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Physico-Chemical Analysis of Surface and Ground Water Samples in Warri Area, Southern Nigeria

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INFORMATION

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ABSTRACT

Surface and ground water quality in Warri, Southern Nigeria were investigated in order to determine the potability of the water in the study area. A total of nine (9) water samples were obtained (six (6) river samples and three (3) borehole samples) and analyzed for their physico-chemical properties and heavy metal concentrations using standard techniques. The results of the analysis reveals the following: pH (5.80-7.40), Temperature (28.7-30.3), Total Dissolved Solid (13.00-14,400.00), Electrical Conductivity (27.00-28,800.00) Turbidity (2.87-31.46), Dissolved Oxygen (3.30-7.40), Total Solids (23.00-14,430.00), Total Hardness (8.00-2700.00), Total Alkalinity (19.00-68.00), Total Suspended solids (4.00-30.00), Biological Oxygen Demand (1.20-2.90), Chemical Oxygen Demand (2.56-6.64), Salinity (8.06-12,390.16), SO_4^{2-} (0.451-757.809), NO_3^- (<0.001-21.237), PO_4^{3-} ((<0.001-1.616), CO_3 (NP), Ca^{2+} (0.841-168.21), Mg^{2+} (0.411-554.27), Na^{2+} (1.426-1136.65), K^+ (0.043-96.453), Fe^{2+} ((<0.001-0.047), Cr^{3+} ((<0.001-0.023), Cd^{2+} ((<0.001-0.004), Zn^{2+} ((<0.001-0.218), Cu^{2+} ((<0.001), and Pb^{2+} ((<0.001). The physico-chemical analysis reveals that the values obtained for all parameters do not fall under WHO (2018) standard for drinking water, with the exception of Biological Oxygen Demand, NO_3^- and PO_4^{3-}. The bulk of the metrics had high concentrations, indicating that surface anthropogenic activities are likely the source of the water contamination. As a result, the water is not potable, hence unfit for human consumption. Therefore, before usage, the water must be adequately treated.

1. Introduction

The importance of water in the ecosystem cannot be over emphasized as it is a key ingredient in our daily activities. However, this vital ingredient is being polluted at an alarming rate which in turn poses an adverse effect to those who depend on it for survival. Humans are majorly the ones responsible for the degradation of this vital ingredient as a lot of activities carried out by them (anthropogenic activities) results in the pollution of these water bodies (Rivers, streams, lakes, ponds, springs etc.). These anthropogenic activities (domestic sewage disposal, mining, oil spillage, fossil fuel burning, recreational activities and lots more) may alter the composition of water physically, chemically or biologically, rendering it unfit for consumption. River water aids human development, and various forms of life depends on it for support and maintenance (Bhardwaj et al., 2017). It generally serves as a source of potable water where groundwater supplies are inadequate/unavailable, and it naturally possesses a high degree of self-purification (Seiyaboh et al., 2017).

However, self-purification is disturbed by excessive pollution problems, especially those occasioned by socio-economic, institutional, and industrial processes (Mbuligwe and Kaseva, 2005).

As a result of urbanization and industrialization, Warri and environs has been exposed to higher levels of pollution as it is an area that supports diverse commercial activities.

The aim of this work is to conduct a qualitative analysis of surface and ground water, in order to determine the potability of the water for human consumption. The primary objective of this analysis is to evaluate the pollution levels of surface and groundwater bodies in the study area. This is done by analyzing various physical and chemical parameters and comparing them to standard limits for safe drinking water (WHO, 2018).

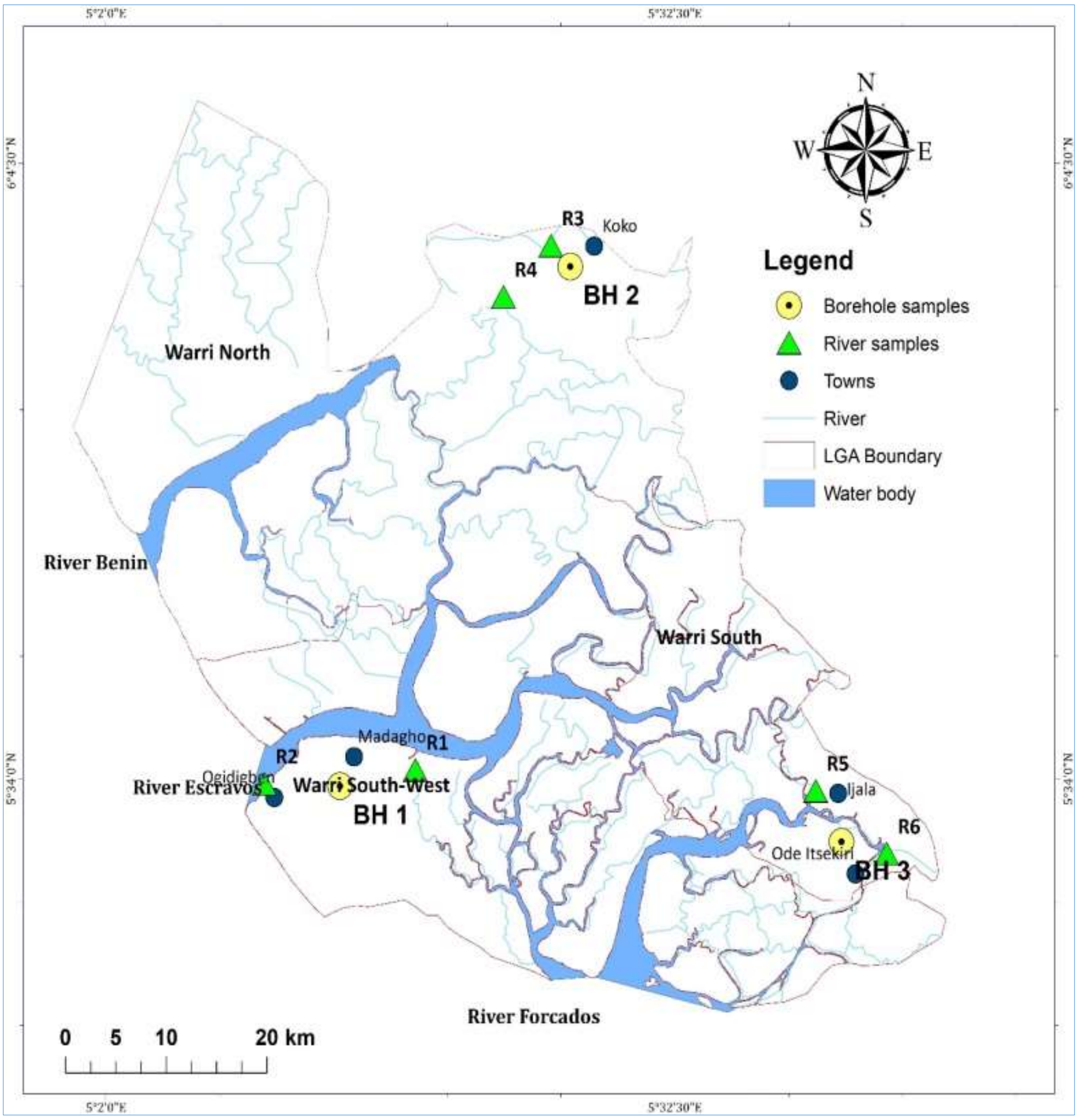

Fig. 1. Location map of Warri and environs indicating points of sample collection

2. Geological Setting

Warri is located in Delta State between longitudes $5^{0}2^{1}0^{11}$ E and $5^{0}32^{1}30^{11}$E and latitudes $5^{0}34^{1}0^{11}$N and $6^{0}4^{1}30^{11}$N (Figure 1). The study was carried out in five (5) communities, across three (3) local government areas in Delta State. They are Madagho and Ogidigben in Warri Southwest, Ijala and Ode-Itsekiri in Warri South and Koko in Warri North Local Government Areas respectively. The study area is rich in oil and gas which makes it a commercial city that houses a lot of businesses and infrastructure like Refineries, Gas Companies, Iron and Steel Companies, Markets and Warehouses etc.

3. **Local Geology of Warri and Environs**

The study area lies on the Benin Formation and is composed of coastal plain sands. The sands have a greyish yellow colour and is poorly sorted, loose and lateritic. The area is also host to part of the Sombreiro-Warri Deltaic plain deposits, beach ridges and freshwater swamps. The top of the soil layers consists of human materials due to weathering effects. The area is sparsely vegetated with grasses and shrubs. Fig. 2 shows the local geology of Warri and Environs, while Plates 1 and 2 displays sample collection from study area.

The study area covers Warri in the Southwestern part of the Niger Delta Sedimentary Basin. The Niger Delta is located in the South Central and Eastern part of Nigeria. It is within longitude 3^{0} E to 90^{0} E and latitude 4^{0} 30N to 4^{0} 20N. The Delta development could be approached from two (2) different phase of development with one grading into the other.

The first is the Cenozoic delta, which is located where the South Atlantic Ocean and the Benue Trough converge. It was formed as a result of the separation of South America from Africa (Burke and Dewey 1972). While the present delta's construction started in the Eocene, the proto delta originated in the northern portion of the basin during the companion transgression and stopped during the Paleocene transgression.

Kogbe (1989) recognized three (3) subsurface chrono-stratigraphic units in the Niger Delta. They are Akata Formation, Agbada Formation and Benin Formation. The Niger Delta Basin's lowest unit is the Akata Formation. It is distinguished by a continuous marine shale unit, but it also has lenses of fine-grained sandstones and siltstones under very high pressure. These are believed to have been deposited as continental slope, channel deposits and turbidities. The shale has a thickness between 600 and 6,000 meters, medium to fine grain size, and a dark grey color. Its age ranges from Recent to Eocene.

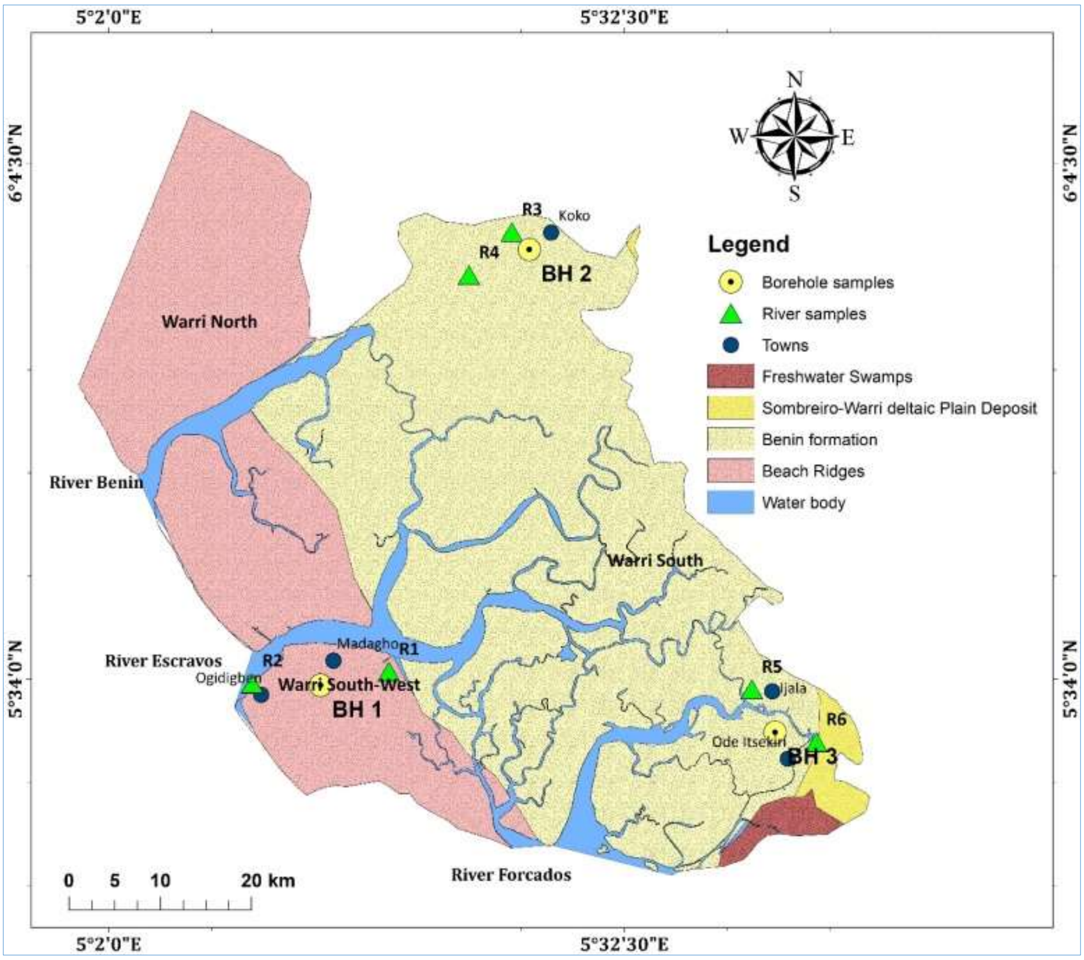

Fig. 2. Geological map of Warri and environs

The Agbada Formation is primarily composed of shale below, with alternating layers of sand and shale above, representing the unmediated offshore and continental shelf environment. It is characterized by fossils at the base, which diminishes upward. The Agbada Formation exists in the subsurface of the entire Delta region and may be continuous with the Eocene to Oligocene of Ogwashi-Asaba and Ameki Formations. It is roughly 10,000ft thick, with ages ranging from the Eocene in the north to the Paleocene in the south, and Recent in the Delta subsurface.

The study area is underlain by the Benin Formation. The Benin Formation was first described by Tattam in 1943 as a coastal plain sand. It stretches southward past the coast and from the west throughout the entire Niger Delta region. The Formation is predominantly composed of sands (90%), with few shale intercalations. The sands vary in color, dirty white to light grey to greyish brown. They are pebbly to fine grained, coarse grained, sub-angular to highly rounded, poorly sorted, and occasionally contain wood fragments and lignite streaks. Shale occurring closer to the base is grayish-brown, sandy to silty, and has some plant debris in it. Its subsurface age is Oligocene in the north and gradually younger in the south. It spans from the Miocene to the Recent, generally. Very little hydrocarbon accumulation has been linked to this stratum, which is likely 1800 meters thick (Kogbe, 1989). The Niger Delta Basin's geological map is displayed in Fig. 3.

4. Materials and Methods

A total of nine (9) samples were obtained on the 6th of June 2023 and were taken to Tudaka Analytical Nigeria Limited at No.1 Onoriji Street, Off Hospital Road Canewood Hotel, Jakpa Road, Ekpan, Delta State for analysis. Table 1 displays sample names and location. Materials used to obtain water samples were the Global Positioning System (GPS) used to establish the longitude and latitude of the terrain, Sample bottles and Sample bags were used for sample collection and transportation. A calibrated Hanna pH meter was used in measuring the degree of acidity and alkalinity of water samples. Hanna instrument (3-in-1) was used in determining the electrical conductivity and total dissolved solids of water samples. A flame photometer was used in identifying various heavy metals while the Atomic Absorption Spectrometer (AAS) was used to analyze specific parameters in the water samples.

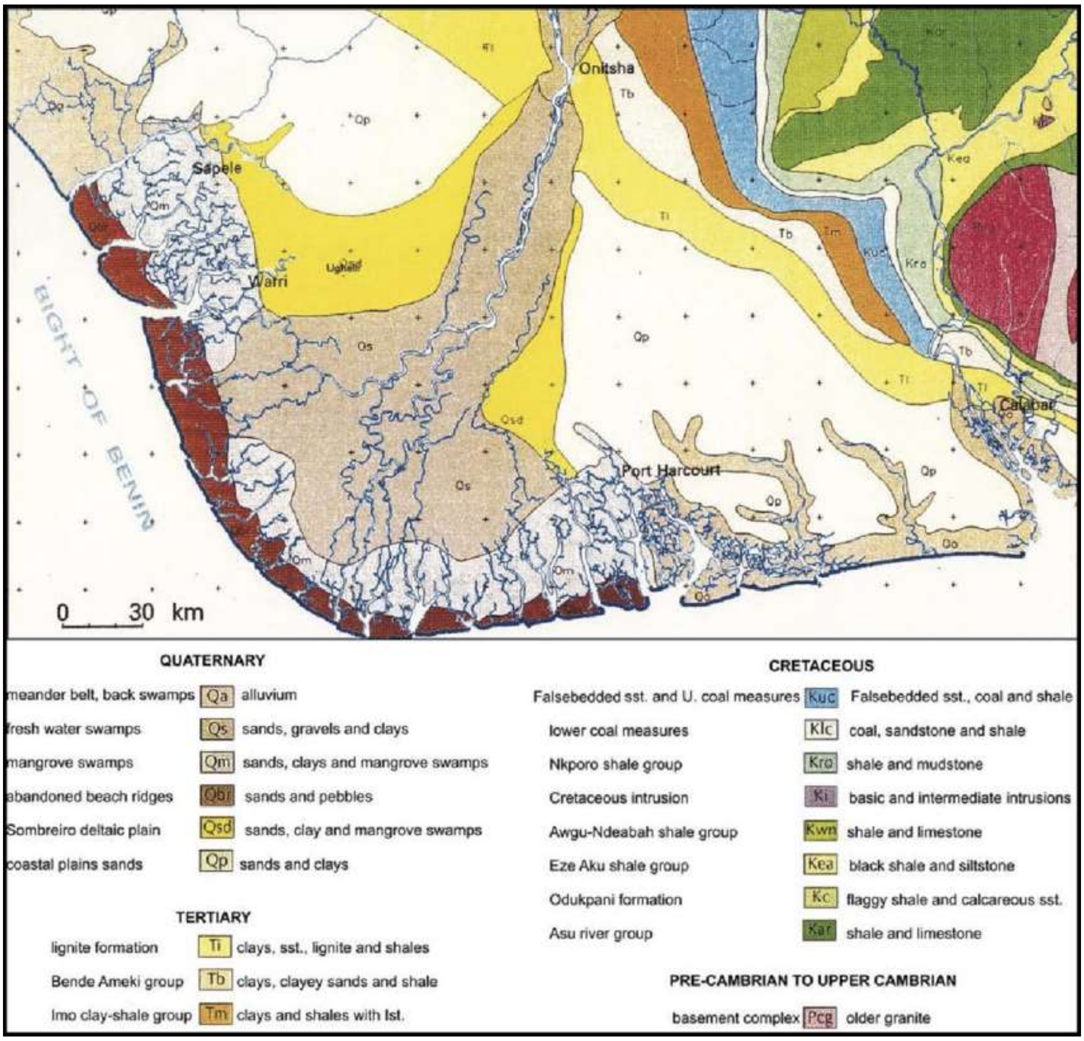

Fig. 3. A geological map of the Niger Delta Basin (Reijers, 2011)

Table 1: Sample names and location

Sample name	Location
MAR	Madagho
OGR	Ogidigben
KOR 1	Koko 1
KOR 2	Koko 2
IJAR	Ijala
ODR	Ode-Itsekiri
MABH	Madagho Borehole Control
KOBH	Koko Borehole Control
ODBH	Ode-Itsekiri Borehole Control

In order to identify the point and non-point sources of pollution in the study areas, a reconnaissance study was conducted there prior to sample collection. Following the reconnaissance study, samples were gathered according to the study area's accessible water source. The importance of sampling ensures the reliability of data which are acquired from the representatives of the water under investigation. However, requires a careful planning and execution of the appropriate sampling storage and analytical procedures.

5. Presentation and Discussion of Results

The physico-chemical parameters and heavy metal concentrations from the study area in comparison with World Health Organization (WHO, 2018) standard for safe drinking water are presented in Tables 2 and 3, respectively.

5.1. pH of the Samples

This is the concentration of hydrogen ion and it ranges from zero (0) which is acidic to fourteen (14) which is alkaline. According to Table 2, the sample's mean pH values range from 5.8 to 7.4 mg/l, with KOBH having the lowest pH value (5.8) and OGR and ODR having the highest pH value (7.4).

With the exception of KOR 1 and KOBH, which have slightly acidic pH levels, all pH levels are within the WHO permitted range of 6.5-8.5. pH values more than 8.5 is regarded as being too alkaline for human consumption, while pH values less than 6.5 are thought to be too acidic for human consumption and can result in health issues like acidosis. Odokuma-Alonge et al. (2019) has a similar report which was attributed to anthropogenic activities.

Table 2. Results of physico-chemical analysis of surface and borehole (groundwater) water samples from Warri and environs with WHO (2018) standard

Parameter	Unit	MAR	OGR	KOR 1	KOR2	IJAR	ODR	MABH	KOBH	ODBH	W.H.O (2018)
pH		7.1	7.4	5.9	6.2	6.9	7.4	7.3	5.8	7.1	6.5-8.5
Temperature	^{0}C	29.1	30.2	28.7	30.1	30.3	29.6	30.2	28.9	30.1	24 - 30
TDS	mg/l	6160.00	14,400.00	809.00	13.00	196.00	37.00	13,800.00	87.00	295.00	500.00
EC	μS/cm	12,260.00	28,800.00	1,616.00	27.00	393.00	75.00	27,700.00	174.00	588.00	1000.00
Turbidity	NTU	18.06	24.04	6.10	8.47	15.06	31.46	13.62	10.41	2.87	5.00
DO	mg/l	6.40	3.30	4.10	4.60	5.20	7.40	3.50	5.90	6.50	5.00
TS	mg/l	6180.00	14430.00	817.00	23.00	216.00	77.00	13820.00	107.00	299.00	N/A
T/Hardness	mg/l	1300.00	2700.00	140.00	8.00	40.00	18.00	2500.00	14.00	108.00	<200
T/Alkalinity	mg/l	52.00	68.00	26.00	37.00	41.00	78.00	66.00	19.00	68.00	5.00
TSS	mg/l	20.00	30.00	8.00	10.00	20.00	40.00	20.00	20.00	4.00	N/A
BOD	mg/l	1.40	2.90	2.20	1.90	1.70	1.20	2.70	1.40	1.10	5.00
COD	mg/l	3.52	6.64	5.34	4.43	4.11	2.94	6.52	3.32	2.56	N/A
Salinity	mg/l	5,032.93	12,390.16	676.30	8.06	158.93	31.57	11,154.44	64.00	235.20	N/A
SO_4^{-2}	mg/l	144.821	757.809	47.113	0.451	10.521	2.314	623.876	0.976	3.782	<250

Table 3: Results of heavy metal concentrations of water samples from Warri and environs with WHO (2018) standard

Parameter	Unit	MAR	OGR	KOR 1	KOR 2	IJAR	ODR	MABH	KOBH	ODBH	W.H.O (2018)
Fe^{2+}	mg/l	<0.001	<0.001	0.011	<0.001	<0.001	<0.001	<0.001	<0.001	0.047	0.30
Cr^{2+}	mg/l	0.023	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.003	0.05
Cd^{2+}	mg/l	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Zn^{2+}	mg/l	0.176	0.005	<0.001	0.218	<0.001	<0.001	<0.001	<0.001	<0.001	1.00
Cu^{2+}	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2.00
Pb^{2+}	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01

5.2. Temperature

The mean temperature was highest in IJAR (30.3) and lowest in KOR 1 (28.7). In general, the values were slightly above the permissible limit except in MAR, KOR 1 and ODR where it was normal. This was as a result of the intensity of the sun during sample collection.

5.3. Total Dissolved Solids and Electrical Conductivity

The Total Dissolved Solids (TDS) and Electrical Conductivity (EC) mean values were highest in OGR (14,400.00, 28,000.00) and lowest in KOR 2 (13.0, 27.00) respectively. The permissible limit was greatly exceeded in MAR, OGR, KOR 1 and MABH. Similar findings have also been reported by Olomukuro et al. (2022) stating that excessive concentration of dissolved solids can be harmful to aquatic life and that the higher values of Electrical Conductivity can be attributed to high organic load from anthropogenic activities along the study area.

5.4. Turbidity

Turbidity values exceeds the permissible limit greatly in all sampling stations except ODBH where it has the value of 2.87mg/l. According to Asibor and Ofuya (2019), it may be due to poor waste management practice along the river's course as industrial wastes are dumped in water bodies untreated.

5.5. Dissolved Oxygen

The Dissolved (DO) mean value was highest in ODBH (6.50) and lowest in OGR (3.30). The standard permissible limit was greatly exceeded in sampling stations MAR, IJAR, ODR, KOBH and ODBH. Umedum et al. (2013) attributed this high concentration to untreated waste from industries.

5.6. Total Hardness

The total hardness (HT) mean value was highest in OGR (2700.00) and lowest in KOR 2 (8.00). The values for total hardness only exceeded the standard permissible limits in MAR, OGR and MABH. This was because of high concentrations of Calcium and Magnesium compounds in the samples and can lead to cardiovascular diseases and cancers.

5.7. Total Alkalinity

In every sampling station, the total alkalinity was higher than the usual allowable limits. This can be explained by the sample's bicarbonates, carbonates, and hydroxides.

5.8. Biological Oxygen Demand, Nitrate and Phosphate

Biological Oxygen Demand (BOD), Nitrate (NO_3^-) and Phosphate (PO_4^{3-}) parameters were within the standard permissible limits.

5.9. Carbonate

Carbonate (CO_3^{2-}) parameter is not present in the samples.

5.10. Sulphate

The mean value of Sulphate (SO_4^{2-}) is highest in OGR (757.809) and lowest in KOR 2 (0.451). This parameter exceeds the standard permissible limits only in sampling stations OGR and MABH. The high concentrations can be related to industrial activities as stated by Umedum et al. (2013).

5.11. Calcium, Magnesium and Sodium

Calcium (Ca^{2+}), Magnesium (Mg^{2+}) and Sodium (Na^{2+}) all exceeded the standard permissible limits in sampling stations MAR, OGR, and MABH. These concentrations can be attributed to oil spillage in the study area as bunkering activities have been reported in the area. A similar finding has also been reported (Ibiam et al., 2017).

5.12. Iron, Chromium, Zinc, Copper and Lead

Iron (Fe^{2+}), Chromium (Cr^{3+}), Zinc (Zn^{2+}), Copper (Cu^{2+}) and Lead (Pb^{2+}) were all within the standard permissible limits.

5.13. Cadmium

The Cadmium (Cd^{2+}) value at sampling station KOR 1 was the only value to exceed standard permissible limit. A similar finding has also been reported by Odokuma-Alonge et al. (2015) where high Cadmium concentration was as a result of gas flaring.

6. Conclusion

Warri and environs are located in Delta State, a commercial area with a lot of businesses and infrastructures (Refineries, Gas Companies, Iron and Steel Companies, Markets and Warehouses etc.). The results analyzed from the study area, indicated the BOD, NO_3^- and PO_4^{3-} to be within WHO's (2018) permissible limits, pH and temperature to be slightly above the standard permissible limits, while the others exceeded the standard permissible limits. The high concentrations of the other parameters can be attributed to discharge of industrial effluents into water bodies and oil spillage in the study area which can pose a threat to human health and the ecosystem at large. In conclusion, upon analysis, the water is unfit for human consumption and requires adequate treatment before consumption.

7. Recommendations

- Treatment of industrial effluents before disposal.
- Remediation of oil spilled water bodies.
- Regular clean-ups of water bodies by members of the community.
- Consistent monitoring programs should be implemented by the government to ensure clean and clear water for consumption.

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