H

EGYPTIAN ACADEMIC JOURNAL OF
BIOLOGICAL SCIENCES
BOTANY

ISSN 2090-3812

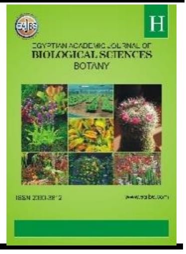
www.eajbs.com

Vol. 13 No.1 (2022)

Citation: Egypt. *Acad. J. Biolog. Sci.* (H. Botany) *Vol.13(1) pp67-77(2022)*
DOI: 10.21608/EAJBSH.2022.235088

Egypt. Acad. Journal Biolog. Sci., 13(1): 67-77 (2022)

Egyptian Academic Journal of Biological Sciences
H. Botany
ISSN 2090-3812
www.eajbsh.journals.ekb.eg.



The Effect of Covid-19 Lockdown on the Water Chemistry and Photosynthetic Pigments in An Estuarine Nigerian Lagoon

***Onyema, I. C. and Akanmu, R. T.**
Department of Marine Sciences, Faculty of Science, University of Lagos, Nigeria.
*****E-mail: ionyema@unilag.edu.ng - iconyema@gmail.com

ARTICLE INFO
Article History
Received:11/3/2022
Accepted:19/4/2022
Available:22/4/2022

***Keywords*:**
COVID-19**,**
Water quality,
algal pigments,
chlorophyll,
physico-chemistry,
phytoplankton

ABSTRACT

The coronavirus (COVID-19) pandemic is the defining health crisis of our time. It has led to lockdowns of major cities and curbed industrial, commercial and vehicular activities. Lagos is the commercial and industrial hub of Nigeria and has the Lagos lagoon as the sink for the flow of wastes streams from all these activities. Here we examine the water chemistry features and photosynthetic pigment parameters before the lockdown, during the lockdown and around the ease of the lockdown. Results show that parameters such as Dissolved Oxygen, Chlorophyll *a* and *b*, pH, Total Suspended Solids, Zinc, Copper, Lead, Chromium and Manganese increased considerably during the lockdown. On the other hand, parameters such as Conductivity, Total Dissolved Solids, Salinity, Acidity, Alkalinity, Total Hardness, Chloride, Sulphate, Phosphate, Calcium, Magnesium, Dissolved Inorganic Phosphate, Sodium and Chlorophyll *c* values reduced in the same period. In all, trends signify cleaner and clearer waters of the Lagos lagoon and these positive effects lingered during the ease of the lockdown period characterized by the cessation of major industrial and vehicular activities. During the lockdown, there were improved water quality conditions as well as primary production. The effects of seasonal variation in water chemistry factors including salinity were also noted.

INTRODUCTION

Since its emergence in China in November of 2019, the coronavirus disease (COVID-19) has become a pandemic and has defined the global health crisis of our world. The severe acute respiratory syndrome coronavirus (SARS – Cov – 2) has also significantly affected Nigeria. A common action across countries was the enactment of a lockdown across major cities of the world and people stayed home. Ali *et al.*, (2020) and Fawape *et al* 2020 are of the view that increased industrialization and anthropogenic activities in the last two decades and more have severely polluted the atmosphere, hydrosphere and biosphere in major cities. In most countries of the world including Nigeria, a ban on social and economic activities and gatherings as well as the cessation of movement of people on land and by air vehicles were significantly stopped. In Lagos, the commercial hub of Nigeria, Ogun state and surrounding cities, these measures were taken to stem the spread of the virus. This restriction applied as well to Ogun state due to its close proximity to Lagos and the heavy traffic between the two states. These lockdown measures impacted greatly and led to a marked reduction and stoppage of industrial and most manufacturing activities. By implications, the directive affected traffic emissions, vehicular and industrial wastes materials released into the atmosphere and water during the period. Importantly, pollution is the singular largest environmental threat to the aquatic ecosystem and its biodiversity in and around the coastal waters of Nigeria (Nwankwo, 2004, Kadiri, 1999). Pollution in Nigeria has been rising for decades now with staggering levels in the last few years (Onyema, 2016 domestic, Otitoloju, 2018; Onyema *et al.* 2019; Fawape *et al*, 2020).

The Lagos lagoon is the most notable of the lagoons in Lagos, especially with regard to the effects and fallouts of human activities. The waste materials in the Lagos lagoon usually reflect the content of waste from the Lagos and Ogun states (Onyema, 2009; Nwankwo, 2004; Nwankwo *et al*., 2012). Waste materials in southwestern Nigeria and specifically Lagos state eventually end up in the Lagos lagoon enroute to the Atlantic Ocean. The Lagos lagoon is the lowest point in southwestern Nigeria.

The measurement of algal or photosynthetic pigment levels is a useful tool in determining the trophic levels and health of aquatic ecosystems (Kowalewska *et al.*, 2004). Several studies have as well shown that photosynthetic pigments are an excellent tool for the study of phytoplankton communities (Jeffrey and Vesk, 1997; Agirbas *et al*, 2015). It is expected that there would be a reduction in pollution inputs from industrial and commercial activities getting to the Lagos lagoon following the lockdown declaration and a possible rise as the ease of the lockdown measures were released in phases.

Here we attempt to qualify and quantify the changes and trends in water quality and primary production parameters particularly connected to pollution, before the lockdown, during the lockdown and as the cessation of industrial, commercial and vehicular activities were eased in Lagos and Ogun state axis. It is expected that these data would help identify the key parameters or similar features in water quality that show clear and pointed differences in environmental conditions for this and other related environmental situations.

MATERIALS AND METHODS

Description of the Study Area:

Lagos state is the commercial and industrial hub of Nigeria, West Africa. It has over 20 million people living in it. It boasts of 10 lagoons with the Lagos lagoon being the most central and impacted by human activities and pollution inputs such as wastes from human activities in the region (Onyema *et al*, 2010). A brew of wastes even from neighboring states including Oyo, Ondo, Ogun and importantly other non-neighboring parts of Lagos states empty into the Lagos lagoon system, hence making it serve as a sink for waste discharges for the region. The Lagos lagoon is an integral part of the Lagos lagoon system (**Fig. 1**). Other lagoons in the Lagos lagoon system are Yewa, Ologe, Badagry, Kuramo, Iyagbe, Onijegi, Epe, Lekki and Mahin lagoons.

Collection of Water Samples:

The first water sample was collected about 3 weeks before Lagos state, Nigeria issued the lockdown measure. This represented the pre-lockdown situation. Four samples were collected weekly during the lockdown and five samples were collected weekly as the lockdown was eased starting from the 4th of May, 2020. In all, 10 samples were collected for this study. Samples for water and photosynthetic pigment determinations were collected between 09.00 and 12.00 hours on each sampling day in 75 cl screw-capped plastic containers and moved to the laboratory for analysis. The sample collection point is shown in Plate 1. This was just off the University of Lagos waterfront.

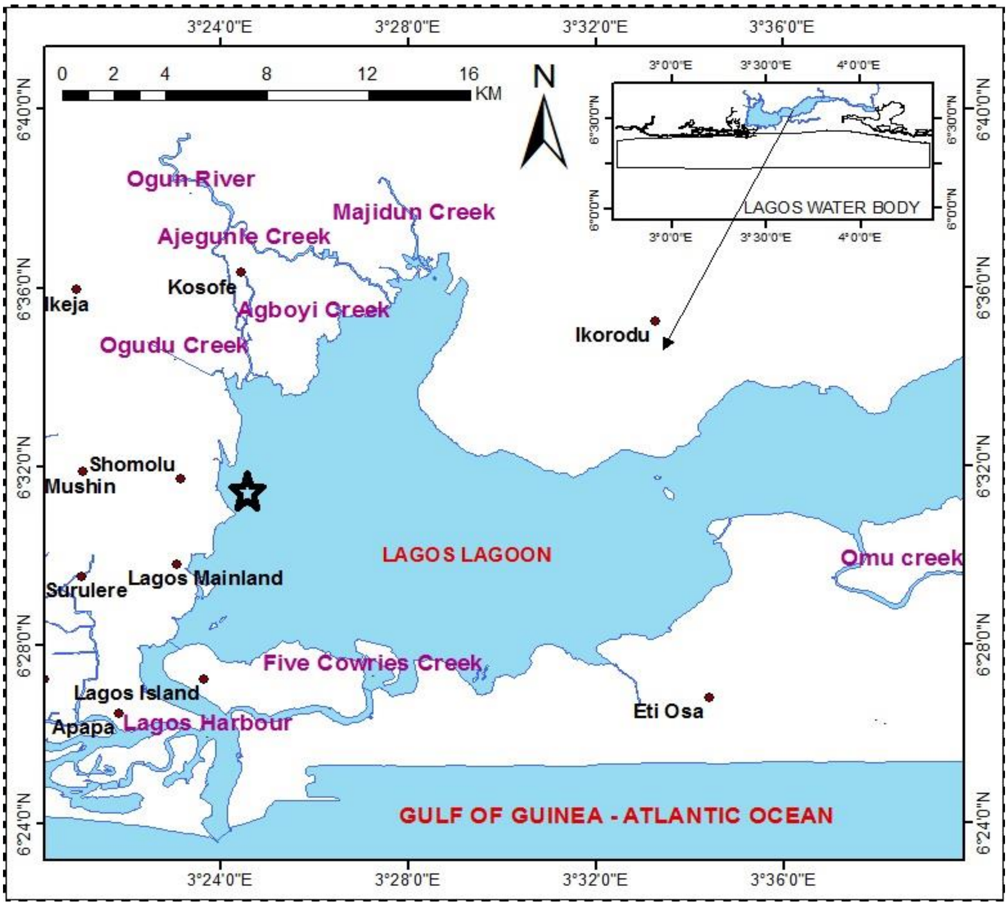


Fig. 1: The Lagos lagoon showing the sampling location.

Plate 1: The Lagos lagoon from the sampling area during the lockdown of activities.
Laboratory Analyses

Total suspended solids, salinity, dissolved oxygen, nitrate, phosphate, sulphate and silica were measured using methods according to American Public Health Association (APHA, 2012) for water analysis. Calcium, magnesium, sodium, potassium, copper, iron, zinc, manganese and cadmium were estimated using inductively coupled plasma, an optical emission spectrometer (Agilent ICP-OES 710 Axial). Photosynthetic pigments (Chlorophyll *a*, *b* and Pheophytin *a*) (μg/L) were analyzed using spectrophotometric determination of chlorophylls in water samples. The photosynthetic pigments were determined using different computational formulae as reported in Onyema and Akanmu (2017).

Statistical Analysis:

Standard deviation on normally distributed data was used to treat the water parameters, nutrients, heavy metals and photosynthetic pigments.

RESULTS

From the pre-lockdown period through the lockdown and then the resumption of activities (ease of lockdown), some parameters recorded reducing values throughout the study (Conductivity, TDS, Salinity, Acidity, Alkalinity, Total Hardness, Chloride, Sulphate, Phosphate, Calcium, Magnesium, Dissolved Inorganic Phosphate, Sodium and Chlorophyll c). Other parameters increased (pH, Total Suspended Solids, Dissolved Oxygen, Zinc, Copper, Lead, Chromium and Manganese) in the same stead. Table 1 shows the mean and standard deviation values for water chemistry and photosynthetic pigments characteristics for the pre-lockdown, during lockdown and ease of lockdown periods.

Conversely, some parameters generally reduced during the lockdown but increased as the lockdown eased. They were Turbidity, Nitrate, Silica, Iron, Dissolved Inorganic Nitrogen, Dissolved Organic Nitrogen and Chlorophyll *a*. Furthermore, other parameters such as Biological Oxygen Demand, Chemical Oxygen Demand, Calcium, Chlorophyll *b* and Pheophytin *a* generally increased during the lockdown but reduced as the lockdown eased. Specifically mean values of chlorophyll *b* and Phaeophytin *a* levels rose with the lockdown as well as dissolved oxygen values, while nitrate and sulphate values reduced (Fig. 2). Fig. 3 shows the relationship trends in DO, photosynthetic pigments and nutrients (Nitrate) during these times.

Table 1: Mean and standard deviation of water chemistry and photosynthetic pigments characteristics for the pre-lockdown, during lockdown and ease of lockdown period.

PARAMETERS		Pre-Lockdown (1 week)	Lockdown (4 weeks)		Ease of lockdown (5 weeks)		Lockdown and Ease of Lock-down	
			Mean	±Std. Dev.	Mean	±Std. Dev.	Average	±Std. Dev.
	Chemical Parameters							
1	pH (at 25°C)	7.07	8.2975	**0.59**	7.626	**0.33**	7.924	**0.50**
2	Conductivity (µS/cm)	31700.0	20657.5	**5117.2**	18403	**3137.29**	19405.00	**4641.71**
3	Total Suspended Solids (mg/L)	2	7.5	**3.85**	13.2	**3.49**	10.667	**4.98**
4	Total Dissolved Solids (mg/L)	19654.0	12872.9	**3150.3**	10645.56	**2048.28**	11635.48	**3137.32**
5	Turbidity (NTU)	15.35	10.4125	**3.23**	17.55	**7.54**	14.378	**6.36**
6	Salinity (ppt, at 25°C)	18.80	11.94	**3.18**	11.222	**0.86**	11.541	**2.46**
7	Acidity (mg/L, as $CaCO_3$)	22.0	3.75	**10.61**	4.52	**1.13**	4.300	**6.36**
8	Alkalinity (mg/L, as $CaCO_3$)	120.4	86.1	**15.98**	77.92	**10.57**	81.556	**15.03**
9	Total Hardness (mg/L, as $CaCO_3$)	2373.6	1052.2	**595.47**	989.32	**75.97**	1017.267	**435.77**
10	Dissolved Oxygen (mg/L)	4.91	5.575	**0.53**	5.884	**0.87**	5.747	**0.72**
11	Biological Oxygen Demand (mg/L)	3	6.75	**3.16**	4	**2.35**	5.222	**2.83**
12	Chemical Oxygen Demand (mg/L)	7	31	**19.25**	14.4	**10.16**	21.778	**15.79**
13	Chloride (mg/L)	9212.0	5836.975	**1566.1**	5498.88	**422.19**	5649.144	**1206.03**
	Nutrients							
14	Nitrate (mg/L, as NO_3^-)	4.31	2.3875	**1.52**	10.16	**6.36**	6.706	**5.85**
15	Sulphate (mg/L)	1146.0	722.475	**197.47**	676	**55.56**	696.656	**153.24**
16	Phosphate (mg/L, as PO_4^{3-})	0.280	0.1425	**0.07**	0.12	**0.11**	0.130	**0.09**
17	Silica (mg/L, SiO_2^-)	4.02	2.8825	**0.91**	4.006	**0.73**	3.507	**0.91**
18	Dissolved Inorganic Phosphate	0.094	0.04925	**0.02**	0.0414	**0.04**	0.045	**0.03**
19	Dissolved Inorganic Nitrogen (mg/L)	0.974	0.5415	**0.34**	2.2962	**1.44**	1.516	**1.32**
20	Dissolved Organic Nitrogen (mg/L)	0.512	0.292	**0.23**	0.996	**0.55**	0.683	**0.53**
21	Particulate Organic Nitrogen (mg/L)	0.177	0.059	**0.07**	0.1562	**0.10**	0.113	**0.09**
	Cations							
22	Calcium (mg/L)	206.40	45.36	**72.09**	42.644	**3.27**	43.851	**51.51**
23	Magnesium (mg/L)	451.09	227.96	**101.05**	214.34	**16.47**	220.393	**74.84**
24	Sodium (mg/L)	5414.10	3437.28	**915.99**	3231.932	**248.11**	3323.198	**707.46**
25	Potassium (mg/L)	141.02	106.2225	**17.24**	99.878	**7.67**	102.698	**14.40**
	Heavy Metals							
26	Zinc (mg/L)	0.005	0.0286	**0.03**	0.0267	**0.04**	0.028	**0.03**
27	Iron (mg/L)	0.602	0.3785	**0.15**	0.663	**0.15**	0.537	**0.19**
28	Copper (mg/L)	0.0010	0.011125	**0.01**	0.01164	**0.00**	0.011	**0.00**
29	Cadmium (mg/L)	0.0009	0.0019	**0.00**	0.00112	**0.00**	0.001	**0.00**
30	Lead (mg/L)	0.0010	0.004575	**0.00**	0.0043	**0.01**	0.004	**0.01**
31	Chromium (mg/L)	0.0013	0.01105	**0.01**	0.01354	**0.01**	0.012	**0.01**
32	Manganese (mg/L)	0.052	0.1164	**0.03**	0.30866	**0.35**	0.223	**0.26**
33	Nickel (mg/L)	0.0017	0.092875	**0.04**	0.06514	**0.02**	0.077	**0.03**
	Photosynthetic Pigments							
34	Chlorophyll *a* (µg/L)	12.3	10.8	**4.38**	14.8	**3.42**	13.022	**4.18**
35	Chlorophyll *b* (µg/L)	0.6	1.065	**0.50**	0.818	**0.23**	0.928	**0.37**
36	Chlorophyll *c* (c1+c2; µg/L)	-	0.9925	**0.13**	0.666	**0.16**	0.811	**0.22**
37	Pheophytin (µg/L)	0.4	0.4725	**0.12**	0.304	**0.14**	0.379	**0.15**

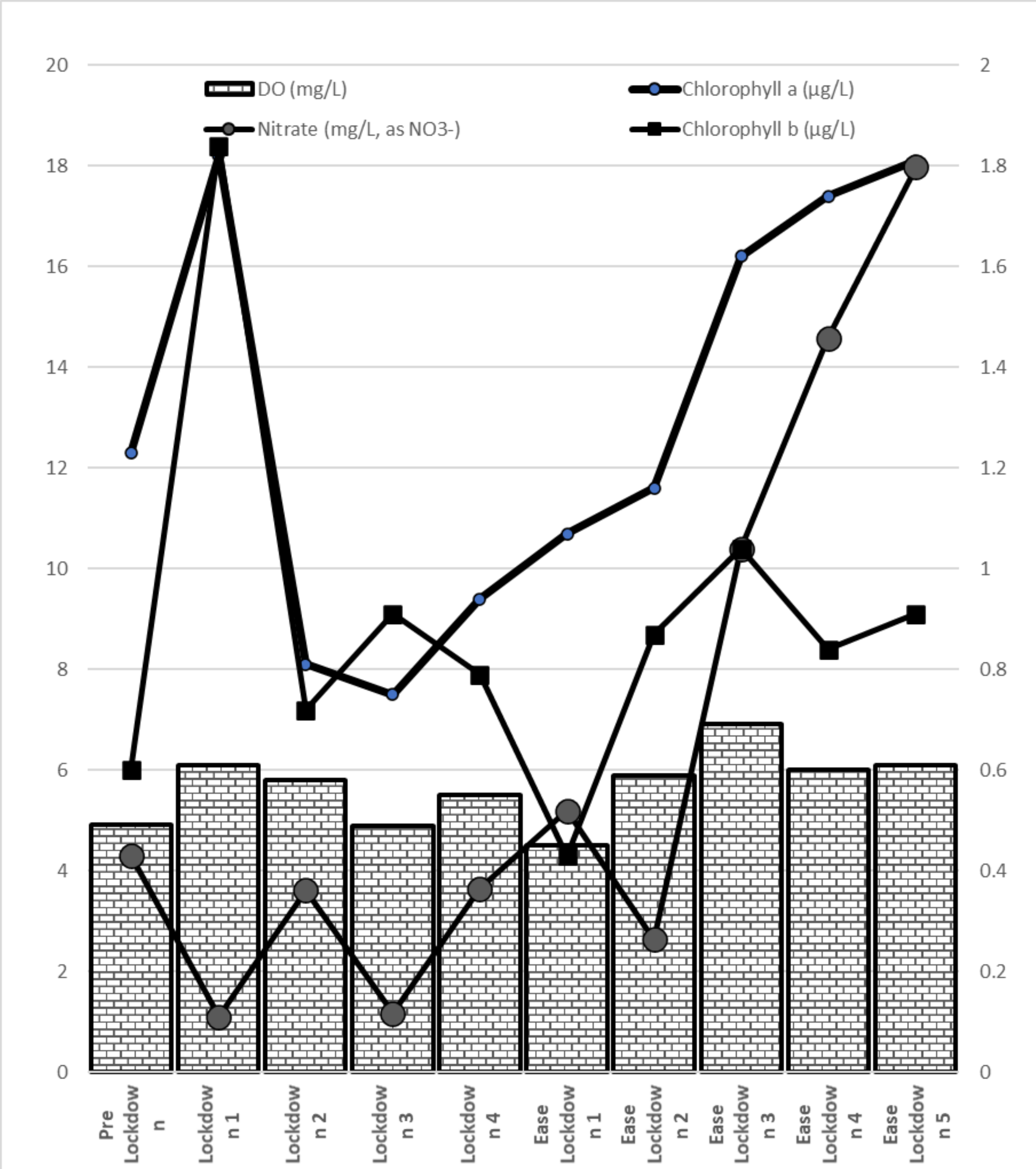


Fig. 2: Changes in values for DO, Chlorophyll *a*, *b* and Nitrate for the pre-lockdown, during lockdown and ease of lockdown period.

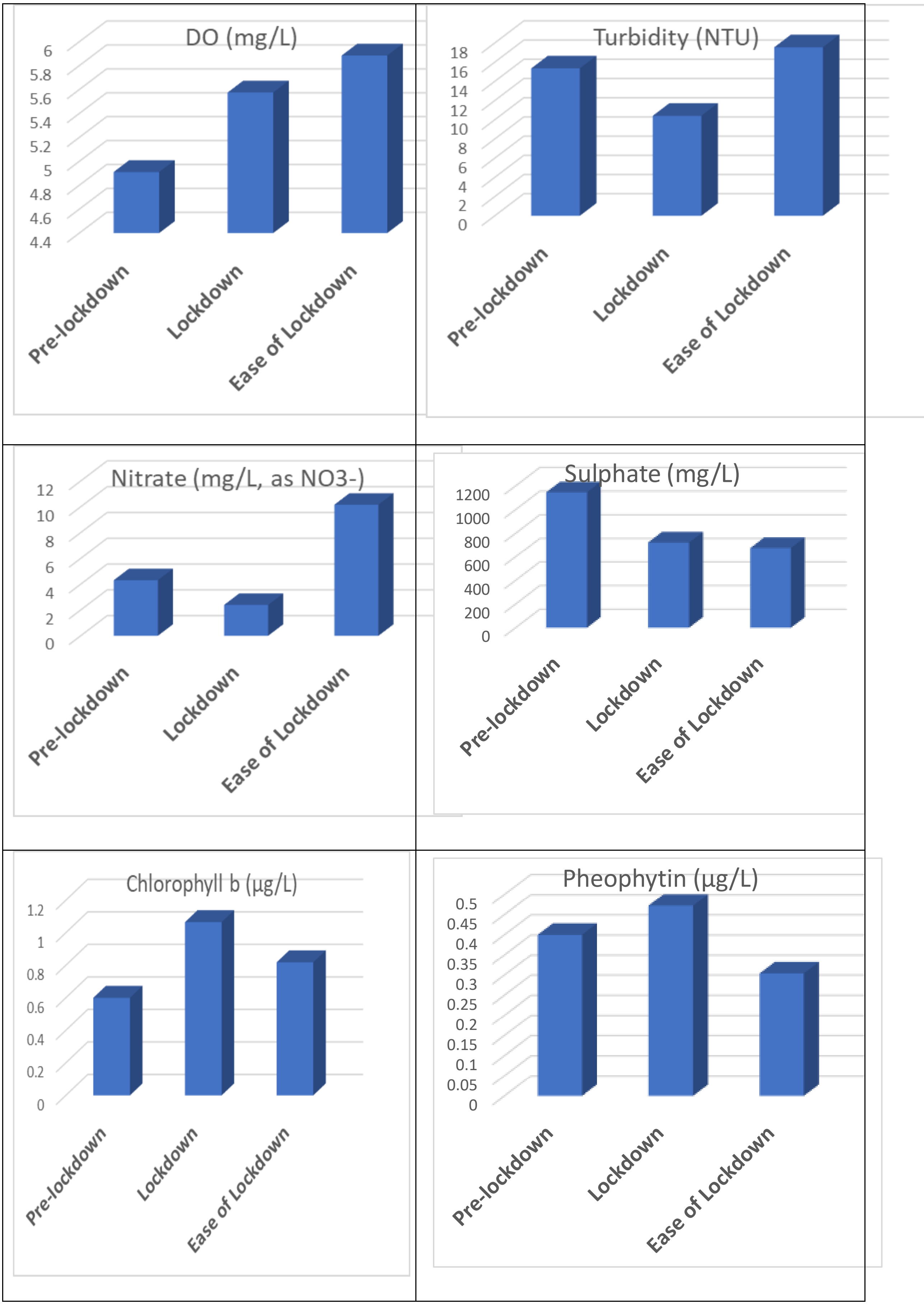


Fig. 3: The mean trend values for DO, Turbidity, Nitrate, Sulphate, Chlorophyll *b* and Phaeophytin *a* for the pre-lockdown, lockdown and during the ease of lockdown period.

DISCUSSION

Turbidity of the waters of the Lagos lagoon showed a remarkable drop in value immediately after the lockdown was imposed. Water clarity increased. The subsequent rise in turbidity after a few weeks was probably due to the turbidity current associated with agitated floodwaters initiated by the rains and mixed with the lagoon water. According to Ali *et al.*, (2020) in the Vembanad Lake, the longest freshwater lake in India, in a matter of days following the enforcement of lockdown, the carbon emission levels had dropped significantly and they quantitatively demonstrated the improvement in surface water quality in terms of suspended particulate matter.

Connectedly, reducing values were noted for salinity, Conductivity, Chloride, Cations and the like. The reduced input from industrial, vehicular and commercial waste generating activities impacting the Lagos lagoon was evident in the spread of values especially when the pre-lockdown values were compared with values during the lockdown and cessation of large-scale industrial and vehicular activities. Importantly, the period of stoppage of industrial activities in the region is reflected in the reduction in Turbidity, Nutrients - Nitrate, Sulphate, Phosphate, Silica, Dissolved Inorganic Phosphate and Dissolved Inorganic Nitrogen values on the one hand and corresponding increases in Dissolved Oxygen, Chlorophyll *a* and Chlorophyll *b* values. Hence, increased primary production values with the lockdown and more dissolved oxygen. This evidently gave rise to a cleaner and clearer Lagos lagoon aquatic ecosystem. With regards to the chlorophyll values, Varadharajan and Soundarapandian (2014) are of the view that phytoplankton species diversity responds rapidly to changes in the aquatic environment, particularly in relation to nutrients. The trend of the data from the water chemistry over the period of the study showed the effect of seasons in the variations of these parameters. Some of these trends in variations have been previously documented for the south-western ecoregion by a number of authors in the creeks, lagoons, harbour and immediate ocean (Nwankwo,1996, Onyema *et al*., 2016, Onyema and popoola, 2013, Akanmu and Onyema, 2019).

For instance, the effect of the rains on increasing Turbidity and Total Suspended Solids has been evident before now (Onyema, 2018; Onyema and Akanmu, 2020). This also means that while nutrient levels from pollution reduced during the lockdown period, there was a corresponding increase in primary production as shown in increased chlorophyll *a, b* and as well as dissolved oxygen levels. Increases in dissolved oxygen levels could be attributed to the improved health status of the lagoon and as a result of increases in primary production. Oxygen is a byproduct of photosynthesis.

Invariably, pollution from pre-lockdown periods partly suppressed primary production in the Lagos lagoon. In other climes globally, healthier and less turbid waters and skies were mostly reported as a result of imposed lockdown measures in major cities of the world (Ali *et al.*, 2020). In the surface water resources in the Meriç-Ergene River Basin Turkey, Tokatlı and Varol (2021), realized the limited operational status of most industrial facilities in the basin during the lockdown reduced the number of industrial effluents, leading to significant improvement in surface water quality and the lockdown has shown that the solution for preservation and sustainability of natural water resources lies in the efficient management of pollution sources that can prevent surface water pollution at a very rapid pace. According to Chakraborty *et. al*., (2021), evidence from recent studies in a part of India reveals that the river water quality was revived significantly during the lockdown phase, due to the complete closing of industrial, transport, business sectors stopped waste discharge admixing to riverbed directly. Also, values showed that the complete lockdown of industrial activities helped to lower heavy metal concentration in river water for the studied area. In a previous study by Onyema *et. al*. (2019) for a freshwater swamp in Lagos Nigeria, heavy metals level from a solids waste dumpsite was significantly responsible for depressing and limiting levels of primary production in the wetland ecosystem.

Over the years, there has been a remarkable increase in the discharges of pollutants into coastal ecosystems due to urbanization, population growth, and high industrial activities. This has resulted in surface water degradation (Ibanga *et al*., 2019). It is also important to note that iron levels are reduced with nutrient levels. Increased iron or heavy metal levels have been implicated in limiting the primary productivity of coastal waters of south-western Nigeria over recent years (Nwankwo, 2004, Onyema *et al*., 2016, Onyema 2018, Onyema *et al*., 2019). Another study for Nigeria has also shown that the COVID-19-induced lockdown was responsible for a decrease in NO_2 levels (Fawape *et al* 2020).

During the lockdown period, there were additionally visible cleaner and clearer waters with reduced nutrient load estimates and improved primary production. In another study, the lockdown has been associated with better water quality in Vembanad Lake, India (Yunus *et al*. 2020). Additionally for Malaysia, several observations conducted by reporters of local news media organizations, reported that waters in the country especially in the early days of the lockdown showed positive changes in water river quality (Chai, 2000). Swamp areas especially in coastal zones of the world are under increasing stress due to the development of industries, trade, commerce, tourism and their resultant human population growth leading to deteriorating water quality and hydrological conditions (Wu *et. al*, 2014).

Conclusion

The lockdown period brought the following noticeable effects namely cleaner and clearer waters of the Lagos lagoon as shown by the reduced turbidity and nutrients values. Secondly, the lagoon experienced increased primary production as shown in the increased levels of photosynthetic pigment concentration and thirdly, the lagoon became healthier as reflected in the increase in Dissolved oxygen concentration. The COVID-19 lockdown has been reported as a “ventilator” for the reinstatement of natural resources across the globe (Khan *et. al*, 2021).

REFERENCES

Agirbas, E., Feyzioglu, A.M., Kopuz, U. and Llewellyn, C.A. (2015). Phytoplankton community composition in the south-eastern Black Sea determined with pigments measured by HPLC-CHEMTAX analyses and microscopy cell counts. *Journal of the Marine Biological Association*, U. K. 95 (1): 35 - 52,

Ali, P.Y., Yoshifumi, M. and Yasuaki, H. (2020). COVID-19 and surface water quality: Improved Lake water quality during the lockdown. *Science of the Total Environment***.** 731(20): https://doi.org/10.1016/j.scitotenv.2020.139012

APHA. (2012). Standard Methods for the Examination of Water and Wastewater. 20. Published by American Public Health Association, Washington D. C. 1287pp.

Chai, L. G. (2020). The river water quality before and during the Movement Control Order (MCO) in Malaysia. *Case Studies in Chemical and Environmental Engineering*, doi: 10.1016/j.cscee.2020.100027

Chakraborty, B., Bera, B., Adhikary, P. P., Bhattacharjee, S., Roy, S., Saha, S., Ghosh, A., Sengupta, D. and Shit, P. K. (2021). Positive effects of COVID-19 lockdown on river water quality: evidence from River Damodar, India. *Scientific Reports*. 11(20140). https://doi.org/10.1038/s41598-021-99689-9

Chukwu, L.O. (2010). *Ecophysiology of marine life*: *A science or management tool*. University of Lagos Press. Inaugural lecture series, 62pp.

Fuwape, I. A., Okpalaonwuka, C. T. and Ogunjo, S. T. (2020). Impact of COVID -19 pandemic lockdown on distribution of inorganic pollutants in selected cities of Nigeria. *Air Quality*, *Atmosphere* & *Health*, 5: 1–7

Jeffrey, S.W. and Vesk, M., (1997). Introduction to marine phytoplankton and their pigment signatures. In: Jeffrey, S.W., Mantoura, R.F.C., Wright, S.W. (Eds.), Phytoplankton Pigments in Oceanography: *Guidelines to Modern Methods*, *UNESCO,* Paris, 19 - 36.

Kadiri, M. O. (1999). Phytoplankton Distribution in Some Coastal Waters of Nigeria. *Nigerian Journal of Botany*. 12 (1): 51 - 62.

Khan, R., Saxena, A., Shukla, S., Sekar, S and Goel, P. (2021). Effect of COVID-19 lockdown on the water quality index of River Gomti, India, with potential hazard of faecal-oral transmission. *Environmental Science* and *Pollution Research*, 28, 33021–33029 (2021). https://doi.org/10.1007/s11356-021-13096-1

Kowalewska Al-Kandari, M., Al-Yamani, F. Y. and Al-Rifaie, K. (2009). *Marine Phytoplankton Atlas of Kuwait's Waters.*Kuwait Institute for Scientific Research, Safat, Kuwait. 350pp.

Nwankwo, D.I. (1996). Phytoplankton diversity and succession in Lagos Lagoon. Nigeria. *Archiv Fur hyddrobiologie*, 135(4): 529-542.

Nwankwo, D.I. (2004). *The Microalgae*: *Our indispensable allies in aquatic monitoring and biodiversity sustainability*. University of Lagos Press. Inaugural lecture series, 44pp.

Nwankwo, D.I., Okedoyin, J.A. and Adesalu, T.A. (2012). Primary productivity in tidal creeks of south-west Nigeria II. Comparative study of nutrients and chlorophyll *a* variations in two Lagos Harbour creeks. *World Journal of Biological Research,* 5(1): 41 – 48.

Onyema, I. C. (2016). Hydrochemistry and some algal photosynthetic pigments in a mangrove swamp and adjoining creeks in Lagos. *Nigerian Journal of Fisheries and Aquaculture*. 5(1): 50 – 56.

Onyema, I. C. (2017). Water Quality Characteristics and Phytoplankton Diversity Around a Domestic Waste Polluted Site in Lagos lagoon. *Egyptian Academic Journal of Biological Sciences H. Botany*. 8(1): 13-23.

Onyema, I. C. and Akanmu, R. T. (2017). Environmental Variables, Algal Pigments and Phytoplankton in The Coast Of Badagry, Lagos. *Journal of Aquatic Sciences,* 32 (1B):171-191.

Onyema, I. C. and Omokanye, A. (2016). The influence of environmental variables on algal pigment in the western Lagos lagoon, Nigeria. *Nigerian Journal of Life Science* 6(2): 197 – 213

Onyema, I. C., Akanmu, R. T. and Plumptre, A. O. (2019). Photosynthetic Pigments and Nutrients In A Freshwater Swamp, Lagos. acta SATECH 11 (2):14 - 23

Onyema, I. C., Nkwoji, J. A. and Eruteya, O. J. (2010). The Water Chemistry and Plankton Dynamics of a Tropical High Energy Erosion Beach in Lagos. *Journal of American Science*. 6(1): 111 - 122.

Onyema, I.C. (2018). Water chemistry, microscopy and algal pigment concentration analyses of phytoplankton in the western and eastern parts of the Lagos lagoon. *Egyptian Academic Journal of Biological Sciences (H. Botany),* 9(1): 75 – 85.

Onyema, I.C. and Akanmu, R.T. (2018). Algal pigments variations and water chemistry variables from a Mangrove swamp and creek in Lagos, Nigeria. *Nigerian Journal of Fisheries and Aquaculture*, 6(2): 27 – 34.

Otitoloju, A.A. (2018). *Understanding Environmental Pollution and Management*. University of Lagos Press and bookshop Ltd., Lagos. 459pp.Rupani, P. F., Nilashi, M. Abumalloh, R. A. Asadi, S., Samad, S. and Wang, S. (2020).

Coronavirus pandemic (COVID-19) and its natural environmental impacts. *International Journal of Environmental Science and Technology*, 17: 4655–4666

Tokatlı, C. and Varol, M. (2021). Impact of the COVID-19 lockdown period on surface water quality in the Meriç-Ergene River Basin, Northwest Turkey. *Environmental Research*, 197. https://doi.org/10.1016/j.envres.2021.111051

Varadharajan, D. and Soundarapandian, P. (2014). Effect of Physico-Chemical Parameters on Species Biodiversity with Special Reference to the Phytoplankton from Muthupettai, South East Coast of India.*Journal of Earth, Science and Climate Change*, 5(5): 200 – 209.

Wu, M.L., Wang1, Y.S., Wang, Y.T., Sun, F.L., Sun, C.C., Jiang, Z.Y. and Cheng, H. (2014). Influence of Environmental Changes on Phytoplankton Pattern in Daya Bay, South China Sea. *Revista de Biología Marina y Oceanografía*, 49(2): 323 – 337.

Yunus, A. P., Masago, Y. and Hijioka, Y. (2020). COVID-19 and surface water quality: Improved Lake water quality during the lockdown. *Science* of the *Total Environment*, 12: 731:139. doi: 10.1016/j.scitotenv.2020.139012.