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Research Article

Biological Characteristics and Geochemistry of Surface and Groundwater in Uhonmora-Ora, Owan West Local Government Area, Edo State, Nigeria

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Abstract

Physicochemical and biological characteristics of surface and groundwater in Uhonmora-Ora were undertaken. Physicochemical parameters examined include pH, turbidity, dissolved oxygen, total dissolved solids, total suspended solids, and electrical conductivity. The heavy metals studied were Iron, Cadmium, Calcium, Copper, Magnesium, Lead, and Zinc. The bacteriological parameters were counts for pneumoniae, coli, typhi, and aerogenes. The study objective assessed the chemical and biological characteristics of surface and groundwater in Uhonmora-Ora and ascertained its suitability. Data from sixty surface and groundwater samples from streams/rivers and hand-dug wells were analyzed. Primary data from 30 water samples of “A” surface and “B” groundwater samples from hand-dug wells were obtained and analysed from the field of study. The technique of study was purely experimental. The study was conducted during the dry season and water samples collections from the 2 sources were analysed in the laboratory to ascertain their state of water quality of physicochemical parameters and biological counts in comparison with the recommended standards of WHO (2015) and NSDWQ (2007), in line with the Nigeria Ministry of Environment standards (2018), on water quality for drinking desire uses. Results showed that a combination of very high and positive correlations exists between and among the tested parameters. However, variations exist within and among the mean concentrations of NTU, DO, TSS, TDS, Fe, Cd, Cu, Ca, Mg, Pb, Zn, K, E, S, and Ea parameters in surface and groundwater sources. The study recommends that at regular intervals, samples from these water sources should be assessed against water quality standards.

Keywords

Geochemistry, Biology, Heavy Metals, Surface and Groundwater Sources, Wet-season

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1. Introduction

Water gives life, but when not well treated and managed, the water can have deleterious effects and consequently lead to the loss of lives and death [20]. The seasonal variations, drainage patterns, and soil matrices influence the shared contaminants, recharge, and discharge [2, 3, 15]. Since the inception of the Uhonmora-Ora, the community has been relying on the combination of water sourced from streams, rivers, hand-dug wells, and rainwater supplies for its sustainability [14]. This is because the community is unable to connect to the central water supply system from the [9]. Subsequently, the collapse of the central pipe-borne water supply in the Afuze community close to Uhonmora-Ora over 35 years ago led to the discovery of the artesian aquifer and the drilling of boreholes in Sabongida-Ora, another neighbouring community. So far, the indigenous people of Uhonmora-Ora believe that freshwater sources can never be contaminated but get purified naturally in the course of movement. Thus, about 85% of the groundwater sources from hand-dug wells are open and exposed to dust and gasoline particles throughout the season [5]. This is because domestic animals defecate and urinate in these facilities, and their feces leach into groundwater sources. Furthermore, the proximity of sucker ways and pit toilets close to hand-dug wells and dumped sites in clustered houses, as well as the mal-built buildings management affect and contaminates water quality during the wet season. Thus, the constituent effects on human health are the prevalent cases of fever, typhoid, malaria, and cholera, which are water-borne diseases [16, 18, 19]. Many studies on water quality have been carried out in most rural communities in Edo State, but none have been undertaken in Uhonmora-Ora. The seasonal pollution of shared contaminants, movement of sediments, colouration, taste, and human attitudes towards water management compelled the researchers to examine the safety of the supply of these sources of water to human health. The objective of the study is to assess the biological and geochemical characteristics of surface and groundwater sources during the wet season in Uhonmora-Ora, as well as to determine the quality and ascertain their portability for human consumption [12].

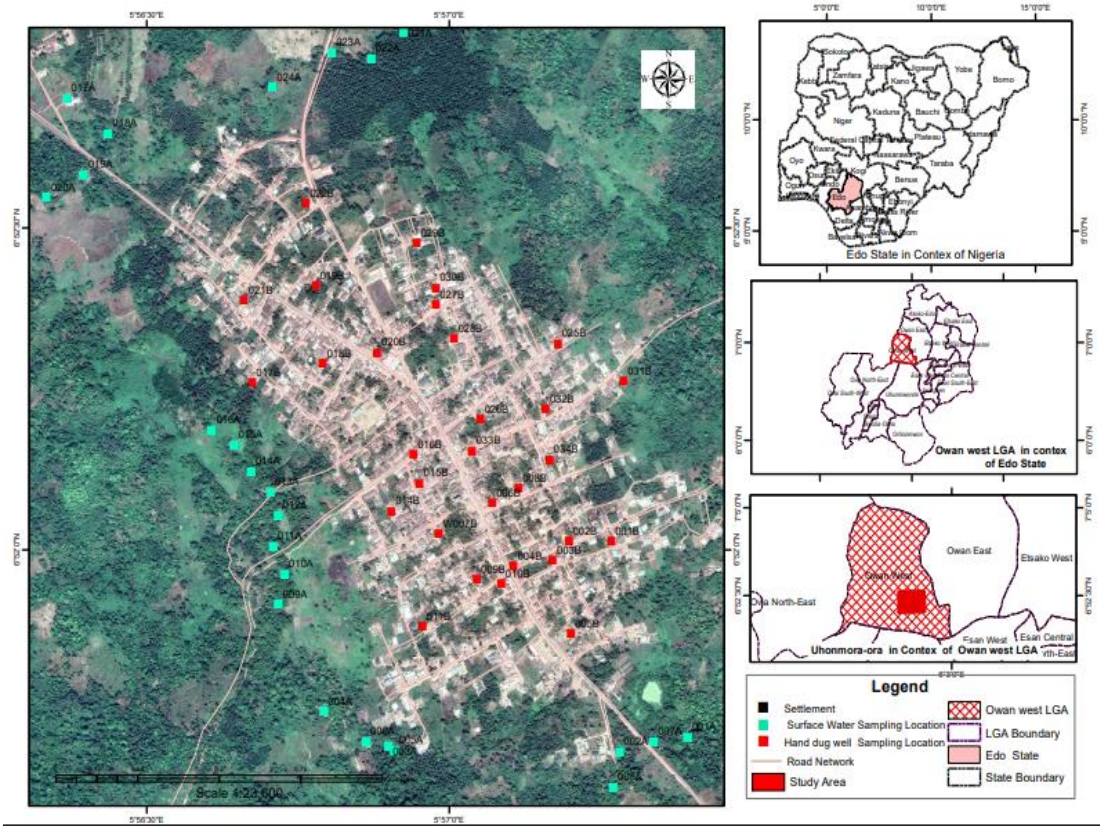
2. Materials and Methods

2.1. The Study Area

Uhonmora–Ora is one of the six Ora communities in Owan West Local Government Area, Edo State, Nigeria. The Community is located between Latitudes 6° 10ˈN and 6° 45ˈN and Longitudes 6° 10ˈE and 6°40ˈE. The community is bounded to the North by Sabongida-Ora, North-East by Eme-Ora, and South by Ozalla communities of the Ora clan, which constitute parts of the Owan-West Local Government Area. Uhonmora-Ora comprises eight quarters which include: Oduosi, Ukpafoga, Ukhuedeodu, Ukpafisi, Ukpokhunmu, Ukpafekhai, Ukpafortisi, and Ukhuoro. The community is characterized by a relatively flat and simple undulating topography of about 78.64 meters above sea level and records its highest temperature (36.1°C) in February and March, and the lowest temperature (19.4°C) in April and May. The community experiences heavy rainfall between March and November every year [10]. The community's annual rainfall is between 2000mm and 3000mm. The area is well-drained by three major Rivers which are perennial, and several streams of water sources, which are seasonal. The perennial rivers are River Owan, River Oruen, and Obvioti River [5, 14]. These significant rivers meandered and cut across eight-quarters of the community. The community is underlain by sedimentary rocks. The characteristics of the hand-dug wells of groundwater were dry and wet. Thus, recharge and discharge were within the vadose zone above the water table owing to the geology of the bedrock. The brownish earth materials support the production of food and cash crops such as plantain, cassava, palm oil, and cocoa production in the State and Nigeria as a whole [1, 5, 20]. The community had a population of 785,676 in 2016 [13].

2.2. Methodology

Both primary and secondary data collection methods were employed to facilitate the research. The primary source comprised field observations, sample collection, and mapping of the study area. The secondary data explored were documentary materials and established sources. Mapping of the study area was undertaken using geo-informatic tools such as Global Positioning System (GPS) and Geographical Information System (GIS) techniques. The global positioning system (GPS) Garmin Channel 78. The Sc model was used to acquire the coordinates (x, y) in each of the sample points. The derived maps with insets of Edo State, Owan West Local Government Area, and Uhonmora-Ora community are presented in Figures 1 to 3. Figure 1 shows 25 sampling points and 35 groundwater sources, Figure 2 shows the pH of water from Uhonmora – Ora, while Figure 3 shows the three major rivers in Uhonmora – Ora used for the study. These maps were generated from the Departments of Geography and Planning, Lagos State University, Ojo, and Kogi State University, Anyigba, respectively.



Source: GIS and Cartography Unit, LASU (2024)

Figure 1. Sampling Location Imagery of Uhonmora - Ora.

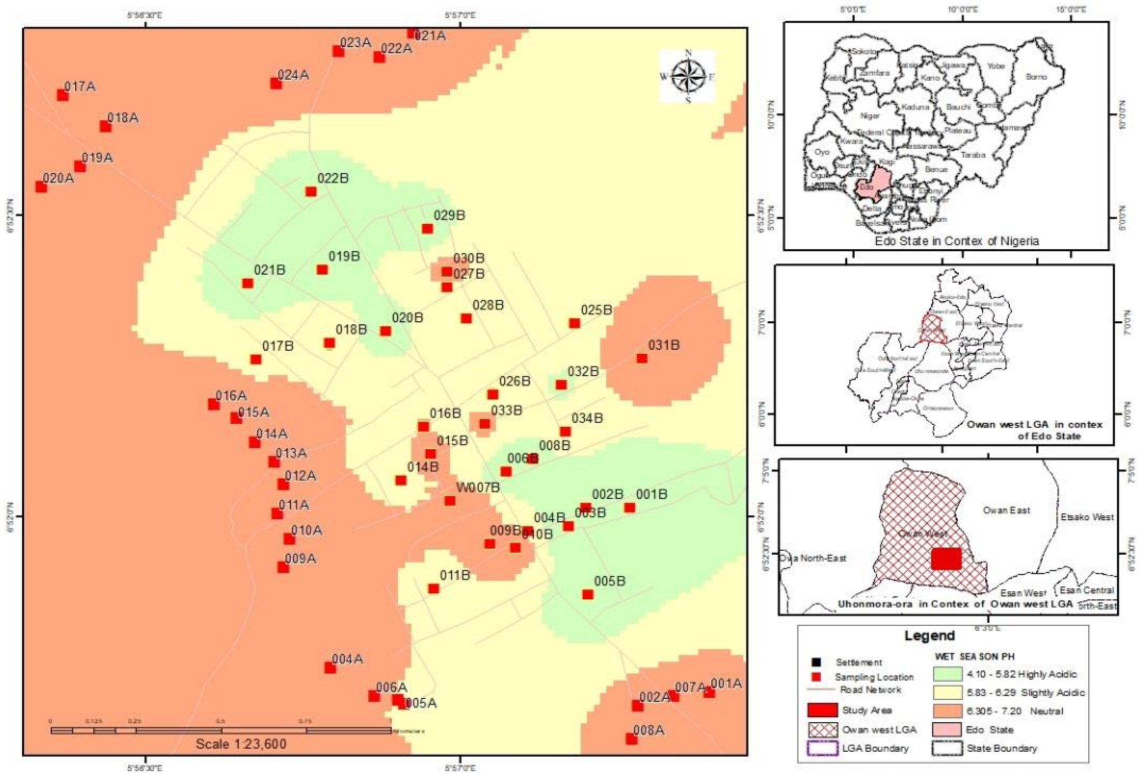
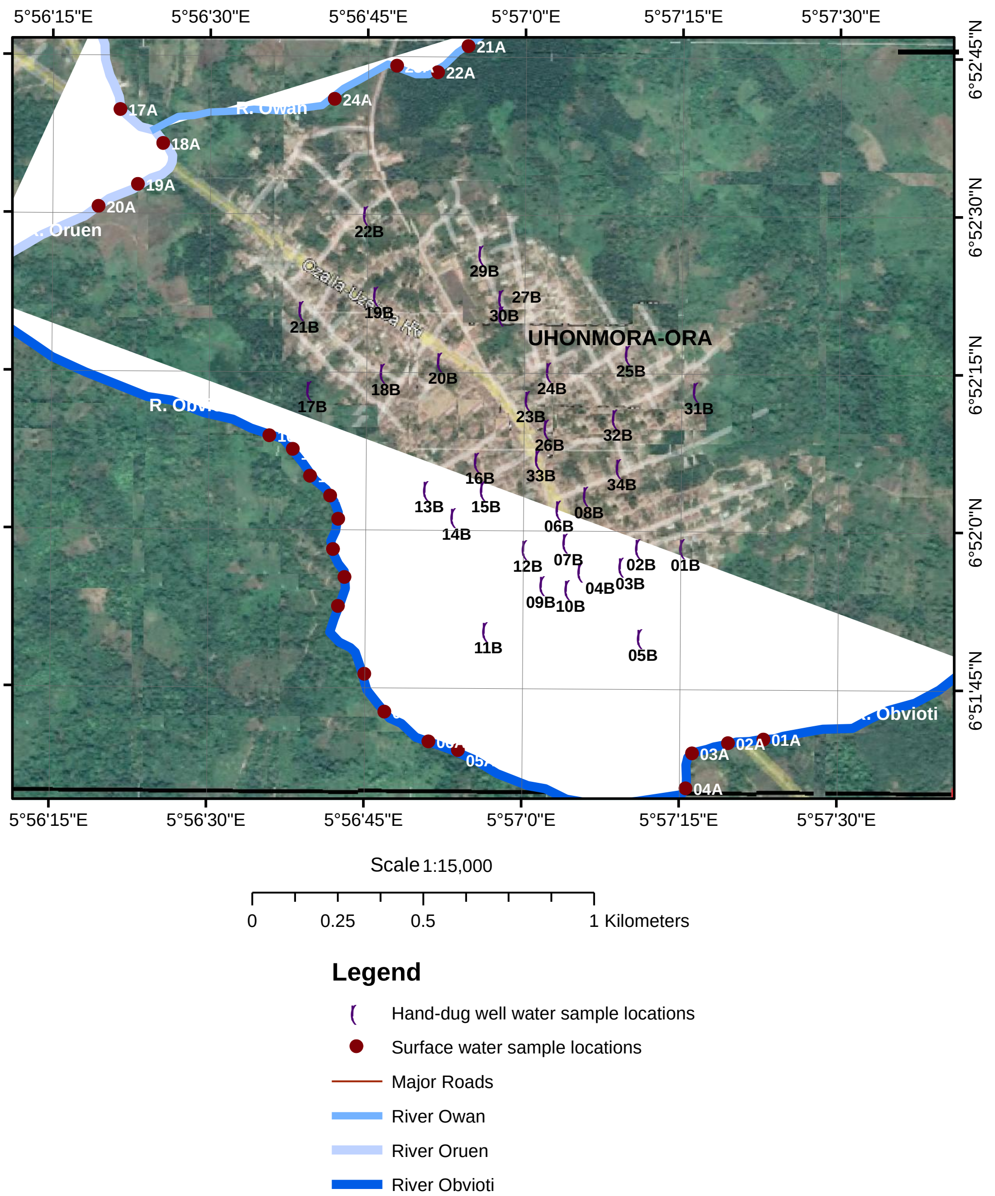


Figure 2. Plot of pH of Water Readings along with Sample Numbers from Uhonmora - Ora. Source: GIS and Cartography Unit, LASU (2024).



Source: GIS and Cartography Unit, Kogi State University, Anyigba, 2024

***Figure 3**. Sampling Location Imagery of the Rivers in Uhonmora-Ora.*

Other materials used were a water cooler, ice blocks, 2000ml of the new plastic bottle, paper tape, a pen, an indelible marker, a notebook, electrical conductivity meters, a compass, a drilling soil auger, a geological hammer, a hand lens, a nose mask, polyethene, and sack-bags. Electrical conductivity meters, test tubes and glass bottles (McCartney), reagents, and test soil were also used for field measurements. The Atomic Absorption Spectrometer (Agilent 280, FSAA), and s. The Mettler balance (FA2104) was used to carry out the physicochemical analyses at the Department of Chemistry laboratory, National Open University of Nigeria, Abuja. Equipment such as thermostat incubator (Jenlab Medical Instrument USA Technology), laboratory incubator (DNP.9022A), bacteriological incubator (i-therm A1-7741), colony counter (J-2), top loading weighing balance, vortex mixer/shaker (SM-C), autoclave (YX-280A), refrigerator, sterilizing Petri boxes, bacteriological wire loop, petri dish disposal/glass, stacking rack, filter Duncan burners, conical flask and laminar flow chamber (SuGold) were used for the bacteriological analyses carried out at the Biological Sciences laboratory, National Open University of Nigeria, Abuja. Thus, this study contributes to the assessment of the biological and geochemical characteristics of surface and groundwater sources in Uhonmora-Ora and ascertains their suitability. This study further lays the foundation for research into this field and the baseline for future academics and researchers [26].

2.2.1. Water Sampling

A total of 60 water samples were collected. These comprise 25 and 35 samples each from “A001 to A025” for surface (SU) and "B001 to B035" for groundwater (GW) sources, respectively, (Figure 2). Sampling was undertaken between the hours of 6 a. m. and 12 noon each day, to test for physical parameters and filled into the 1-litre plastic containers, labelled and stored in the pack-of-ice-cooler for preservation. The samples, tagged as 001 (A and B), 002 (A and B), and 003 (A and B), to 025 (A and B), for surface water and 001 (A and B), 002 (A and B), and 003 (A and B) to 035 (A and B), for groundwater sources respectively. Plate 1 shows the sampling of surface water collection at the study area, while Table 1 shows the sampling code and location of water samples collected from the eight quarters of the study.

Source: This Study, 2024

Figure 4. *Sampling of Surface Water in the Study Area.*

Source: This Study, 2024

Figure 5. *Sampling of Groundwater in the Study Area.*

Table 1. *Sampling code and location of water samples collected from the eight quarters.*

S/N	Quarter and Sampling Code	Wet Season (September) 2024
1	Odosi (ODO)	a. Hand-Dug Well: ODO-GW^2/001A, ODO-GW^2/002A, ODO-GW^2/003A and ODO-GW^2/004A only
2	Ukpafoga (UKP)	a. Hand-Dug Well: UKP-GW^2/001A, UKP-GW^2/002A, UKP-GW^2/003A and UKP-GW^2/004A. b. Surface Water: UKP-SU^2/001B, UKP-SU^2/002B, UKP-SU^2/003B, and UKP-SU^2/004B.
3	Ukhuedeodu (ODU)	a. Hand-Dug Well: ODU-GW^2/001A, ODU-GW^2/002A, ODU-GW^2/003A, and ODU-GW^2/004A. b. Surface Water: ODU-SU^2/001B, ODU-SU^2/002B, ODU-SU^2/003B, and ODU-SU^2/004B.
4	Ukpafisi (UFI)	a. Hand-Dug Well: UFI-GW^2/001A, UFI-GW^2/002A, UFI-GW^2/003A, and UFI-GW^2/004A. b. Surface Water: UFI-SU^2/001B, UFI-SU^2/002B, UFI-SU^2/003B, and UFI-SU^2/004B.
5	Ukpokunmu (UMU)	a. Hand-Dug Well: UMU-GW^2/001A, UMU-GW^2/002A, UMU-GW^2/003A, UMU-GW^2/004A, UMU-GW^2/005B, and UMU-GW^2/006B. b. Surface Water: UMU-SU^2/001B, UMU-SU^2/002B, UMU-SU^2/003B, UMU-SU^2/004B, UMUSU^2/005B, and UMU-SU^2/006B.

S/N	Quarter and Sampling Code	Wet Season (September) 2024
6	Ukpafekhai (UAI)	a. Hand-Dug Well: UAI-GW²/001A, UAI-GW²/002A, UAI-GW²/003A, and UAI-GW²/004A. b. Surface Water: UAI-GW²/001B, UAI-GW²/002B, UAI-GW²/003B, and UAI-SU²/004B.
7	Ukpafortisi (USI)	a. Hand-Dug Well: USI-GW²/001A, USI-GW²/002A, USI-GW²/003A, USI-GW²/004A. b. Surface Water: USI-SU²/001B, USI-SU²/002B, USI-SU²/003B, and USI-SU²/004B.
8	Ukhuoro (URO)	a. Hand-Dug Well: URO-GW²/001A, URO-GW²/002A, URO-GW²/003A, and UROGW²/004A only.

Source: This Study, 2024

2.2.2. Water Analyses

Water samples were filtered into a 100 standard volumetric flask, and 1 ml of nitric acid was added to free the ions and metals before analysis to capture the different wavelengths automatically as selected by the instrument. Using the most probable number (MPN) and spread plate methods (SPM) for the examination of bacteriological analysis. Both the test analyses of physicochemical and bacteriological analyses were carried out in line with the recommended standards of the global practices on the water regulatory body of the WHO [23], as adopted by [6, 11].

2.2.3. Statistical Evaluation

The descriptive statistical methods of Table illustrations, such as mean concentration (MC), correlation matrix (CM), and [21], were adopted and used for the study. The correlation analysis was used to identify the mean concentration and correlations matrix of the synergy between surface and groundwater parameters. The results from the text of physicochemical and bacteriological parameters were analyzed with the aid of SPSS (IBM, 29) and inferential statistical methods, as presented in the correlation matrix of Tables 2 to 10, respectively. In addition, the use of Bivariate Correlation and ANOVA statistical analyses was used to analyze the collected data.

3. Results

The results of the study were compressed, summarized, and presented in Tables 2 to 10. Table 2 shows the comparison of the detected parameters from the surface and groundwater samples and a comparative study with the [22] standards on water quality with the detected variables in Uhonmora-Ora.

Table 2. Physical Parameters of Surface and Groundwater Sources in Uhonmora-Ora during the Wet Season.

Variable	SU Temp	GW Temp	SU NTU	GW NTU	SU DO	GW DO	SU TSS	GW TSS	SU PH	GW PH	SU EC	GW EC	SU TDS	GW TDS
WHO 2018	36.1°C	36.1°C	5.0	5.0	3.0	3.0	200	200	8.5	8.5	1000	1000	500	500
001	25.5	28.4	11.46	48.69	3.99	4.08	25.0	35.0	6.5	4.8	0.03	0.18	32	136
002	25.4	28.9	10.02	103.10	3.93	4.17	24.0	40.6	6.4	4.9	0.03	0.40	28	288
003	25.4	28.7	9.67	122.08	3.99	345.51	26.1	53.6	6.5	4.6	0.03	0.48	27	341
004	25.4	28.5	10.02	112.05	3.93	5.28	22.4	43.5	6.4	6.2	0.03	0.44	28	313
005	25.7	29.2	8.95	112.41	3.81	4.34	30.3	45.7	6.2	5.1	0.02	0.44	25	314
006	28.7	28.7	8.95	80.19	3.93	4.26	24.7	43.7	6.4	5.0	0.02	0.31	25	224
007	25.8	29.4	8.95	106.68	3.93	5.02	24.0	61.7	6.4	5.9	0.02	0.42	25	298
008	26.4	29.4	8.95	124.58	3.93	4.51	26.8	63.5	6.4	5.3	0.02	0.49	25	348
009	27.2	29.8	8.95	346.54	4.11	5.53	30.0	35.7	6.7	6.5	0.02	1.34	25	968
010	26.9	29.7	8.95	161.82	3.93	5.79	30.2	36.3	6.4	6.8	0.02	0.63	25	452
011	26.6	28.1	9.31	155.01	3.93	5.19	24.6	35.0	6.4	6.1	0.02	0.61	26	433
012	26.6	28.4	9.31	201.55	3.93	5.79	25.8	40.6	6.4	6.8	0.02	0.78	26	563
013	26.1	28.2	10.74	191.17	4.18	5.19	32.0	53.6	6.8	6.1	0.03	0.75	30	534

Variable	SU Temp	GW Temp	SU NTU	GW NTU	SU DO	GW DO	SU TSS	GW TSS	SU PH	GW PH	SU EC	GW EC	SU TDS	GW TDS
014	25.8	28.9	10.74	181.51	4.11	5.28	32.8	43.5	6.7	6.2	0.03	0.71	30	507
015	25.8	29.1	10.74	228.05	4.05	5.45	24.2	45.7	6.6	6.4	0.03	0.89	30	637
016	26.9	27.6	11.10	174.35	3.99	5.36	25.8	43.7	6.5	6.3	0.03	0.68	31	487
017	27	29.2	19.69	148.93	4.42	5.28	25.0	61.7	7.2	6.2	0.07	0.58	55	416
018	26.7	28.5	17.18	110.26	4.18	5.36	24.0	63.5	6.8	6.3	0.05	0.43	48	308
019	26.2	29.2	16.83	75.54	4.18	4.68	26.1	35.7	6.8	5.5	0.06	0.29	47	211
020	26.6	29.2	16.83	91.29	4.18	4.51	22.4	36.3	6.8	5.3	0.05	0.34	47	255
021	26.4	28.7	14.68	134.25	3.99	4.34	30.3	35.0	6.5	5.1	0.04	0.52	41	375
022	26.3	29.4	14.32	18.62	3.99	4.34	24.7	54.3	6.5	5.10	0.04	0.1	40	52
023	26.1	29.4	13.60	89.50	4.05	5.19	24.0	54.3	6.6	6.1	0.04	0.35	38	250
024	26.1	29.8	13.60	167.54	3.99	5.19	25.0	54.2	6.5	6.1	0.04	0.65	38	468
025	25.8	29.7	7.52	33.29	4.11	4.60	24.0	45.6	6.7	5.4	0.02	0.12	21	93
026	-	28.1	-	265.28	-	5.62	-	43.2	-	6.6	-	1.03	-	741
027	-	28.4	-	334.01	-	5.28	-	45.3	-	6.2	-	1.29	-	933
028	-	28.2	-	181.86	-	5.28	-	43.6	-	6.2	-	0.71	-	508
029	-	28.9	-	120.65	-	5.11	-	42.7	-	6.0	-	0.47	-	337
030	-	28.5	-	126.73	-	5.36	-	38.9	-	6.3	-	0.49	-	354
031	-	29.2	-	160.38	-	6.13	-	40.7	-	7.2	-	0.60	-	448
032	-	29.1	-	93.44	-	4.85	-	43.5	-	5.7	-	0.36	-	261
033	-	29.2	-	209.79	-	5.45	-	45.6	-	6.4	-	0.82	-	586
034	-	28.9	-	224.11	-	5.36	-	46.2	-	6.3	-	0.87	-	626
035	-	29	-	148.69	-	4.08	-	45.8	-	6.8	-	0.58	-	536

Source: This Study, 2024

From the Table, the measured values from NTU, DO, TSS, PH, EC, and TDS were compared with the [23] recommended standards limit. The variance in values could be attributed to a combination of factors such as climate variation, shared contaminants from pollutants, seepages, interactions, and associations of these parameters between surfaces and groundwater sources [27]. These findings are consistent with the summation of [17, 3], which indicates that climatic variation, shared contaminants from pollutants, interactions, and associations are determinant factors for the sources of surface and groundwater pollution.

Table 3. *Geochemistry of Surface and Groundwater Sources in Uhonmora-Ora During the Wet Season.*

Variable	SU Iron (Fe)	GW Iron (Fe)	SU Cad. (Cd)	GW Cad. (Cd)	SU Cop. (Cu)	GW Cop. (Cu)	SU Cal. (Ca)	GW Cal. (Ca)	SU Mag (Ma)	GW Mag (Ma)	SU Lead (Ph)	GW Lead (Pb)	SU Zine (Zn)	GW Zine (Zn
WHO 2018	0.1	0.1	0.003	0.003	3.0 (2mg/L)	3.0 (2mg/L)	75	75	100–300 mg/litre,	100–300 mg/litre,	0.01	0.01	5.0	5.0
001	0.058	0.536	0.004	0	0	0.012	3.176	38.5	6.3776	0.813	0.05	0.01	0.46	0.4599

Varia-ble	SU Iron (Fe)	GW Iron (Fe)	SU Cad. (Cd)	GW Cad. (Cd)	SU Cop. (Cu)	GW Cop. (Cu)	SU Cal. (Ca)	GW Cal. (Ca)	SU Mag (Ma)	GW Mag (Ma)	SU Lead (Ph)	GW Lead (Pb)	SU Zine (Zn)	GW Zine (Zn
002	0.355	0.187	0.003	0	0.018	0	14.105	58.6	12.0407	0.6984	0.05	0.01	0.4677	0.4625
003	0.14	0.021	0.003	0	0	0.033	4.974	5.207	4.36	0.7021	0.03	0.02	0.4699	0.4596
004	0.048	0.564	0.003	0	0.057	0	6.707	5.015	15.9744	13.7454	0.03	0.04	0.4824	0.4873
005	0.156	0.265	0.004	0	0.038	0	4.864	4.735	18.3124	13.2272	0.01	0.04	0.4608	0.4627
006	0.198	0.313	0.004	0	0	0.024	5.012	43.9	0.5945	8.3672	0.02	0.05	0.4666	0.4649
007	0.145	0.313	0.004	0	0.01	0.005	39.1	4.82	14.971	4.747	0.02	0.04	0.4631	0.467
008	0	0.206	0.004	0	0	0.028	25.2	21.4	23.2766	9.1902	0.02	0.04	0.454	0.4613
009	0	0.156	0.007	0	0	0	23.2	5.124	0.5757	2.1966	0.02	0.03	0.461	0.4648
010	0.123	0.2	0	0	0	0	14.554	0	0.4999	0.849	0.02	0.03	0.4617	0.4613
011	0.047	0.068	0	0.001	0.035	0	22.7	4.14	0.4507	6.3776	0.05	0.06	0.4614	0.4614
012	0.1	0.042	0	0.001	0	0	7.768	27.1	14.085	12.0407	0.03	0.07	0.4666	0.4622
013	0.578	0.448	0	0.001	0	0	6.12	24.7	0.6261	4.36	0.05	0.05	0.4604	0.4666
014	0.43	0.391	0	0.002	0	0	25.6	5.425	6.424	15.9744	0.06	0.06	0.4604	0.4637
015	0.318	0	0	0.002	0	0.032	30.7	77.4	0.5089	18.3124	0.05	0.05	0.4636	0.4667
016	0.267	0.162	0	0.001	0	0	6.66	5.387	13.7095	0.5945	0.05	0.04	0.4689	0.4659
017	0.207	0.414	0.002	0.002	0.012	0	59.6	10.737	0	14.971	0.05	0.04	0.4594	0.4618
018	0.259	0.11	0.003	0.002	0	0	38.1	4.25	8.082	23.2766	0.05	0.01	0.4596	0.4645
019	0.477	0.733	0.003	0.002	0.033	0	5.335	41.4	8.6049	0.5757	0.06	0.01	0.46	0.4657
020	0.199	0.084	0.002	0.002	0	0	38.5	5.647	0.4946	0.4999	0	0.01	0.4792	0.4638
021	0.105	0.072	0.003	0	0	0.041	58.6	25.3	6.3776	0.4507	0	0.01	0.4589	0.4628
022	0	0.246	0.004	0.002	0.024	0.011	5.207	5.108	12.0407	14.085	0	0	0.49	0.4634
023	0	0.521	0.003	0.001	0.005	0.007	5.015	14.057	4.36	0.6261	0	0.03	0.4599	0.4632
024	0.069	0.058	0.003	0.002	0.028	0	4.735	131	15.9744	6.424	0.05	0.01	0.4612	0.4681
025	0.114	0.259	0.002	0.003	0	0	43.9	5.972	18.3124	0.5089	0.05	0.02	0.4596	0.4564
026	-	0.477		0.003	-	0	-	36.4	-	13.7095	-	0.03	-	0.0246
027	-	0.199		0.002	-	0	-	43	-	0	-	0.04	-	0.4681
028	-	0.105		0.003	-	0	-	5.429	-	8.082	-	0.02	-	0.4599
029	-	0.1		0.004	-	0	-	5.381	-	8.6049	-	0.04	-	0.4625
030	-	0.2		0.003	-	0.097	-	38.5	-	0.4946	-	0.04	-	0.4596
031	-	0.069		0.004	-	0	-	58.6	-	26.3013	-	0.05	-	0.4873
032	-	0.114		0.003	-	0	-	5.207	-	0.589	-	0.01	-	0.4627
033	-	0.075		0.005	-	0	-	5.015	-	8.6075	-	0.01	-	0.4649
034	-	0.297		0.003	-	0	-	4.735	-	0.0628	-	0.02	-	0.467
035	-	0.332		0.003	-	0	-	43.9	-	9.0266	-	0.04	-	0.4613

Source: This Study, 2024

The measured values of Fe, Cd, Cu, Ca, Mg, Ph, and Zn were compared with the WHO [24] recommended standard limits on water quality. The variance of the detected and recommended values could be attributed to a combination of factors such as climatic variation, shared contaminants from pollutants, seepages, interactions, and associations of these parameters between surfaces and groundwater sources. These findings are consistent with the summation of [7, 1, 2, 16], which shared contaminants from pollutants, interactions, and associations are determined factors for the sources of surface and groundwater pollution.

Table 4*. Descriptive and Mean Concentration Analysis of Geochemistry of the Surface Water during the Wet Season.*

Variables	Mean	Min.	Max.	S.D.	C.V.
Turbidity (NTU)	11.64	7.52	19.69	3.27	28.09
DO	4.03	3.93	4.42	0.13	3.26
TSS	26.17	24	32.8	2.96	11.31
Ph	65.64	6.2	6.8	0.21	3.20
EC	0.16	0.02	0.07	0.01	42.06
TDS	32.52	21	55	9.23	28.09
Fe	0.18	0	0.578	0.15	87.31
Cd	0.00	0	0.007	0.002	62.62
Cu	0.010	0	0.057	0.02	152.11
Ca	19.98	3.176	59.6	17.29	86.53
Ma	8.281	0	23.2766	6.96	84.04
Pb	0.032	0	0.06	0.020	61.29
Zn	0.464	0.46	0.4824	0.008	1.73

Source: This Study, 2024

Table 4 shows the mean concentration of the examined parameters of the geochemistry of the surface water during the wet season in Uhonmora-Ora. From the Table, the value of pH (65.64), the mean concentration was relatively higher than other examined geochemistry variables. In addition, the maximum value of Mg (23.27), the mean concentration was relatively higher than other examined geochemistry variables in the study. These findings are consistent with the summation of [7, 20, 19], which shared that contaminants from pollutants, interactions, and associations are determined factors for the sources of surface and groundwater pollution.

Table 5*. Mean Concentration of Geochemistry of the Groundwater Sources during the Wet Season.*

Variables	Mean	Min.	Max.	S.D.	C.V.
Turbidity (NTU)	148,11	18.62	346.54	74.22	50.12
DO	14.76	4.08	345.51	58.39	387.22
TSS	45.63	35	61.7	8.49	18.59
Ph	17.21	4.8	7.2	0.64	10.91
EC	0.57	0.1	0.89	0.29	49.9
TDS	417.17	52	968	207.33	50.12
Fe	0.24	0	0.733	0.18	74.41
Cd	0.001	0	0.005	0.001	85.70

Variables	Mean	Min.	Max.	S.D.	C.V.
Cu	0.008	0	0.097	0.02	228.07
Ca	23.46	0	131	27.08	115.43
Ma	7.116	0	26.3013	7.08	99.44
Pb	0.030	0	0.07	0.018	57.13
Zn	0.452	0.024	0.4667	0.074	16.27

Source: This Study, 2024

Turbidity, DO, TSS, and TDS concentrations were much higher in the groundwater sources than in surface water, pH is higher on the surface than in groundwater sources. The concentration of EC was higher in groundwater sources and between surface and groundwater sources. From the Table, a lot of variations exist within and among surface and groundwater quality during the wet season. The mean concentrations of Fe, Cd, Cu, Ca, Mg, Pb, and Zn were in variance between surface and groundwater sources in Uhonmora-Ora. These findings are consistent with the summation of [7, 18-20], which shared that contaminants from pollutants, interactions, and associations are determining factors for the sources of surface and groundwater pollution.

Table 6. *Rate of Isolation of Bacteria Counts from Surface (SU) and Groundwater (GW) Sources during the Study.*

	Isolates Rate, Number (%)									
Quarter	**K. pneumoniae**		**E. coli**		**S. typhi**		**E. aerogenes**		**Total**	
Samples	**Su**	**GW**	**Su**	**GW**	**Su**	**GW**	**Su**	**GW**	**Su**	**GW**
Odosi (n=4)	1 (25)	1 (25)	2 (50)	2 (50)	1 (25)	1 (25)	2 (50)	2 (50)	6 (17.14)	6 (10.71)
Ukhuoro (n=4)	1 (10)	2 (50)	1 (0)	2 (50)	1 (25)	0 (0)	0 (0)	3 (75)	3 (8.57)	7 (21.42)
Ukpafoga (n=4)	1 (25)	2 (50)	2 (50)	3 (75)	1 (25)	1 (25)	2 (20)	2 (50)	6 (17.14)	8 (14.29)
Ukhuedeodu (n=4)	1 (10)	2 (25)	1 (0)	2 (25)	1 (25)	0 (0)	0 (0)	3 (75)	3 (8.57)	7 (21.42)
Ukpafisi (n=4)	1 (25)	0 (0)	1 (25)	2 (50)	1 (25)	1 (25)	2 (50)	0 (0)	5 (14.20)	3 (5.36)
Ukpokunmu (n=6)	1 (25)	3 (50)	3 (75)	3 (50)	2 (50)	2 (33)	2 (50)	3 (50)	8 (22.86)	11 (19.64)
Ukpafekhai (n=4)	1 (25)	1 (25)	2 (20)	2 (50)	2 (25)	0 (0)	2 (50)	2 (50)	7 (20.0)	5 (8.93)
Ukpafortisi (n=4)	1 (25)	1 (25)	2 (50)	2 (50)	0 (0)	0 (0)	1 (25)	2 (50)	4 (11.43)	5 (8.93)
Control (n=2)	1 (25)	0 (0)	0 (0)	2 (50)	0 (0)	1 (25)	1 (25)	1 (25)	2 (5.71)	4 (7.14)
Total	6 (17.14)	12 (21.43)	11 (31.43)	20 (35.71)	8 (22.86)	6 (10.71)	10 (28.57)	18 (32.14)	35 (100.0)	56 (100)

Key: n number of samples N= number of isolates, %= Percentage. Klebsiella pneumonia, Escherichia coli, Salmonella typhi, Enterobacter aerogenes
Source: Fieldwork, 2024.

Table 6 shows the counts of bacteriological parameters of K. pneumoniae, E. coli, S. typhi, and E. aerogenes vary from quarter to quarter between surface and groundwater sources and are relatively low from the control point in the study. The variance in values was compared with the [6, 23], recommended standards limit on water quality in the study. These findings are consistent with the summation of [3, 7, 8, 20], which shared contaminants from pollutants, seepages, interactions, and associations are determined factors for the sources of surface and groundwater pollution.

Table 7. *Distribution of Bacteria Isolates from Surface (SU) and Groundwater (GW) Sources Across the Eight Quarters in Uhonmora-Ora During the Study.*

Sample Location	Number of Bacterial Isolates		Percentages (%)	
	SU	GW	SU	GW
Odosi	2	2	7.14	7.14
Ukhuoro	2	2	7.14	7.14
Ukpafoga	6	3	17.14	13.42
Ukhuedeodu	4	3	8.57	13.42
Ukpafisi	4	3	14.29	13.42
Ukpokunmu	8	8	22.86	25.64
Ukpafekhai	5	2	19.0	8.93
Ukpafortisi	4	2	11.43	8.93
Control	1	1	5.71	4.14
Total	36-1	26-1	100	100

Key: n= number of samples N= number of isolates %= Percentage
Source: Fieldwork, 2024

Table 7 shows that there were some levels of tied and variation in the counts of bacterial isolates across the eight quarters in the study. The variance in values was compared with the [23] recommended standards limit on water quality in the study. These findings are consistent with the summation of [3, 8], which shared contaminants from pollutants, seepages, interactions, and associations are determined factors for the sources of surface and groundwater pollution.

Table 8. *Frequency of Occurrence of Bacteria Isolates from Surface (SU) and Groundwater (GW) Sources Across the Eight Quarters in Uhonmora-Ora During the Study.*

Sample Location	Occurrence Frequency		Percentages (%)	
	SU	GW	SU	GW
K. pneumoniae	6	12	17.14	21.43
E. coli	11	20	31.43	35.71
S. typhi	8	6	22.86	10.71
E. aerogenes	*10*	18	28.57	32.14
Total	35	56	100	100

Key: n= number of samples N= number of isolates %= Percentage
Source: This Study, 2024

Table 9. *Summary of the Frequency of Occurrence of Bacteria Isolates from Surface (SU) and Groundwater (GW) Sources Across the Eight Quarters in Uhonmora-Ora During the Study.*

Summary								
Groups	**Count**		**Sum**		**Average**		**Variance**	
	SU	**GW**	**SU**	**GW**	**SU**	**GW**	**SU**	**GW**
K. pneumoniae	6	7		6	1		0.	
				12	1.714286		0.571429	
				11	1.833333		0.566667	
E. coli	6	9		20	2.222222		0.194444	
S. typhi	6	5	8	6	1.333333	1.2	0.266667	0.2
10								
E. aerogenes	6	8		18	1.66667	2.25	0.26666.7	0.5

Source: This Study, 2024.

The results show there is no significant difference between the surface water samples. There are significant differences between the groundwater sources (P< 0.05).

Table 10. *Correlation Matrix of the Physiochemical Parameters and Biological Counts in Uhonmora-Ora Surface Water.*

	T	**DO**	**TSS**	**Ph**	**EC**	**TDS**	**Fe**	**Cd**	**Cu**	**Ca**
T	0									
DO	- 0.435**	0								
TSS	0.858**	-0.431*	0							
Ph	0.059	0.487**	0.150	0						
EC	0.318	0.172	0.212	0.503**	0					
TDS	0.322	0.168	0.229	0.560**	0.961*	0				
Fe	0.313	0.027	0.155	0.355	0.651**	0.627**	0			
Cd	0.227	0.225	0.148	0.502**	0.873**	0.821**	0.437	0		
Cu	0.239	0.214	0.124	0.504**	0.973**	0.936**	0.625**	0.972*	0	
Ca	0.170	0.366*	0.118	0.568**	0.897**	0.859**	0.512**	0.924**	0.934**	0
Ma	0.352*	0.072	0.250	0.535**	0.930**	0.868**	0.561**	0.937**	0.915**	0.873**
Pb	0.324	-0.028	0.265	0.453*	0.819**	0.823**	0.789**	0.719**	0.764**	0.632**
Zn	0.425*	-0.058	0.257	0.343*	0.812**	0.841**	0.609**	0.762**	0.650**	0.606**
K	0.500**	-0.031	0.340	0.369**	0.821**	0.830**	0.521**	0.768**	0.753**	0.625**
E	0.547	0.655	0.665	0.506*	0.538**	0.345**	0.678**	0.647**	0.537**	0.644**
S	0.965	0.947*	0.617	0.708*	0.623**	0.618**	0.654**	0.624**	0.615**	0.626**
E	0.559	0.546	0.443	0.548	0.523*	0.546	0.638**	0.525**	0.514**	0.524**

	Ma	Pb	Zn	K. Pneumo	E. Coli	S. Typhi	E. Aerog
T							
DO							
TSS							
Ph							
EC							
TDS							
Fe							
Cd							
Cu							
Ca							
Ma	0						
Pb	0.731**	0					
Zn	0.636**	0.835**	0				
K	0.737**	0.802**	0.959**	0			
E	0.619**	0.547**	0.937**	0.462**	0		
S	0.937**	0.528**	0.512**	0.513**	0.523**	0	
E	0.523**	0.540**	0.531**	0.503**	0.415**	0.456**	0

Source: This Study, 2024
*Significant @ 0.05 **Significant @ 0.01

Table 10 shows the correlation matrix of the physiochemical parameters and biological counts in the Uhonmora-Ora surface water of the study. The comparative analyses of the examined variables of surface and groundwater quality are discussed in detail in Table 11.

Table 11. *Correlation Matrix of the Physiochemical Parameters and Biological Counts in Uhonmora-Ora Groundwater.*

	T	DO	TSS	Ph	EC	TDS	Fe	Cd	Cu	Ca
T	0									
DO	-0.455**	0								
TSS	0.958**	-0.441*	0							
Ph	0.060	0.487**	0.151	0						
EC	0.320	0.182	0.214	0.603**	0					
TDS	0.325	0.171	0.233	0.580**	0.961*	0				
Fe	0.316	0.037	0.158	0.375	0.661**	0.687**	0			
Cd	0.267	0.245	0.168	0.592**	0.973**	0.921**	0.477	0		
Cu	0.259	0.234	0.154	0.604**	0.983**	0.936**	0.635**	0.982*	0	
Ca	0.170	0.366*	0.118	0.568**	0.897**	0.859**	0.512**	0.924**	0.934**	0
Ma	0.372*	0.076	0.270	0.545**	0.950**	0.888**	0.571**	0.957**	0.955**	0.873**

	T	DO	TSS	Ph	EC	TDS	Fe	Cd	Cu	Ca
Pb	0.334	-0.028	0.285	0.463*	0.839**	0.843**	0.799**	0.729**	0.784**	0.636**
Zn	0.455*	-0.058	0.277	0.363*	0.832**	0.847**	0.609**	0.752**	0.750**	0.626**
K	0.505**	-0.034	0.360	0.389**	0.841**	0.860**	0.524**	0.778**	0.759**	0.655**
E	0.567	0.675	0.765	0.566*	0.638**	0.345**	0.678**	0.657**	0.567**	0.674**
S	0.965	0.987*	0.657	0.768*	0.723**	0.658**	0.674**	0.644**	0.645**	0.656**
E	0.589	0.566	0.453	0.578	0.543*	0.566	0.668**	0.545**	0.534**	0.544**

	Ma	Pb	Zn	K. Pneumo	E. Coli	S. Typhi	E. Aerog
T							
DO							
TSS							
Ph							
EC							
TDS							
Fe							
Cd							
Cu							
Ca							
Ma	0						
Pb	0.751**	0					
Zn	0.736**	0.845**	0				
K	0.757**	0.802**	0.979**	0			
E	0.639**	0.567**	0.967**	0.467**	0		
S	0.997**	0.568**	0.532**	0.523**	0.533**	0	
E	0.543**	0.544**	0.534**	0.533**	0.455**	0.456**	0

Source: This Study, 2024
*Significant @ 0.05 **Significant @ 0.01

Table 11 shows the correlation matrix of the physiochemical parameters and biological counts in the Uhonmora-Ora groundwater of the study.

4. Discussion

From Tables 10 and 11, the results of the correlation matrixes of the physiochemical parameters and biological counts of surface and groundwater sources show that TSS has no relationship with other parameters. Thus, a very positive and perfect relationship exists between the physicochemical parameters and bacteriological counts for both surface and groundwater. From the Tables, it was observed that there is a very high and positive correlation between Turbidity and TSS for surface (r = 0.858) and groundwater (r = 0.958). This implies that the higher the concentration of TSS, the more the water turbidity owing to the shared contaminants from interactions and associations between surface and groundwater. In addition, a very high and positive correlation exists between EC and Ph for surface (r = 0.503), and for groundwater (r = 0.603), TDS and Ph (r = 0. 560), for surface and (r = 0. 508) for groundwater, Cd and Ph (r = 0.821), Cu (r = 0.973), Ca (r = 0.879), Ma (r = 0.930) and K (r = 0.821), for surface water sources, and Cd (r = 0.592), Cu (r = 0.604), Ca (r = 0.568), Ma (r = 0.545), and K (r = 0.389), for groundwater respectively. Perfect and high correlation occurred between TDS and Fe (r = 0.625), Cd^{-}(r = 0.821), Cu (r = 0.936), Ca (r = 0.859), Ma (r = 0.868), Ph (r = 0. 823), Zn (r = 0. 841), K (r = 0. 830), E (r = 0. 345), and S (r = 0.618), surface water sources, and Fe (r = 0.687), Cd (r = 0.921), Cu (r = 0.936), Ca (r = 0.859), Ma (r = 0.888), Ph (r = 0. 843), Zn (r = 0. 847), K (r = 0. 860), E (r = 0. 345), and S (r = 0.658), for groundwater sources respectively. Furthermore, very high and positive correlations exist between Ca and Cd, Ma, Ph and Zn for surface and groundwater sources respectively as presented in the Tables. The results from Tables 8 and 11 revealed that there was a very high and positive correlation among the counts of E and Fe (r = 0.638), E and Cd (r = 0.525), E and Cu (r = 0.514), E and Ca (r = 0.524), E and Ma (r = 0.523), E and Ph (r = 0.540), and E and Zn (r = 0.531), respectively for surface water sources and E and Fe (r = 0.668), E and Cd (r = 0.545), E and Cu (r = 0.534), E and Ca (r = 0.544), E and Ma (r = 0.543), E and Ph (r = 0.544), and E and Zn (r = 0.534), for groundwater. A very high correlation occurred for S (r = 0.947), DO (r = 0.98), E (r = 0.708), and Ph (r = 0.566), respectively for surface and groundwater sources where comparison analyses were made from other biological counts. The high correlation of these counts could be a result of climatic variation, shared contaminants from pollutants, interactions and associations of these parameters and counts which conformed with the studies of [2, 4, 6, 8, 15, 19], Factors such as the land use pattern and habitat conditions for the microorganisms to thrive in groundwater could be added factors to their correlations and this summation also conformed to the [23, 25, 26], the permissive limit for water quality.

5. Conclusion

The study examined the geochemistry of surface and groundwater sources during the wet season in Uhonmora-Ora. There exists some level of shared contaminants from anthropogenic and natural sources on the contamination, interactions and associations of surface and groundwater sources. The study has shown there is not much difference between the observed and detected parameters of physicochemical and bacteriological counts between the surface and groundwater in Uhonmora-Ora during the wet season. Given this, the minimum variation could be a result of the shared contaminants of pollutants and seepages. The study revealed that a very positive and perfect relationship exists between the physicochemical parameters and biological counts for surface and groundwater. While a very high and positive correlation exists between Turbidity and TSS (r = 0.858) for surface and groundwater (r = 0.958), as a result of; climatic variation, shared contaminants from pollutants, seepages, interactions and associations of these parameters between surfaces and groundwater sources. In essence, the results of geochemistry and heavy meters in surfaces and groundwater sources show the combination of a very high and positive correction, perfect and high correlation exists between and among the texted parameters. Variations exist within and among the mean concentration of NTU, DO, TSS, TDS, Fe, Cd, Cu, Ca, Mg, Pb, Zn, K, E, S and Ea and there is no significant difference between surface and groundwater sources.

6. Recommendations

The study recommends that at regular intervals, samples on sources of water quality should be carried out and made available to researchers to examine and ascertain conformity to water quality standards. In addition, there should be urgent measures such as improving the quality sources of water in Uhonmora-Ora to combat the adverse effects of polluted water.

Abbreviations

IBM	International Business Machines
MPN	Most Probable Number
SPM	Spread Plate Methods

Conflicts of Interest

The authors declare no conflicts of interest.

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