wjert, 2023, Vol. 9, Issue 1, 72-83. *Research Article* ISSN 2454-695X

World Journal of Engineering Research and Technology

WJERT

www.wjert.org SJIF Impact Factor: 5.924

WATER QUALITY ASSESSMENT AND POLLUTION INDICES IN PORT HARCOURT, SOUTHERN NIGERIA

Offodile P. O.[1], Nwankwoala H. O.[1], Onwualu-John J. N.[1] and Osayande A. D.[2]*

[1]Department of Geology, University of Port Harcourt, Nigeria.

[2]Department of Geology and Mining Technology, University of Port Harcourt, Nigeria.

Article Received on 21/11/2022 Article Revised on 11/12/2022 Article Accepted on 01/01/2023

***Corresponding Author**
Dr. Osayande A. D.
Department of Geology and Mining Technology,
University of Port Harcourt,
Nigeria.

ABSTRACT

The physico-chemical and trace metal profiles of surface and groundwater samples collected from several locations in both Obio-Akpor LGA and Port Harcourt LGA of Rivers State was evaluated using appropriate procedures such as the usage of calibrated meter electrodes and spectrophotometry. The water quality index (WQI) and Nemerow's Pollution index (NPI) values of the examined samples was also conducted using relevant standards. The overall mean pH and TDS values ranged from 5.133 to 6.003 and 76.6 mg/l to 391.5. Turbidity values ranged from 4.2 to 4.5 NTU. The mean Fe and Cu values ranged from 0.021 ± 0.02 mg/l to 0.117 ± 0.1 mg/l and 0.033 ± 0.01 mg/l to 0.066 ± 0.1 mg/l. The mean Pb and Cd data varied from 0.023 ± 0.01 mg/l to 0.771 ± 0.9 mg/l and 0.002 ± 0.004 mg/l to 0.0024 ± 0.005 mg/l. All the WQI values for the water samples were >100 which indicated the unsuitability of the water samples for direct human consumption. The NPI values for Pb was >1 for all the water samples. The observed variety of anthropogenic activities occurring within the study area ranging from the indiscriminate disposal of wastes to improper placement of commercial facilities such as car wash, auto mechanic workshops invariably affected the quality of the exposed water bodies in a negative manner.

KEYWORDS: *Groundwater, Surface water, Pollution index, Port Harcourt, Water Quality Index.*

INTRODUCTION

Water is one of the main six classes of food that is essential and necessary for the growth and development of humans. More water is required each day than any other nutrient, and as such, the need for clean and portable drinking water is a dietary necessity (Popkin *et al*., 2010). When humans, plants and animals consume water having high concentrations of heavy metals such as Fe, Zn, Pb, Cu, Cr and Cd above the tolerable limits, this intake can cause a serious harm or damage to them (Jaishankar *et al*., 2014).

A current global environmental concern is the trace metal pollution of soil and water niches, which can result in environmental toxicity and negative impacts on human health and ecosystems (Ali *et al*., 2019). Human exposure to heavy metals is known to occur through the consumption of contaminated water or food or through respiration by inhaling atmospheric particles harbouring heavy metals (Jaishankar *et al*., 2014).

The bioaccumulation of the heavy metals in the human body even at trace levels can cause neurological disorders, hormone imbalance, cardiovascular failure, kidney diseases, infertility, hair loss, endocrine disorders, respiratory and digestive problems, and cancer (Jaishankar *et al*., 2014). A range of industrial activities discharge their wastewaters into the rivers, which then deposits and enrich the river and the river sediments. River and river sediments are typically used to assess pollution of heavy metals using a range of defined pollution indices (Mahboube *et al.*, 2020).

During the rainy season, the water from the water channels rises and floods the surrounding environment because of a very poor drainage system in Port Harcourt city which contribute to the contamination of the soil around the area (Akukwe, 2014).As water is involved, there is a serious concern about these heavy metals being present in the water because both aquatic life is being affected and when they are affected, their population decreases and poses a very serious environmental challenge to some species of aquatic life. This is because some of them might go into extinction and also humans beings consume some of these aquatic animals of which these aquatic animals have already consumed these heavy metals present in their environment and when humans consume them (the aquatic animals), they take in some amount of these heavy metals and when they exceed the tolerable limit in the human body, they result in different health challenges.

Poor drainage systems within Port Harcourt metropolis is also known to result in flooding and during precipitation in the city, lots of refuse are washed into the waterways coupled with the fact that people equally dump their refuse in the waterways and these wastes are carried by the water to different locations (Akukwe, 2014).

Anthropogenic compounds enter the aquatic environment through various activities in the environment such as water runoff, erosion, flooding, dumping of wastes into drains which eventually cause blockage and this result in the build-up of contaminants that eventually deface the environment (Akhtar *et al*., 2021). Depending on their physical and chemical properties some substances remain dissolved in the water phase while others bind onto particles, sink to the ground and become part of the sediment (Ogbonna *et al.*, 2007).

Surface water bodies located in the Rumuokoro and Eliozu areas serve as one of the several water resources found within Port Harcourt, Rivers State which empties its content directly into the Bonny river which flows through the Trans Amadi area before it empties its content into the Atlantic ocean.

Also, the Ntawongba Creek is another water resource which flows through GRA Phase 3 to D-line. The two water resources have a confluence at Abuloma where they meet before flowing to Bonny River and then empty its content into the Atlantic Ocean. In some areas, these water resources serves some major purposes such as washing of food products like vegetables and fishes, a car wash, channel for dumping of hospital and hotel waste products, dumping of waste products from automobiles, dumping of human faeces, indiscriminate dumping of refuse including plastic wastes.

Heavy metals can also find their way into the groundwater and contaminate the groundwater through infiltration (Oyeleke and Okparaocha, 2016). Considering the porous soil structures and permeable nature of the subsurface geologic formation and the shallow depth of water table of the Niger Delta region, the ground water bodies eventually becomes highly vulnerable to leachates from these wastes which find its way into underground aquifers, rivers, lakes, wells and other water bodies (Ogbonna and Ogbuku 2018).

This study aims at assessment of water quality/determining the physico-chemical profiles as well as pollution indices of the examined water samples from different water sources in Obio-Akpor and Port Harcourt local government areas of Rivers State, Nigeria.

MATERIALS AND METHODS

The study area

The study area is located within Obio-Akpor and Port Harcourt Local Government Areas of Rivers State, Nigeria. The study area is found within latitude 4º 52' 13''N and longitude 6º 59' 54''E. The study area is generally a part of the Niger Delta Basin sedimentary sequence (which is made up of the Akata, Agbada and Benin formations). It generally has a tropical climate which is made up of two seasons (the rainy and dry season) with rainfall occurring mostly throughout the year.

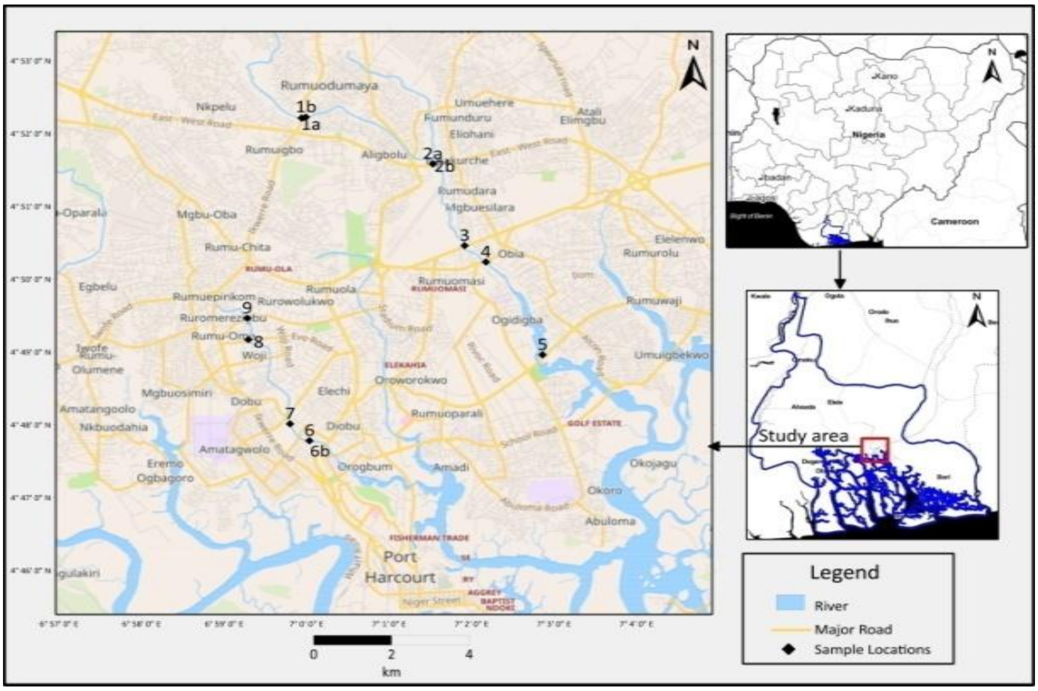

Figure 1: Map of the study area.

The study area is made of three stations; Station 1 is made up of five different selected locations of the water resources which are; Location 1A (Rumuokoro market/slaughter), Location 2A (Eliozu market/car wash), Location 3 (Artillery bus stop by Aba road), Location 4 (Block industry beside Mobil filling station by Old Aba road) and Location 5 (Bonny River by Trans-Amadi market/slaughter).

Station 2 comprises of four different locations which are as follows; Location 6A (Afam Street by car wash behind Winners Chapel D-line), Location 7 (Mechanic village Anyama by Ikeokwu road), Location 8 (Car wash beside Blueridge International School, Abacha road) and Location 9 (Tombia Street extension GRA phase 3).

Station 3 is made up of three different locations which are as follows; Location 1B (Rumuokoro market/slaughter borehole (groundwater)), Location 2B (Eliozu market/car wash borehole (groundwater) and Location 6B (Afam Street by car wash behind Winners Chapel D-line borehole (groundwater).

Table 1: Station 1: Locations in the study area with their coordinates, Elevation.

Location numbers	Location names	Latitude	Longitude	Elevation
Location 1A	Rumuokoro Market/Slaughter	N4˚ 52' 12.68''	E6˚ 59' 56.34''	6m
Location 2A	Eliozu Market/Car Wash	N4˚ 51' 34.94''	E7˚ 1' 31.71''	8m
Location 3	Artillary Bus Stop by Aba Road	N4˚ 50' 27.58''	E7˚ 1' 54.88''	5m
Location 4	Block Industry Beside Mobil Filling Station by Old Aba Road	N4˚ 50' 14.08''	E7˚ 2' 10.32''	9m
Location 5	Trans Amadi River by Trans Amadi Market/Slaughter	N4˚ 48' 57.66''	E7˚ 2' 51.55''	11m

Table 2: Station 2: Locations in the study area with their coordinates, elevation.

Location numbers	Location names	Latitude	Longitude	Elevation
Location 6A	Afam street by car wash behind Winners Chapel D-line	N4˚ 47' 46.9''	E7˚ 0' 2.04''	5m
Location 7	Mechanic village Anyama by Ikeokwu road	N4˚ 48' 0.80''	E6˚ 59' 47.96''	5m
Location 8	Car wash beside Blueridge international school Abacha road	N4˚ 49' 10.17''	E6˚ 59' 17.55''	9m
Location 9	Tombia Street extension GRA phase 3	N4˚ 49' 27.82''	E6˚ 59' 16.84''	9m

Table 3: Station 3: Locations in the study area with their coordinates, Elevation and Borehole depth.

Location numbers	Location names	Latitude	Longitude	Elevation	Borehole depth
Location 1B	Rumuokoro Market/Slaughter borehole (groundwater)	N4˚ 52' 13.51''	E6˚ 59' 49''	6M	75 ft
Location 2B	Market/CarWash	N4˚ 51' 34.9''	E7˚ 1' 31.71''	8M	70 ft

	borehole (groundwater)				
Location 6B	Afam Street by Car Wash behind Winners Chapel D-line borehole (groundwater)	N4˚ 47' 46.9''	E7˚ 0' 2.04''	5M	70 ft

Sample Collection and Physico-chemical analyses

Water samples were collected from the sampling points using sterile plastic containers. The pH, temperature, electrical conductivity and total dissolved solids were determined using relevant meters (Radojevic and Bashkin, 1999). The electrode of the respective meters were calibrated prior to usage (Radojevic and Bashkin, 1999). The turbidity of the samples was determined using a spectrophotometer. The trace metal content of the samples were determined using atomic absorbance spectrophotometry (AAS) (APHA, 1999). Metals investigated included; Mn, Fe, Cu, Pb, Cd, Cr, Ni, Zn and Co. Prior to AAS analysis, the samples were digested using a digestion mixture (10ml) which was a ratio (1:2:2) of perchloric, nitric and tetraoxosulphate (VI) acid respectively (Radojevic and Bashkin, 1999).

Statistical analysis

Descriptive parameters which included the mean and standard deviation were derived for the examined samples using MS Excel version 2012.

Determination of the Water Quality Index (WQI) and Nemerow's Pollution Index (NPI)

The water quality index (WQI) of the samples was calculated using Weighted Arithmetic Index method as described by Brown *et al*. (1972).

The formula for weighted arithmetic index method is given below;

Step 1: The unit weight (Wn) factor for each parameter was derived using the formula

$$Wn = \frac{k}{Sn} \text{.................................(1)}$$

Where k = $\frac{1}{\frac{1}{S1}+\frac{1}{S2}+\frac{1}{S3}+\text{ ....}+\frac{1}{Sn}} = \frac{1}{\sum\frac{1}{Sn}}$

Where;

Sn = standard desirable value of the n^{th} parameters

On summation of all selected parameters unit weight factors, Wn = 1(unity)

Step 2: The sub-index (Qn) value was calculated using the formula

Qn = $\frac{[(Vn-V0)]}{[(Sn-V0)]} = 100$.......................................(2)

Where;

Vn = mean concentration of the n^{th} parameters

Sn = standard desirable value of the n^{th} parameters

V_0 = actual values of the parameters in pure water (generally $V_0 = 0$, for most parameters except for pH and dissolved oxygen)

QpH = $\frac{[(VpH-7)]}{[(8.5-7)]} = 100$........................(3)

Step 3: The step1 and step2 were combined and the WQI is calculated

Overall WQI = $\frac{\sum WnQn}{\sum Wn}$.................................(4)

Table 4: WQI as described by Brown *et al.*, (1972).

Water Quality Index	Water Quality Status	Usage possibilities
0 - 25	Excellent	Drinking, irrigation, industrial
26 - 50	Good	Drinking, irrigation, industrial
51 - 75	Poor	Irrigation, industrial
76 - 100	Very Poor	Irrigation
> 100	Unfit for Consumption	Proper treatment is required before use

Nemerow's Pollution index (NPI) is a pollution index utilized to ascertain individual parameters amongst all the parameters that contributed significantly to the water quality deterioration. The NPI valuation was derived using the formula provided below;

$NPI = \frac{Cn}{Sn}$..(5)

Where;

Cn = Concentration of the n^{th} parameters

Sn = Prescribed standard limit of the n^{th} parameters

The NPI values for the water samples were interpreted were as follows;

NPI values <1

NPI values >1

If the water parameter NPI value is >1, it meant its presence is in surplus amount or concentration and it has the potential of contributing to the pollution of the water studied.

If it's <1 that meant it doesn't have the potential of contributing to the pollution of the water studied.

RESULTS AND DISCUSSION

The overall mean pH values ranged from 5.133 for ground water samples collected at station 3 to 6.003 for Station 2 surface water samples (Table 5). The temperature value of 25 ^oC was recorded for all the samples. The EC and TDS data ranged from 153.3 for station 3 to 790.4 µS/cm for station 2 and 76.6 mg/l for station 3 to 391.5 for station 2. Turbidity values ranged from 4.2 NTU for station 1 to 4.5 for station 2 (Table 5).

The elevated acidic status of the surface water samples can be linked to the existing magnitude of domestic and industrial activities around the catchment area of the surface water bodies. The range of pH values recorded for the surface water samples were at variance with data reported by Edori *et al.* (2021) with respect to water samples collected from Mini Whuo Stream, Port Harcourt. The slightly acidic nature of the ground water could be attributed to the infiltration of acidic precipitation into the aquifer and acidic rainfall has been known to a consequence of the dissolution of CO_2 in rain droplets (Fashola *et al.*, 2013). The Electrical Conductivity (EC) values were below the Standard Organization of Nigeria (SON) limits for potable water.

The EC valuation of any samples abstracted from a water body is dependent on the concentrations of ions or current carrying species that are present in that water body (Edori *et al.*, 2021). The TDS values of all the water samples were below the SON permissible limits and the range observed for the surface water contrasted with values reported by Edori *et al.* (2021). The mean TDS value differed from values reported by Nwankwoala and Udom (2011) with respect to groundwater sampled from several areas in Port Harcourt, Rivers State.

Table 5: Overall mean physico-chemical values for the water samples.

Samples	pH	Temp (^oC)	EC (µS/cm)	TDS (mg/l)	Turbidity (NTU)
Station 1 surface water	5.734	25	423.8	211.9	4.2
Station 2 surface water	6.003	25	790.4	391.5	4.5
Station 3 groundwater	5.133	25	153.3	76.6	0
SON limits	6.5 – 8.5	20 – 30	1000	500	5

The overall mean Mn data varied from 0.023 ± 0.009 mg/l for station 3 samples to 0.306 ± 0.46mg/l for Station 2 surface water samples (Table 6). The mean Fe and Cu values ranged from 0.021 ± 0.02 mg/lfor station 3 samples to 0.117 ± 0.1mg/l for Station 1 surface water samples and 0.033 ± 0.01mg/l for station 2 samples to 0.066 ± 0.1 mg/l for Station 1 surface water samples (Table 7). The mean Pb and Cd data varied from 0.023 ± 0.01mg/l for station 2 samples to 0.771 ± 0.9mg/l for Station 1 surface water samples and 0.002 ± 0.004mg/l for station 2 samples to 0.0024 ± 0.005mg/l for Station 1 surface water samples. The mean Cr and Ni values ranged from 0.009 ± 0.02 mg/l for station 1 samples to 0.011 ± 0.02mg/l for Station 2 surface water samples and 0.003 ± 0.005 mg/l for station 3 samples to 0.252 ± 0.5 mg/l for Station 1 surface water samples. The mean Zn and Co values ranged from 0.04 ± 0.03 mg/l for station 3 samples to 0.231 ± 0.3 mg/l for Station 1 surface water samples and 0.003 ± 0.005 mg/l for station 3 samples to 0.034 ±. 0.04 mg/l for station 2 samples (Table 6).

Aside from Mn and Pb mean values recorded for station 2, station 1 and station 3, all the heavy metal readings were below the Standard Organization of Nigeria (SON) allowable limits for drinking water. The variations in the mean heavy metal values could be a reflection of the extent of anthropogenic activities occurring around the study areas on a daily basis. It has been stated that although Fe is a heavy metal, it is an essential element in the metabolism of animals and plants (Akinfolarin and Chukwuji, 2020). The author further indicated that when trace metals are present in water in excessive levels, it can form red oxy-hydroxide precipitate that stains laundry and plumbing fixtures due to its very reactive nature. Fashola *et al.* (2013) stated that occurrence of Fe in groundwater can also be associated with the geological background and source rocks of the deposits that constitute the aquifer material in the Niger Delta. The accumulation of these trace metals is also known to negatively affect the organoleptic quality of water (Abbey *et al.*, 2021). The range of surface water associated mean heavy metal values (Zn, Cd, Ni, Cr and Pb) observed in this study was in disagreement with mean values reported by Abbey *et al.*, (2021) with regard to surface water of the Miniokoro Stream, Port Harcourt.

Table 6: Overall mean trace metal values for the water samples.

Samples	Mn (mg/l)	Fe (Mg/l)	Cu (Mg/l)	Pb (Mg/l)	Cd (Mg/l)	Cr (Mg/l)	Ni (Mg/l)	Zn (Mg/l)	Co (Mg/l)
Station 1 SW	[a]0.206 ± 0.2	0.117± 0.1	0.066 ± 0.1	0.771± 0.9	0.0024 ± 0.005	0.009 ± 0.02	0.252 ± 0.5	0.231± 0.3	0.0162± 0.04
Station 2 SW	0.306 ± 0.46	0.042 ± 0.02	0.033 ± 0.01	0.023 ± 0.01	0.002 ± 0.004	0.011 ± 0.02	0.035 ± 0.02	0.155 ± 0.23	0.034± 0.04
Station 3 GW	0.023 ± 0.009	0.021 ± 0.02	0.049 ± 0.03	0.049 ± 0.02	0.0 ± 0.0	0.0± 0.0	0.003 ± 0.005	0.04 ± 0.03	0.003 ± 0.005
SON limits	0.2	1	1	0.01	0.03	0.05	0.02	3	0.05

Key: SW; Surface water, GW; Ground water, a; mean ± std. Deviation

All the WQI values for the water samples were > 100 (Table 7). This indicated that the water samples were generally non-potable and required adequate treatment if it were to be utilized for drinking purposes. The very poor status of the surface water samples was similarly observed by Abbey *et al.* (2021). The authors stated the need by relevant Governmental tiers to implement effective waste management plans in these areas. It was also advocated that pollution levels of surface water bodies within Port Harcourt should be measured and monitored on a regular basis as this activity would provide valuable information on the impact of polluting activities on the exposed surface water bodies (Abbey *et al.*, 2021).

Table 7: WQI for the water samples.

Stations	Index values	Water quality index	Water Quality Status	Usage possibilities
Station 1	3621.888	> 100	Unfit for consumption	Proper treatment required before use
Station 2	148.9359	> 100	Unfit for consumption	Proper treatment required before use
Station3	196.2424	> 100	Unfit for consumption	Proper treatment required before use

The NPI data shown in Table 8 indicated that for Station 1, Pb and Ni were the two major parameters that contribute significantly to the pollution status of the samples. Pb had a value of 77.1mg/l while Nickel has a value of 12.61mg/l which was >1 (Table 8). For station 2 samples, EC, Pb and Ni contributed significantly to the pollution status of the water samples. The EC value was 1.5808µs/cm while Pb and Ni had values of 2.325mg/l and 1.75mg/l (Table 8). For station 3 samples, Pb was the only parameter that contributed significantly to the pollution profile of the water. The parameter had a NPI value of 4.4333mg/l (Table 8). The non-contribution of parameters such as pH and TDS to the pollution status of all the surface water samples was similar to a report by Dawood *et al.* (2017) with respect to surface water sampled from Basrah Marshes, Southern Iraq.

Table 8: NPI values for the water samples.

Parameters	WHO Standard (Sn)	Station1	Station 2	Station 3
pH	8.5	0.67458824	0.70617647	0.60392153
Temperature (˚C)	30	0.83333333	0.83333333	0.83333333
EC (µS/cm)	500	0.84764	1.5808	0.30652
TDS (Mg/l)	1000	0.21192	0.391475	0.07663
Turbidity (NTU)	5	0.84	0.9	0
Fe (Mg/l)	0.3	0.39	0.13833333	0.07111
Pb(Mg/l)	0.01	77.1	2.325	4.4333

Cu (Mg/l)	1	0.0662	0.03275	0.049333
Ni (Mg/l)	0.02	12.61	1.75	0.15
Mn(Mg/l)	0.4	0.514	0.765625	0.0583325
Zn(Mg/l)	5	0.04616	0.031	0.0074666
Cr (Mg/l)	0.05	0.192	0.225	0
Cd (Mg/l)	0.03	0.08	0.06666667	0
Co (Mg/l)	0.05	0.324	0.71	0.06666

CONCLUSION

The poor quality valuation of all the water samples collected from the sampling points was revealed in this study. The observed variety of anthropogenic activities occurring within the study area ranging from the indiscriminate disposal of wastes to improper placement of commercial facilities such as car wash, auto mechanic workshops invariably affected the quality of the exposed water bodies in a negative manner. It is recommended that the some of these commercial facilities currently located very close to the water bodies should be re-located to a farther distance from the banks of the water bodies. Also, the municipal authorities should provide adequate amounts of large waste bins which should be evacuated at regular intervals.

REFERENCES

1. American Public Health Authority (APHA). Standard Methods for Examination of Water and Wastewater. APHA. Washington D.C., 1999; 18: 1421.
2. Abbey, D. M., Abbey, M. E., Ogunyemi, T. C. and Abbey, M. E. Pollution evaluation based on physicochemical and heavy metal levels of Miniokoro Stream, Port Harcourt, Nigeria. *Asian Journal of Chemical Sciences, 2021;* 9(2): 27-37.
3. Akhtar, N., Syakir I. M.I., Bhawani, S. A. and Umar, K. Variousnatural and anthropogenic factorsresponsible for water quality degradation: A review. *Water, 2021;* 13: 2660. https://doi.org/10.3390/w13192660.
4. Akinfolarin, O. M. and Chukwuji, G. Assessment of bore whole water in Oroworukwu Port Harcourt, Rivers State, Nigeria. *Journal of Earth and Environmental Science Research*, 2020; 2(3): 1-5.
5. Akukwe T. I. Determinants of flooding in Port Harcourt metropolis, Nigeria. *IOSR Journal of Humanities and Social Science*, 2014; 19 (11): 64-72.
6. Ali, H., Khan, E. and Ilahi, I. Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation. *Hindawi Journal of Chemistry*, 2019; Article ID 6730305, https://doi.org/10.1155/2019/6730305.

7. Dawood, S. A. Using of Nemerow's Pollution Index (NPI) for water quality assessment of some Basrah Marshes, Southof Iraq. *Journal of Babylon University/Engineering Sciences*, 2017; 25 (5): 1708 -1720.
8. Edori, E. S., Iyama, W. A .and Awari, J. O. Some physicochemical parameters in the surface water of mini Whuo Stream in Port Harcourt, Rivers State, Nigeria. *GSC Advanced Research and Reviews*, 2021; 09(03): 039–047.
9. Fashola, F. I., Nwankwoala, H. O and Tse, A. C. Physico-chemical characteristics of groundwater in Old Port Harcourt Township, Eastern Niger Delta. *International Journal of Physical Sciences*, 2013; 1(3): 047-055.
10. Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B. and Beeregowda, N. K. Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 2014; 7(2): 60–72.
11. Mahboube S., Keramat N. A., Sayka J., Vladimir S. and Mojtaba S. Pollution and contamination assessment of heavy metals in the sediments of Jazmurian playa in southeast Iran. *Scientific reports*, 2020; 10: 4775.
12. Nwankwoala, H. O. and Udom, G. J. Investigation of hydro-geochemical characteristics of groundwater in Port Harcourt City, Nigeria: Implication for use and vulnerability. *Journal of Applied Sciences and Environmental Management*, 2011; 15 (3): 479 -488.
13. Ogbonna D. N. and Ogbuku J. O. Heavy metal and microbiological characteristics of wastewater impacted by anthropogenic activities around Ntanwogba Creek in Port Harcourt City. *Journal of Scientific Research & Reports*, *2018;* 21(4): 1-14.
14. Ogbonna, D. N., Amangabara, G. T. and Ekere, T. O. Urban solid waste generation in Port Harcourt metropolis and its implications for waste management. *Management of Environmental Quality, 2007;* 18(1): 71-88.
15. Oyeleke, O. P. And Okparaocha, J. F. Assessment of some heavy metals in groundwater in the vicinity of an oil depot in Nigeria. *American Chemical Science Journal*, 2016; 12(3): 1-7.
16. Popkin, M. B., D'Anci, E. K. and Rosenberg, H. I. Water, hydration and health. *Nutrition Review, 2010;* 68(8): 439–458.
17. Radojevic, M. andBashkin, V. N. Practical Environmental Analysis. The Royal Society of Chemistry.Cambridge, 1999; 466.