*., 2023). Ahi River provide for most domestic water needs of the community including drinking especially during the dry season. To the best of our knowledge, no attempts have been made to determine the parasites content and load of this all important river. Hence, this study aimed at assessing the prevalence as well as parasitic load in relation to some physicochemical parameters of a rural drinking water source in Umuahia, Abia State, Nigeria. The outcome of this study will serve as one of the reference materials in the river and region.

MATERIALS AND METHODS

Study Area

The stretch of studied Ahi River was located in Ohiya Community, Umuahia, Abia State, Nigeria (Figure 1). Located in the sub-equatorial zone, the area is associated with high temperatures of 29.0 to 31.0 °C, high relative humidity exceeding 70% with 4000mm as annual mean rainfall (Nwankwo and Nwankwoala, 2018). Two major seasons prevail in the area with the wet season being from May to October and dry season from November to April. Peaks of wet season usually occur July and September while a short dry season (August break) occurs between late July and mid-August. Station 1 (upstream) witnessed a number of activities like washing and traditional worship events. The station also receives stormwater from the upper parts of the community.

Station 2 (mid-stream) was located about 0.97 km after Station 1. During and after rainfall events, effluents from a refuse dump uphill by the entrance to the station discharge into the river. A traditional worship center located around station 1 also releases its effluent laden with animal blood, wastes and organic matters into the river before station 2. Sand mining, bathing, washing and food processing were other human activities observed in the station. Station 3 (downstream) was remotely situated in a deep valley, about 1.83 km after station 2. Due to its difficult terrain, bathing and washing were the only activities observed. However, the station also receives effluents from some cottage industries (oil palm processing mill, cassava processing mill and pig farm).

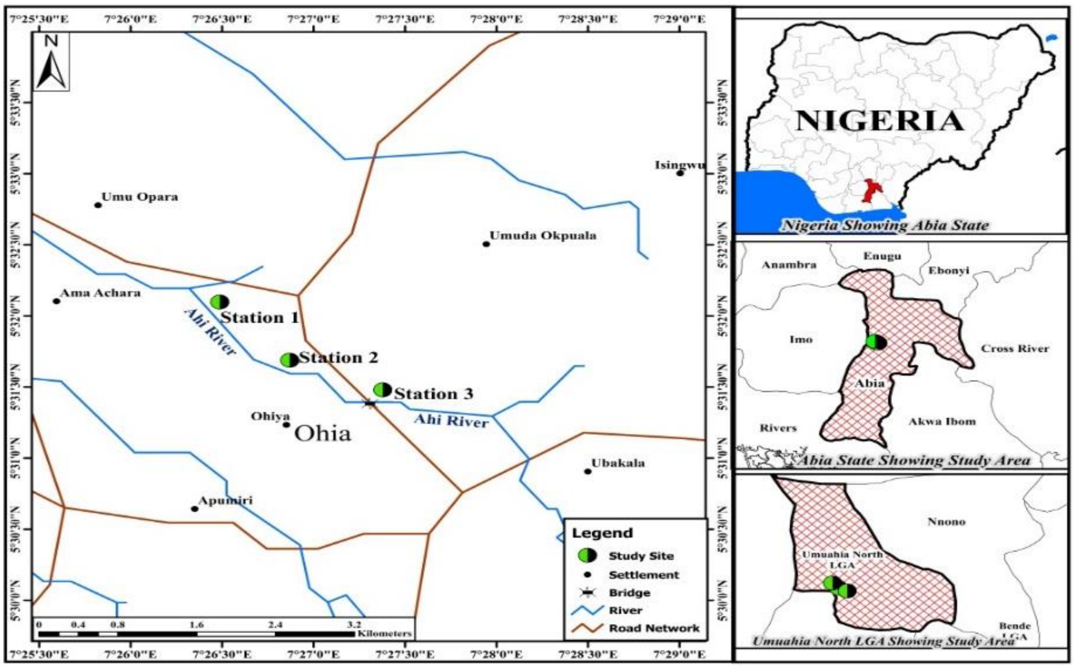

Figure 1: The Study Stretch and Sampling Stations in Ahi River, Ohiya Community, Umuahia, Abia State, Nigeria

Collection of Samples

Water samples for physicochemical analysis

Samples for physicochemical analysis were collected from the river once every month from May to October 2023. Plastic bottles (1litre) were used to collect the water samples and sent to the laboratory for analysis in ice packs. Nine physicochemical parameters were assessed using standard analytical procedures of American Public Health Association (APHA) (2017) - water temperature (Mercury-in-glass Thermometer), flow velocity (Floatation Method), pH (J550 Portable pH meter, Jenway, U.K.), electrical conductivity and total dissolved solids (CO150 TDS/Conductivity Meter, HACH, USA), dissolved oxygen (HI9146 DO meter, Hanna, Romania), biochemical oxygen demand (Azide Modification of Winklers Method), phosphate (Stannous Chloride Method) and nitrate (SPECTRONIC 200 Visible Spectrophotometer, Thermo Fisher Scientific, China).

Water samples for parasite analysis

Grab and composite filtration methods were used to collect the parasites along with the water samples. The grab samples were collected from below the surface of the water with plastic containers while plankton net was used to filter 100 litres of water for the composite filtration method (Anyanwu et al., 2024). The samples were sent in ice packs to Department of Zoology and Environmental Biology Laboratory, Michael Okpara University of Agriculture, Umudike and analyzed on the same day.

The samples for analysis of parasites were mixed thoroughly and filtered through a sieve (0.45 µm pore size) as described by Cheesbrough (2010). The particulate was discarded while the filtrate was centrifuged at 2500 rpm for 10 minutes. The test tubes were allowed to stand for 2 hours after which the supernatant was discarded. The sediments smeared on a clean grease free glass slide stained with a drop of Lugol's iodine solution. The mixture was covered with a cover slip and examined using the microscope (BI-KG-7A/BMC-220, Micro Optik, India) at 10x and 40x objective lenses to identify parasite eggs, larvae and cysts (Cheesbrough, 2010).

Statistical Analysis

Descriptive Statistics tool of PAST Statistical was used to summarize the physicochemical parameter data. One-way analysis of variance (ANOVA) with Tukey pairwise posthoc test at $p < 0.05$ was used to test for significant variations in the physicochemical parameters, spatial and temporal parasite loads. Student t-test was used to test for significant variation between the sampling methods while variations in prevalence were tested with Chi-square at $P < 0.05$. The influence of the physicochemical parameters on the parasite load was determined with Correlation analysis.

RESULTS AND DISCUSSION

Water Quality Parameters

The summary of the physico-chemical parameters recorded in Ahi River, Ohiya, Umuahia are presented in Table 1. The water temperatures were moderate (25.2 - 27.0°C). The minimum water temperature was recorded in Station 2 (June 2023) while the maximum values were recorded in May 2023 (Stations 1 and 2). However, generally low temperature values were recorded in Station 3 throughout the study.

Table 1: Summary of The Physicochemical Parameters Recorded in Ahi River, Umuahia, Nigeria

Parameters	Station 1mean±SEM	Station 2mean±SEM	Station 3mean±SEM	P- Value	NESREA (2011)
Water Temperature (°C)	26.3±0.17 (25.9-27.0)	26.1±0.25 (25.2–27.0)	25.9±0.07 (25.6–26.0)	F = 0.96 P > 0.05	-
Flow Velocity (m/s)	0.35±0.03[a] (0.27-0.46)	0.31±0.04[a] (0.15-0.41)	0.24±0.01[b] 0.22-0.28)	F = 4.27 P < 0.05	-
pH	6.85±0.31 (5.7–7.8)	6.85±0.32 (5.7–7.7)	6.81±0.87 (5.6–7.7)	F = 0.00 P > 0.05	6.5-8.5
Electrical Conductivity (µS/cm)	80.33±4.48 (66.0-98.0)	81.66±3.24 (72.0-92.0)	80.0 ± 2.68 (70.0–88.0)	F = 0.06 P > 0.05	-
Total Dissolved Solids (mg/l)	40.17±2.24 (33.0-49.0)	41.00±1.57 (36.0-46.0)	40.17±1.42 (35.0–44.0)	F = 0.07 P > 0.05	-
Dissolved Oxygen (mg/l)	3.93±0.29 (3.2 – 5.2)	3.97±0.30 (3.4–5.2)	4.80±0.38 (3.8–6.4)	F = 0.40 P > 0.05	6
Biochemical Oxygen Demand (mg/l)	1.77±0.26 (1.0–2.6)	1.97±0.17 (1.5–2.4)	2.2±0.23 (1.2–2.7)	F = 0.97 P > 0.05	3
Phosphate (mg/l)	0.03±0.00 (0.02–0.04)	0.02±0.00 (0.01-0.03)	0.02±0.00 (0.01 – 0.03)	F = 0.62 P > 0.05	3.5
Nitrate-N (mg/l)	0.05±0.00 (0.03–0.8)	0.05±0.00 (0.03–0.6)	0.04±0.00 (0.02–0.05)	F = 0.72 P > 0.05	9.1

SEM – Standard Error of Mean; National Environmental Standards and Regulations Enforcement Agency (NESREA) (2011) = Guidelines and Standards for Environmental pollution control in Nigeria.

Moderate flow velocity values were recorded and ranged from 0.15 to 0.46 m/s. The minimum value was recorded in Station 2 (May 2023) while the maximum was recorded in Station 1 (October 2023). Station 3 was significantly lower than Stations 1 and 2.
The pH was moderate acidic to slight alkaline (5.6 – 7.8); 12 out of 18 values (66.7%) recorded conformed to the acceptable range (6.5 – 8.5) set by NESREA (2011). The minimum value was recorded in Station 3 (June 2023) though generally low pH values were recorded in all the stations in June 2023. On the other hand, the maximum pH was recorded in Station 1 (September 2023).
Electrical conductivity values (66.0 - 98.0 µS/cm) and Total Dissolved Solids values (33.0 and 49.0 mg/l) were moderate and exhibited the same spatiotemporal trend. The minimum values were recorded in August 2023 while the maximum values were recorded in May 2023 (Station 1).
The dissolved oxygen (DO) values (3.2 – 6.4 mg/l) did not conform to acceptable limit set by NESREA (2011) except one (Station 3, June 2023). The minimum DO value was recorded in Station 1 (October 2023) while the maximum value was recorded in Station 3 (June 2023).
The biochemical oxygen demand values (1.0 - 2.7 mg/l) conformed to acceptable limit (3 mg/l) set by NESREA (2011). The minimum and maximum values were respectively recorded in stations 1 and 3 in June 2023. However, there was a general increase with the rains in all the stations.
The phosphate values (0.01 - 0.04 mg//l) were low and conformed to NESREA (2011) limit of 3.5 mg/l. The minimum values were recorded in Station 3 (June and July 2023) while the maximum value was recorded in Station 1 (September 2023).
The nitrate values (0.02 - 0.08 mg/l) were equally low as phosphate and conformed to NESREA (2011) limit of 9.1 mg/l. The minimum value was recorded in Station 3 (October 2023) while the maximum was recorded in Station 1 (May 2023).

Parasitic Composition and Prevalence

A high occurrence of eight (8) parasites (egg, oocyst, and trophozoites) of protozoans and helminths of public health importance were recorded in the 36 water samples evaluated. Helminths included *Ascaris lumbricoides, Fasciola hepatica* and *Taenia solium* while protozoa included *Entamoeba coli, Entamoeba histolytica, Giardia lamblia, Cryptosporidium parvum* and *Balantidium coli.*
The overall prevalence was high (75%) while the grab method had higher prevalence (14, 77.8%) than the composite filtration method (13, 72.2%); though not significant ($X^2_{df\,(1)} = 0.02$, $p > 0.05$).
E. coli was the most prevalent parasite, followed by *E. histolytica* and *A. lumbricoides* (Table 2), which was not significant ($X^2_{df\,(16)} = 11.59$, $p > 0.05$).

Table 2: Prevalence in Relation to Parasites Recorded in Ahi River, Umuahia, Nigeria

0.16	Number examined	Parasites and number recorded								P - value
		Ec	*Eh*	*Al*	*Gl*	*Ts*	*Cp*	*Bc*	*Fh*	
Stn 1	12	3(25.0)	4(33.3)	3(25.0)	3(25.0)	0	2(16.7)	0	0	0.77
Stn 2	12	7(58.3)	2(16.7)	3(25.0)	3(25.0)	1(8.3)	2(16.7)	0	1(8.3)	
Stn 3	12	5(41.7)	1(8.3)	1(8.3)	0	1(8.3)	1(8.3)	1(8.3)	1(8.3)	
Total	36	15(41.7)	7(19.4)	7(19.4)	6(16.7)	2(5.6)	5(13.9)	1(2.8)	2(5.6)	

Key: *Ec = Entamoeba coli, Eh = Entamoeba histolytica, Al = Ascaris lumbricoides, Gl = Giardia lamblia, Ts = Taenia solium, Bc = Balantidium coli, Fh = F. hepatica*

Station 2 (11, 91.7%) had the maximum spatial prevalence, then Station 1 (9, 75.0%) and the least was Station 3 (7, 58.3%). Spatial prevalence did not exhibit any significant variation ($X^2_{df\,(2)} = 0.51$, $p > 0.05$).
The monthly maximum number of parasites and prevalence (6, 100.0%) were recorded in May and June 2023 before the onset of rains and early rains while the minimum number and prevalence (3, 50.0%) were recorded as the rains increased in

July and August 2023. Temporal prevalence did not exhibit any significant variation ($X^2_{df(5)} = 1.42$, $p > 0.05$).

Parasitic Load

The parasitic load varied with stations, months and sampling methods (Table 3). Spatially, the parasitic load ranged between 22 and 84. Station 3 had the minimum number while Station 2 had the maximum number. Spatial parasitic load did not exhibit any significant ($p > 0.05$) variation.

Based on sampling method, composite filtration method recorded the maximum number (111) while the grab method recorded 77 with no significant ($p > 0.05$) difference.

Temporally, the maximum parasite count (74) was recorded in May 2023 before the onset of the rains while the minimum (6) was recorded in July 2023. Temporal parasitic load also did not exhibit any significant ($p > 0.05$) variation.

Table 3: The Parasite Loads Recorded in Ahi River, Umuahia, Nigeria Based On Stations, Sampling Methods and Months

Parasites	Spatial			Sampling Method		Temporal					
	Stn1	Stn2	Stn3	CFM	GM	May23	Jun23	Jul23	Aug23	Sep23	Oct23
E. coli	20	42	11	49	24	42	22	4	0	3	2
E. histolytica	15	12	4	20	11	19	8	0	0	0	4
A. lumbricoides	10	9	1	6	14	9	1	0	0	8	2
G. lamblia	21	4	0	11	14	3	6	0	16	0	0
C. parvum	16	14	2	19	13	0	19	0	13	0	0
T. solium	0	2	1	3	0	1	0	0	0	2	0
F. hepatica	0	1	1	1	1	0	0	0	0	0	2
B. coli	0	0	2	2	0	0	0	2	0	0	0
Total	82	84	22	111	77	74	56	6	29	13	10

Key: CFM = Composite filtration method; GM = Grab method.

Correlation between physicochemical parameters and parasite loads

Correlation analysis showed that the parasites variously exhibited significant positive and/or negative relationships with some physicochemical parameters in the different stations. The correlation matrix between the independent variables (physicochemical parameters), and the dependent variable (parasitic load) are presented in Tables 4-6.

Table 4: Correlation Matrix Between Physicochemical Parameters and Parasite Load For Station 1 Of Ahi River, Umuahia, Nigeria

Parameters	Parasites				
	E.coli	***E.histolytica***	***A.lumbricoides***	***G.lamblia***	***C.parvum***
Water temp	0.158	0.515	0.540	-0.533	-0.540
pH	-0.900	-0.557	0.641	-0.071	-0.087
FV	-0.283	0.018	0.146	-0.636	-0.635
EC	0.635	0.648	0.223	-0.596	-0.591
TDS	0.635	0.648	0.223	-0.596	-0.591
DO	0.028	-0.394	-0.205	0.928	0.929
BOD_5	-0.870	-0.648	0.617	-0.242	-0.254
PO_4	0.161	0.086	0.864	-0.287	-0.286
NO_3	0.783	0.560	-0.163	-0.315	-0.306

Bold-faced values are significant (+ve or –ve) correlations at 0.05 (two-tailed)

Table 5: Correlation Matrix Between Physicochemical Parameters and Parasite Load For Station 2 Of Ahi River, Umuahia, Nigeria

Parameters	Parasites						
	E. coli	***E. histolytica***	***A. lumbricoides***	***G.lamblia***	***C. parvum***	***T. solium***	***F. hepatica***
Water temp	0.623	0.332	0.718	0.468	-0.772	0.307	-0.013
pH	-0.572	-0.803	-0.427	-0.711	-0.709	0.528	0.403
FV	-0.846	-0.857	-0.944	-0.880	-0.014	-0.127	0.107
EC	0.471	0.512	0.462	0.527	0.086	-0.226	-0.596
TDS	0.470	0.497	0.443	0.515	0.065	-0.255	-0.637
DO	0.519	0.794	0.442	0.687	0.791	-0.369	-0.369
BOD_5	-0.637	-0.629	-0.469	-0.619	-0.147	0.391	0.391
PO_4	-0.150	-0.130	-0.036	-0.106	-0.079	0.128	-0.285
NO_3	0.489	0.588	0.477	0.575	0.261	-0.231	-0.743

Bold-faced values are significant (+ve or –ve) correlations at 0.05 (two-tailed)

Table 6: Correlation Matrix Between Physicochemical Parameters and Parasite Load For Station 3 Of Ahi River, Umuahia, Nigeria

Parameters	Parasites						
	E. coli	*E. histolytica*	*A. lumbricoides*	*C. parvum*	*T. solium*	*F. hepatica*	*B. coli*
Water temp	-0.062	0.293	0.293	0.293	0.293	0.293	0.293
pH	-0.675	-0.555	-0.555	-0.664	-0.555	0.482	0.100
FV	-0.126	-0.510	-0.510	-0.449	-0.510	-0.079	0.373
EC	0.125	0.447	0.447	0.000	0.447	-0.745	-0.298
TDS	0.123	0.538	0.538	-0.023	0.538	-0.726	-0.304
DO	0.582	0.213	0.213	0.851	0.213	0.000	-0.319
BOD_5	0.467	-0.089	-0.089	0.444	-0.089	0.267	-0.889
PO_4	-0.139	-0.133	-0.133	-0.442	-0.133	-0.177	-0.442
NO_3	0.485	0.396	0.396	0.150	0.396	-0.915	-0.177

Bold-faced values are significant (+ve or –ve) correlations at 0.05 (two-tailed)

Discussion

Environmental factors affect the prevalence, abundance and distribution of water-borne parasites (Berkhout *et al*., 2019; Simon-Oke *et al*., 2020; Sha-Amu *et al*., 2024). Rainfall event during sampling was responsible for the minimum water temperature recorded in Station 2 (June 2023) while the maximum values recorded in May 2023 (Stations 1 and 2) could be attributed to late dry season before the rains started. Seasonal patterns, which are majorly determined by precipitation in the tropics, usually influence atmospheric temperatures and water temperatures in turn (Park *et al*., 2011). Generally low temperature levels observed in station 3 could be attributed to its location in a vegetated deep valley with reduced sun intensity getting to the river. Parasites flourish at their optimum survival temperature range (10 – 26°C) (Villar-Torres *et al*., 2023; Sha-Amu et al., 2024) and their prevalence, persistence and occurrence patterns usually increase as water temperature increases (Abba *et al*., 2018; Fenta and Kebede, 2019; Kirk *et al*., 2022).

The flow velocity values were moderate. Station 3 was significantly lower than Stations 1 and 2; probably because of gradient created by their higher elevations (Ames, 2022). The minimum value recorded in Station 2 before the onset of the rains in May 2023 and the maximum value in October 2023 (Station 1) was attributed to rainfall. Higher flow velocities are usually recorded in the wet season due to increased rainfall and associated surface runoff. Station 3 generally had low values with minimal fluctuation probably due to its location. Flow velocity influences the abundance and transmission of water-borne parasites through flushing or retention (Poulin, 2020; USEPA, 2022).

Lower pH values in the acidic range recorded in June 2023 (all stations) could be due rainfall event during sampling. The pH of a river can be reduced especially after a period of dryness due to input of organic and inorganic substances through runoff during rainfall (Ojok *et al.,* 2017). The pH however, generally increased with the wet season in all the stations especially in station 1 (September 2023), as a result of dilution. Dilution reduces concentrations of solutes and the acidity because of increased runoff discharged into the river. The recorded pH values were suitable for parasite development (Berkhout *et al*., 2019) with possible variations in some species.

The similar spatiotemporal trend observed in electrical conductivity and total dissolved solids values was determined by rainfall. A rainfall event in August 2023 led to minimum value recorded in station 1. High runoff decreases pollutants' residence time in rivers leading to subsequent dilution effect (Yang *et al*., 2021). However, August break was responsible the elevated values observed in stations 2 and 3. Stations 2 and 3 were sampled before the rain started during August sampling. During the August break (short dry season), the concentrations of some water parameters tend to increase due to reduction in rainfall and flow velocity as well as increase in temperatures and evapotranspiration (Anyanwu *et al*., 2022). Relatively higher values were recorded in all the stations (May 2023) before the onset of rains. This could be due to late dry season as higher temperatures during that period increase evaporation and river drying; causing an increase in TDS and EC concentrations (Mueller *et al*., 2017). All the dissolved oxygen values were low except in Station 3 (June 2023). All the values for June 2023 were generally high in all the stations and could be due to rainfall event during sampling. Rainfall-induced turbulence can contribute to aeration and increase in dissolved oxygen content of a river (Chowfin *et al*., 2024). However, there was a general reduction in DO values as the rains increased resulting in the minimum value recorded in October 2023 (station 1). This could be due to reduction in photosynthetic activities caused by low temperatures, high turbidity and total suspended solids (Vonshak *et al*., 2014).

All the biochemical oxygen demand values were within limit and generally increased with the rains in all the stations suggesting allochthonous input from runoff. The BOD values suggest the presence of oxygen-consuming organic materials in the stations. The minimum value recorded in Station 1 (June 2023) could be due to dilution as a result of rainfall during sampling while the maximum in Station 3 (also June 2023) could be due to anthropogenic influence. Human activities were responsible for the higher BOD values recorded in Stations 2 and 3. For example, a traditional worship center located around station 1 discharges its effluent laden with blood and animal wastes into the river before Station 2. Water pollution arising from religious worship activities have been documented (Emelie, 2019; Mujawar *et al.,* 2019; Ogunbode and Oyekan, 2023). Others are effluent from refuse dumps around Station 2 (Indirani *et al*., 2022) as well as sand mining activities (Anyanwu and Umeham, 2020) and effluents from the cottage industries around Station 3 (Izah *et al*., 2018; Cao *et al*., 2021; Lokman *et al.,* 2021).

The phosphate values were low and within limit. Dilution could be responsible for the minimum values recorded in Station 3 (June and July 2023) because there was a drop from May 2023 value in all the stations (Huang et al., 2020). However, allochthonous input could be responsible for the highest recorded in station 1 (September 2023) as the rains increased. Increased rainfall directly increases the amount of nutrients-laden pollutants in water (Shou *et al*., 2022).

The nitrate values were low and within limit. Nitrate exhibited an entirely different trend. It decreased from May to October 2023 in all the stations, which may be as a result of dilution as the rains increased. The minimum value recorded in station 3 (October 2023) was attributed to dilution while the maximum in station 1 (May 2023) could be as a result of late dry season. However, August break (short dry season) was responsible for the higher values recorded in stations 2 and 3 in August 2023.

Parasite Composition and Prevalence

Protozoans and helminths parasites of public health importance were recorded. Protozoa and helminths are major food and water related parasites that are commonly spread from animals and poor water sources to humans (Dinç, 2021; Couso-Perez *et al*., 2023; Okere *et al*., 2024). They are among the most commonly isolated water-borne parasites in the world (Berkhout et al., 2019; Ngowi, 2020; Sente *et al*., 2023). Protozoa and helminths were also reported in related studies (Anyanwu *et al.*, 2018; Ejike *et al*., 2021; Tula *et al*., 2023; Anyanwu *et al*., 2024).

Four of the prevalent parasites with high parasite loads (*A. lumbricoides, E. histolytica, G. lamblia* and *C. parvum*) are causative agents of some diseases within the Neglected Tropical Diseases (NTD) framework and have been implicated in waterborne disease outbreaks globally (Al-Tameemi and Kabakli, 2020; Junaidi *et al*., 2020; Nemati *et al*., 2023), thus requiring national and international interventions. However, the most prevalent parasite (with maximum load) – *E. coli* is non-pathogenic but suggest poor hygienic and sanitary conditions associated with rural areas like Ohiya.

The overall prevalence was higher than 33.33% recorded by Anyanwu *et al*. (2024) in Ikwu River, Umuahia, Abia State, 28.1% recorded by Ani and Itiba (2015) in a stream in Abakaliki, Ebonyi State and 15.6% recorded in a river in Kogi State, Nigeria by Iyaji *et al.* (2018). The high prevalence rate could be due to anthropogenic activities and poor hygienic and sanitary conditions of the area. The public health implication of this high prevalence is that people using the water for other purposes (bathing and recreation) other than drinking are also at risk (Islam and Islam, 2020). The grab method had higher prevalence than the composite filtration method, which was contrary to findings of Anyanwu *et al*. (2024). However, the composite filtration method recorded higher parasitic load than the grab method.

E. coli was the most prevalent parasite and this is contrary to prevalence of *S. stercoralis* and *B. coli* reported by Anyanwu *et al*. (2024) in Ikwu River, Umuahia, Nigeria. The variations may be as a result of seasonal influence and anthropogenic stressors in the rivers. The less prevalent parasites (*F. hepatica*, *T. solium* and *B. coli*) recorded mostly in station 3; suggest the influence of effluents from a pig farm (Bolaji *et al*., 2023). Waterborne parasites are influenced by their environmental conditions which is associated with the physicochemical characteristics of the waterbody (Berkhout *et al*., 2019).

The maximum spatial prevalence and parasitic load recorded in Station 2 could be due to effluents from the traditional worship activities (Emelie, 2019; Mujawar *et al*., 2019; Ogunbode and Oyekan, 2023) and solid wastes dump around the station (Amadi *et al*., 2020; Gboeloh, 2021). On the other hand, the minimum prevalence and parasitic load recorded in station 3 could be attributed to its remote location which limited human activities and impact.

The temporal prevalence was influenced by rainfall. The maximum number of parasites and prevalence were recorded in May and June 2023 before the onset of rains and early rains while the minimum number and prevalence was recorded as the rains increased in July and August 2023. The influence of rainfall events on parasite prevalence and load was also observed in Anyanwu *et al*. (2024). Parasites can be introduced into or removed from a lotic waterbody through rainfall events (Manetu and Karanja, 2021; USEPA, 2022). The implication is that the parasite load will be higher during the dry season when the demand for the water from the river will be high.

Parasitic Load

The parasitic load varied with stations, months and sampling methods. Spatially, Station 3 had the minimum number of individuals while station 2 had the maximum number. The parasitic load was also influenced by the same factors affecting the spatial prevalence. The composite filtration method recorded higher parasitic load than grab method; suggesting that the composite filtration method was more effective in assessing parasitic loads.

The temporal variation of the parasitic load was attributed to rainfall as in the prevalence (Anyanwu *et al.,* 2024). The maximum parasitic count was recorded in May 2023 before the onset of the rains while the minimum was recorded in one of the peaks of rainfall (July 2023). Rainfall influence flow velocity which in turn affect the presence or absence of waterborne parasites (Poulin, 2020; USEPA, 2022).

Correlation between physicochemical parameters and parasitic loads

Physicochemical parameters significantly determine the composition and load of waterborne parasites by influencing their survival, transport, and parasite-host dynamics. Water temperature was positively correlated with *A. lumbricoides* (Station 1) and *E. coli* and *A. lumbricoides* (Station 2); suggesting possible interdependence between water temperature and these parasites while negative correlation existed with *G. lamblia* (Station 1) and *C. parvum* (Station 2); indicating that an inverse linear relationship existed between water temperature and these parasites. No significant positive or negative correlation existed with any parasite in station 3 probably due to relatively low temperatures. Temperature has a positive correlation with water borne diseases (Fenta and Kebede, 2019). However, parasites thrive at different optimum temperatures (10 – 26°C) and relatively higher or lower values negatively affect the parasites (Villar-Torres *et al*., 2023; Sha-Amu e*t al*., 2024). pH had positive correlation with 2 parasites and negative correlation existed with 6 other parasites. Very low or high pH can be fatal to aquatic organisms including parasites (Omer *et al*., 2019). Flow velocity had negative correlations with 6 parasites in all the stations. Flow velocity influences the abundance and transmission of water-borne parasites through flushing or retention (Poulin, 2020; USEPA, 2022). Electrical conductivity and total dissolved solids had positive correlation with *E. coli* and *E. histolytica* (Station 1) and *G. Lamblia* (Station 2) but negative correlation with 6 other parasites. Positive relationship between electrical conductivity and helminths parasites was also observed in related studies (Abba *et al*., 2018; Aghaindum and Landry, 2019). Dissolved oxygen had positive correlation with some of the parasites in all the stations; probably because of the low oxygen content of the river. Parasites flourish in water with low oxygen content (Waruiru *et al*., 2020). Biochemical oxygen demand had negative correlation with many of the parasites especially *B. coli* (station 3) because the BOD values were low. Parasites can indicate a polluted environment and high BOD is an indication of water pollution (EEA, 2024). Phosphate had only one positive correlation with a parasite in station 1 because its maximum value was in the station.

Prevalence of parasites in water is encouraged by high concentration of phosphate (Aghaindum and Landry, 2019). However, no significant negative or positive correlation was recorded in Stations 2 and 3 probably due to the very low concentration. Nitrate had positive correlation with some parasites in stations 1 and 2 because their high values. Prevalence of parasites in water is also encouraged by high concentration of nitrate (Aghaindum and Landry, 2019). However, a significant negative correlation was recorded in station 3 probably due to the very low concentration.

CONCLUSION

This study assessed the composition, prevalence and parasitic load in relation to some physicochemical parameters of a rural river used as drinking water source. The physicochemical parameters were within acceptable limits for sustenance of aquatic life except for some values of pH and dissolved oxygen values. The study recorded eight (8) different waterborne parasites (*Ascaris lumbricoides, Fasciola hepatica, Taenia solium, Entamoeba coli, Entamoeba histolytica, Giardia lamblia, Cryptosporidium parvum* and *Balantidium coli*) known for their public and veterinary health importance. Some of these parasites are causative agents to some diseases considered under the neglected tropical disease (NTD) framework. The maximum spatial prevalence and parasites load were recorded in Station 2 with higher anthropogenic pressure. The maximum temporal prevalence was in May and June 2023 while the maximum temporal parasite load was in May 2023 before the onset of wet season. The composition, prevalence and load were attributed to the physicochemical conditions of the river, sampling method, anthropogenic related stressors and rainfall. Based on the findings of this study, treatment of the water is required before usage. Dumping of solid wastes and discharge of effluents around the river should be prohibited.

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