Determination of Physiochemical Properties of Seawater in Port Harcourt Environment

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Abstract*- This paper seeks to determine the physiochemical properties of seawater around Port Harcourt environ with a view to know the disparities that exist in values between the different rivers around the city. Special attention was given to water around landing jetties in the city to know basic elements in the river water that may cause corrosion of landing jetties, badges, and other vessels that anchor in the rivers. A specialized instrument called Horiba PC210 Water Quality Meter was used to take on the spot measurement of the different physiochemical properties of each unit. It was repeated after seven weeks, one measurement for high tide and the other for low tide. The results obtained shows that the concentration is higher at low tides. Again, temperature values show that the values higher at low tide. The results for temperature are: Marine base 28.460C and 27.90C, Abuloma 27.340C and 26.80C, Bille 27.440C and 26.90C, and Bonny 27.850C and 27.30C. Amongst the heavy metals identified, iron has the highest value (2.648mg/L) at Marine base, copper (0.863mg/L), zinc (0.689mg/L), lead (0.474mg/L), cobalt (0.104mg/L) and cadmium (0.021mg/L) all at Bille jetty area, followed by Bonny jetty area. Results obtained for pH values for low tide: 6.35, 6.38, 6.32, 6.44, and 5.82, for high tide: 6.23, 6.25, 6.20, 6.31 and 5.71 in the order of Abuloma, Bille, Bonny, Marine Base and Okuru. Still in the same order the chloride values are: 11589, 20041, 17172, 12409, 10952mg/L and 9160, 13020, 12960, 12720, and 8410mg/L respectively. Other values obtained are salinity with highest value of 15,480mg/L at low tide at marine base jetty

***Indexed Terms*- Rivers Organic Salinity Concentration Samples Values Humans**

I. INTRODUCTION

The Niger Delta region is a place of several creeks, rivers and seas, most cities in the region are surrounded by either creeks, rivers or located along major seas. This is the situation with Port Harcourt, the hub of oil and gas activities in the region and Nigeria at large. With such oil and gas on the increase around the city, effluence into these creeks, rivers and seas keep altering the physiochemical conditions of the water around the city. A pointer to this fact is the differences in the corrosion rates of structures, platforms and equipment in and around the city. Common features with constant varying depreciations are landing jetties, barges, pontoons, and platforms. It is on this backdrop that the ideas of determining the physiochemical properties of some of the creeks around the city is sought for. The varying corrosion rates of structures, metal objects, platforms and in particular jetties and pontoons at different locations around Port Harcourt became a concern. Hence, this work seeks to determine the changes that is taking place in our creeks with a view to inform policies makers and opinion leaders on the importance of making periodic review of existing records with respect to the changes taking place which are borne out of human activities, before taking decisions or siting projects.

Corrosion is the continuous destructive phenomenon of a material or its properties through the effects of unwanted chemical or electrochemical reactions with its environment which may cause deterioration of the surface and structural properties of the material component. It depends on the pH, temperature and concentrations of many inorganic and organic species at the metal-water interface. Seawater covers 70% of the earth's surface and is a highly complex medium that contains almost every element in the periodic table and a multifarious plethora of living organisms. It contains on average 3.5 to 4% of dissolved salts, mainly sodium chloride (Sylvester *et al*., 2020). The high salt concentration in most marine environments combined with high electrical conductivity makes marine bodies a highly conducive environment for corrosion to occur on metal surfaces. The marine structures such as ships and aquatic platforms are under continuous attack from their surrounding environment, and are sometimes allowed to corrode. The seawater mostly contains two ions which are chloride and sodium. These two ions make up over 90% of all dissolved ions in seawater (Amjad *et al*., 2023). It is of note that infrastructures around harsh marine environment experience gradual depreciation due to corrosiveness of the marine environment. For infrastructures in/close to seawater, the combined effects of seawater corrosive agents, such as wave action, tidal variations and chemical agents, accelerates the rate of deterioration of the structures. Thus, it is imperative to have timely information on the marine environment around us, so as to make useful predictions of its effects on infrastructure sited in such environment.

The essence of this work is to determine the physiochemical properties of the rivers around Port Harcourt, especially the zones where human activities are high, identify each area constituents, salt contents, pH and other relevant properties. So as to make useful predictions on their effects on humans and infrastructures as well as recommendations.

II. FACTORS AFFECTING PHYSIOCHEMICAL PROPERTIES

Analysis of corrosion in marine environment is usually complex, because several factors come into play due to the multifaceted interaction that takes between different organisms, minerals and human activities. Hence, corrosion is affected by a complex interaction of factors that include salinity, temperature, dissolved oxygen, pH, oxidation reduction potential, immersion depth, water velocity, microbiological activity and calcareous deposits. It is on this backdrop this work is designed to ascertain the changes on these properties and their possible effects. Few of these factors identified are discussed in this work to give some clue.

2.1: Water Salinity

The salinity of seawater generally is 35 ppt and far higher than river water which is only 0.02ppt. Test shows that physiochemical properties are influenced by salinity of seawater and rivers, as the corrosion rates reach its maximum when the salinity is 32 to 35ppt, namely the salinity of natural seawater (Cai *et al*., 2018).

2.2: Seawater Temperature

Temperature of seawater is influenced by many geographical factors, but decreases with depth. It also varies seasonally at the surface, ranging from $\sim 35^{o}\mathrm{C}$ at the equator to $\sim -2^{o}\mathrm{C}$ at the poles. Increasing temperature lowers solubility of dissolved gases and scale-forming calcium compounds such as calcium carbonate, but generally increases biofouling.

2.3: Seawater pH

Clean surface seawater is typically slightly alkaline. This is related to the carbon dioxide (CO_2) equilibrium with the atmosphere. Seawater contains bicarbonate (HCO_3^-) ions, carbonate (CO_3^{2-}) ions, undissociated carbonic acid (H_2CO_3), and dissolved CO_2. The pH is influenced by temperature, CO_2 partial pressure. However, seawater is said to be highly buffered. Hydrogen sulfide, for example, from sulfate-reducing bacterial (SRB) activity, can lower the pH considerably and affect the performance of certain materials (Cai *et al*., 2018). This was the experience with our results.

2.4.: Dissolved Oxygen Concentration in Water

Corrosion of most metals in seawater is a function of oxygen depolarization which is a function of other physiochemical properties, the content of dissolved oxygen in seawater is an important factor affecting the physiochemical properties of seawater. The solubility of oxygen in sea water mainly depends on the salinity and temperature of the sea water. With the increase of salinity or temperature, the solubility of oxygen is reduced. Melchers and Tan (2022), opined that there is a linear relationship between dissolved oxygen and values of physiochemical properties.

2.4.5 Depth of Immersion of Material in Water

Generally, dissolved oxygen, temperature, and pH decrease steeply with water depth over the first several hundred meters while salinity and hydrostatic pressure increases with depth. Light penetration also decreases with water depth. Hence, the depth of water plays a significant role for corrosion of materials immersed in water.

III. MATERIALS AND METHODS

3.1: Materials

The materials used for experiment are plastic bottles, boat to convey personnel to required location at the shore and Horiba PC210 Water Quality Meter

Plate 1: Showing Photograph of Horiba PC210 water meter

3.2: Methods

Sea water around five different landing jetties within Port Harcourt environ were collected at both low tide and high tide to check the concentration of inorganic compounds that are capable of influencing corrosion of objects at the shores. The Horiba PC210 water quality meter was used to measure the physiochemical parameters of the seawater. The meter has features to measure values on the spot, but this method was not adopted due to the behaviour of some youngmen around the jetties, who sees every opportunity as government or companies' interest and wish to benefit from it. Hence, plastic bottles were used to collect the seawater and taken to the laboratory for testing on the same day in about one hour interval. The results obtained were printed automatically by the meter, which are presented in tables 1 and 2.

IV. RESULTS AND DISCUSSIONS

4.1: Analysis of Physicochemical Properties of Seawater Samples

Table 1 shows the results of physiochemical parameters of seawater samples conducted on the first day of analysis, 6^{th} of August, 2024, at low tide (as the river ebbs), while Table 2 shows the results of physiochemical parameters of seawater samples collected on 25^{th} of September, 2024, at high tide.

Table 1: Physiochemical Parameter of First Seawater Samples (low tide)

Physiochemical Parameters	Method	Abuloma Jetty	Bille Jetty	Bonny Jetty	Marine Base Jetty	Okuru Jetty
pH	APHA 460	6.35	6.38	6.32	6.44	5.82
EC (µs/cm³)	APHA 145	21,972	31,200	31,032	6,540	20,208
Temperature (°C)	APHA 2550 B	27.34	27.44	27.85	28.46	28.66
Salinity (mg/L)	APHA 2520 B	10,440	14,880	15,480	13,120	10,080
TDS (mg/L)	APHA 2540 C	10,992	15,624	15,552	3,264	10,092
Turbidity (NTU)	APHA 2130 B	5.78	4.99	5.12	5.87	4.74
ORP	APHA 2580 B	15.71	14.48	15.20	21.83	47.02
Chloride (mg/L)	APHA 4500Cl-B	11,589	20,041	17,172	2,409	10,952
Iron (mg/L)	APHA 301A	1.472	2.186	2.503	2.648	1.996
Zinc (mg/L)	APHA 301A	0.485	0.689	0.549	0.392	0.441
Lead (mg/L)	APHA 301A	0.290	0.474	0.392	0.446	0.360
Cobalt (mg/L)	APHA 3111B	0.085	0.104	0.095	0.039	0.026
Copper (mg/L)	APHA 3111B	0.392	0.863	0.802	0.482	0.596
Cadmium (mg/L)	APHA 3111B	0.007	0.021	0.015	0.016	0.013
Mercury (mg/L)	APHA 301A	<0.001	<0.001	<0.001	<0.001	<0.001

ORP = Oxidation-Reduction Potential

Table 2: Physiochemical Parameter of Second Seawater Samples (high tide)

Physiochemical Parameters	Method	Abuloma Jetty	Bille Jetty	Bonny Jetty	Marine Base Jetty	Okuru Jetty
pH	APHA 460	6.23	6.25	6.2	6.31	5.71
EC ($\mu s/cm^3$)	APHA 145	18,310	26,000	25,860	5,450	16,840
Temperature (°C)	APHA 2550 B	26.8	26.9	27.3	27.9	28.1
Salinity (mg/L)	APHA 2520 B	8,700	12,400	12,900	12,600	8,400
TDS (mg/L)	APHA 2540 C	9,160	13,020	12,960	2,720	8,410
Turbidity (NTU)	APHA 2130 B	5.67	4.89	5.02	5.75	4.65
ORP	APHA 2580 B	15.4	14.2	14.9	21.4	46.1
Chloride (mg/L)	APHA 4500Cl-B	11,362	19,648	16,835	2,362	10,737
Iron (mg/L)	APHA 301A	1.443	2.143	2.454	2.596	1.957
Zinc (mg/L)	APHA 301A	0.475	0.675	0.538	0.384	0.432
Lead (mg/L)	APHA 301A	0.284	0.465	0.384	0.437	0.353
Cobalt (mg/L)	APHA 3111B	0.083	0.102	0.093	0.038	0.025
Copper (mg/L)	APHA 3111B	0.384	0.846	0.786	0.473	0.584
Cadmium (mg/L)	APHA 3111B	0.004	0.018	0.011	0.009	0.007
Mercury (mg/L)	APHA 301A	<0.001	<0.001	<0.001	<0.001	<0.001

ORP = Oxidation-Reduction Potential

From Tables 1 & 2, the values of pH, Electrical conductivity and Temperature are higher at low tide than high tide, the same is true for most of the other physiochemical properties measured. Again, these values keep changing from one jetty to another, despite the fact that the same River called Okpoka River connected Okuru, Abuloma and Marine Base axis of Port Harcourt. Although, it is expected that temperature and salinity will decrease with river flowing, the values were quite high as against predicted values. For Abuloma jetty, the deviations for pH, salinity, temperature, chloride content and turbidity are 0.12, 1740µs/cm^3, 0.54^{0}C, 227mg/L and 0.11NTU respectively. The same trend exists for other parameters measured for each jetty environment. This downward trend in values may be attributed to human activities around the jetties and it influences the corrosion rate of the river. From the plot in Figure 1a, it is obvious that no particular physiochemical property influences another property(ies), because, the plot does not give any specific relationships between the properties as shown in Figures 1a & 3a.

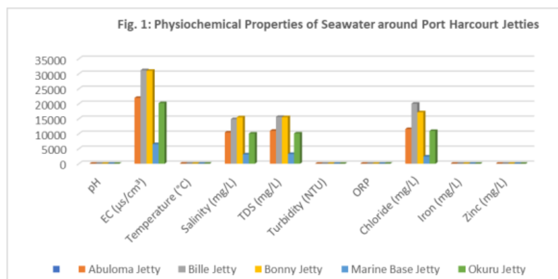

Fig. 1a. Physiochemical Properties of Seawater Around Port Harcourt Jetties (Low Tide)

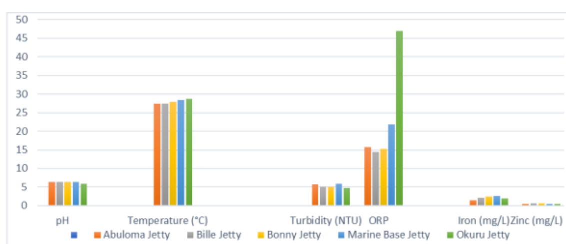

Fig.1b. Physiochemical Properties of Seawater Around Port Harcourt Jetties (Low Tide)

The oxidation reduction potentials (ORP) values obtained are exceptionally high at Okuru jetty area compared to other jetties, whereas the values obtained at Okuru jetty are 46.1 and 47.02 for high and low tides respectively, the closest values gotten from Marine base jetty area were 21.4 and 21.83 respectively. The rest have values below the Marine base figures.

Results from Tables 1 & 2, show that the temperature values at Okuru jetty are the highest of all values, 28.1^0C and 28.66^0C for high and low tides respectively. Values obtained from other jetties are shown in Tables 1 & 2, Marine base 28.46^0C and 27.9^0C, Abuloma 27.34^0C and 26.8^0C, Bille 27.44^0C and 26.9^0C, and Bonny 27.85^0C and 27.3^0C.

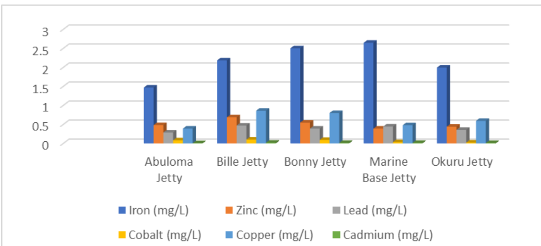

Fig. 2. Distribution of Heavy Metals in Seawater around Port Harcourt Jetties (Low Tide)

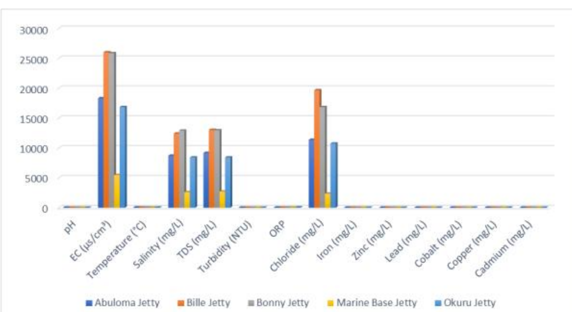

Fig. 3a. Physiochemical Properties of Seawater Around Port Harcourt Jetties (High Tide)

There is a particular observation from Figures 1a and 3a, in both figures, it is observed that Bille Jetty area has higher values for EC, TDS and Chloride compounds followed by Bonny, Abuloma, Okuru Jetties and least of all is Marine base, while the salinity is higher around Bonny Jetty area. Again, a closer look at Figures 2 & 4 shows that Marine base Jetty area water has higher Iron content (2.648mg/L) at both low and high times, the same applies to the pH values obtained. Although, Bonny and Bille jetties are quite close, there is still disparity in their figures. Amongst the heavy metals identified, iron has the highest value (2.648mg/L) at Marine base area, then copper (0.863mg/L), zinc (0.689mg/L), lead (0.474mg/L), cobalt (0.104mg/L) and cadmium (0.021mg/L) all at Bille jetty area, then followed by Bonny jetty area figures, (see details in Figures 2 and 4)

Results obtained show that physiochemical properties can differ within short nautical distances as in the case of Bille and Bonny jetties area, considering their proximity.

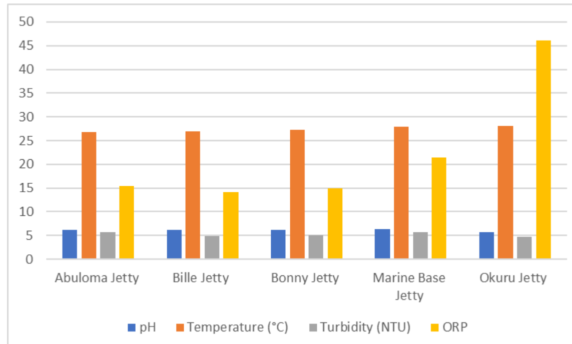

Fig. 3b. Physiochemical Properties of Seawater Around Port Harcourt Jetties (High Tide)

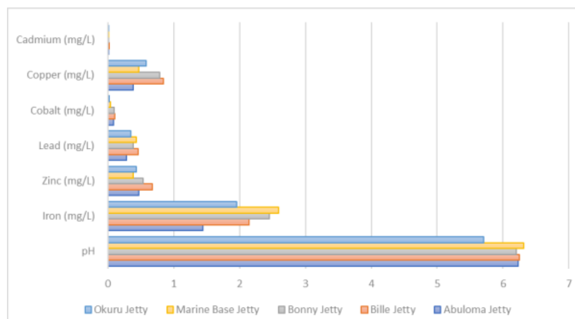

Fig. 4. Distribution of Heavy Metals in Seawater around Port Harcourt Jetties (Low Tide)

CONCLUSION

The results of physiochemical properties obtained showed that low tide and high tides figures are slightly different with low tide values higher than the high tides in rivers around Port Harcourt environs, virtually all values obtained followed the same trend. Again, values are different for all physiochemical properties within short nautical distances as in the case of Bille and Bonny jetties area. Also, though both locations may have the same source of river, but their values are quite different like the case of Abuloma, Okuru and Marine base jetty areas which are supplied by the Okpoka river, but disparity in their figures. Some very high as in ORP and Iron content values. These disparities can be attributed to various human activities at the different locations examined in this research.

REFERENCES

[1] Amjad, H., Rashel, M., Abusina, I., Syed, K. A. & Ibrahim, H. M. (2023). Minimization of corrosion in aquatic environment – a review. *International Journal of Hydrology*, 3 (1), 9 – 16.

[2] ASTM (American Society of Testing and Materials) (G31 – 21). *Standard Guide for Laboratory Immersion Corrosion Testing of Materials*. National Association of Corrosion Engineers.

[3] ASTM-G1-03 (2017), *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens*, West Conshohocken.

[4] Cai, Y., Zhao, Y., Zhang, Z., Ma, X. & Cheng, B. (2018). Atmospheric and marine Corrosion: Influential environmental factors and models. *In Proceedings of the International Workshop on Environmental Management, Science and Engineering (IWEMSE 2018)*, 178-186.

[5] Iyasele, E. O. (2018). Comparative analysis on the mechanical properties of a metal matrix composite reinforced with palm kernel/periwinkle shell ash. *Global Scientific Journal*, 6 (8), 1 – 24.

[6] Melchers, R. E. & Tan, M. Y. (2022). Literature review on prediction of lifespan and corrosion behaviour in the ocean. *A Report by the National Decommisional Research Initiative*, 1 – 21.

[7] Lawal, S. L., Afolalu, S. A., Jen, T-C., & Akinlabi, E. T. (2024). Corrosion Control and its Application in Marine Environment - A Review. *Solid State Phenomena*, 355, 61-73.

[8] Sylvester, O. O., Felix, U. A. & Okiemute, O. (2020). Assessment of the conditions of an existing marine concrete structure in the Niger Delta region of Nigeria. *Journal of Civil Engineering Research*, 10 (3), 63 – 71.