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Seasonal Variation and Pollution Assessment of Some Physicochemical Parameters of the Surface Water of Mahin Lagoon and Its Adjoining creeks, South-Western Nigeria

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ABSTRACT: Indiscriminate discharge of untreated wastes from into the aquatic ecosystem may result in deterioration of water quality, as well as poses a great threat to the balance of aquatic ecosystems and human health. This study investigated the seasonal variation in physicochemical characteristics and assessed the pollution status of Mahin Lagoon and its adjoining creeks using standard method. Results of physico-chemical parameters varied significantly ($p<0.05$) across seasons and stations, with the following mean values: Temperature (27.79±0.96ºC), salinity (7.65±0.99‰), conductivity (15.23±17.63µS/cm), pH (7.74±6.57), DO (7.65±0.99 mg/L), BOD (7.74±6.57mg/L), nitrate (8.00±3.67mg/L), sulphate (8.60±5.01mg/L), phosphate (3.88±1.55mg/L). Heavy metals were with the following mean values: Zn (7.15±6.31mg/L), Pb (0.04±0.21mg/L), Fe (10.63±6.02mg/L), Cu (1.16±1.72mg/L), Cr (0.02±0.00mg/L), Cd (0.01±0.08mg/L), Ni (0.28±0.45mg/L) and Co (0.26±0.44mg/L). The physic-chemical parameters were within the permissible limits recommended by International Organizations for lotic ecosystem. However, the single-factor pollution index (PI) classified pH, DO, BOD, Cu and Zn within the 'medium pollution' category while nitrate and phosphate indicated heavy pollution status. The PI also revealed that Cu, Fe and Ni were at serious pollution level while Co and Cr were at non-pollution level. The comprehensive pollution index revealed that the water was severely polluted (CPI < 2). The Hazard Quotients of heavy metals in the surface water were less than 1 (HQ < 1) indicating there was no risk to human health through ingestion or dermal contact. Therefore, the water from the Mahin lagoon and its adjoining creeks may still be suitable for domestic use and conducive for survival of aquatic life.

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Water is a natural resource essential for life in any ecosystem (Lomsadze *et a*l., 2007). Every living organism on earth depends on water for survival (Igbokwe *et al*., 2021). Sustaining the good quality of water is a major concern for the society which must meet the growing needs for water with the rapid development of the modern economy and the continuous expansion of population (Lu *et al*., 2017). Pollution of coastal water body has been a serious global challenge in recent time especially in developing nation (Otieno, 2008). Rapid pollution of aquatic environment results into the deterioration of water quality, as well as poses a great threat to the balance of aquatic ecosystems, human health and economic development (Milovanovic, 2007; Loto and Ajibare, 2021). In fact, natural factors and anthropogenic activities such as industrial activities, sewage water and irrigation introduce high amount of chemical and biological pollutants, directly or indirectly to the surface water. As a result, the physico-

chemical properties of rivers and other surface features are affected (Négrel *et al*., 2014; Xie *et a*l., 2014; Chiogna *et al*., 2016). The physical and chemical constituents of water form an important component of aquatic ecosystem. The waste discharges into marine ecosystem are liable to upset the ecological equilibrium of both living and non-living resources (Oyeleke *et al*., 2019) Therefore, the study on the physico-chemical parameters of water body is very important to evaluate the condition in term of health and productivity of the aquatic ecosystem. It can further bring a thorough knowledge on the environmental and health status of the water mass (Hayek et al., 2020). Due to the instability of water after it has been extracted from its source, the reliable parameters to monitor for water quality assessment are the physic-chemical characteristics (Loto and Ajibare, 2021). This can provide information on the productivity of water resource, diversity of the organisms as well as type of management strategy to be adopted to enhance better survival of biota in the water. (Alobaidy *et al*., 2015). In achieving the objectives of environmental sustainability program, water quality monitoring is a very important tool. The data obtained from the water quality could be used to estimate the water quality and categories the water bodies into different classes: I, II, III, IV or V according to the Water Quality Index (WQI) (Arman *et. al*., 2013). Water quality monitoring has been described as essential tool in fisheries management and in order to safeguard the health of aquaculture system, certain water quality parameters must be monitored (Shelle *et al.,* 2010). Therefore, there is need to continuously monitor the physico-chemical parameters of Mahin lagoon and its adjoining creeks to safeguard the improved health status of the aquatic ecosystems. This study aims at investigate the seasonal variations and pollution of some physicochemical parameters of Mahin lagoon and its adjoining creeks. Moreover, this study is essential to the establishment of the baseline information for future research and pollution status of the Mahin lagoon and its adjoining creeks.

MATERIALS AND METHODS

Study Area: The Mahin Lagoon and its adjoining creeks are located within the Ilaje LGA of Ondo state, South Western Nigeria, between Latitude 6.175989 °N – 6.206869 °N and Longitude 4.810944 °E – 4.823770 °E (Figure 1). It is approximately 2.3 ×1 km, and at a distance of 9 km from the Atlantic Ocean (Akinrinade *et al.*, 2016).

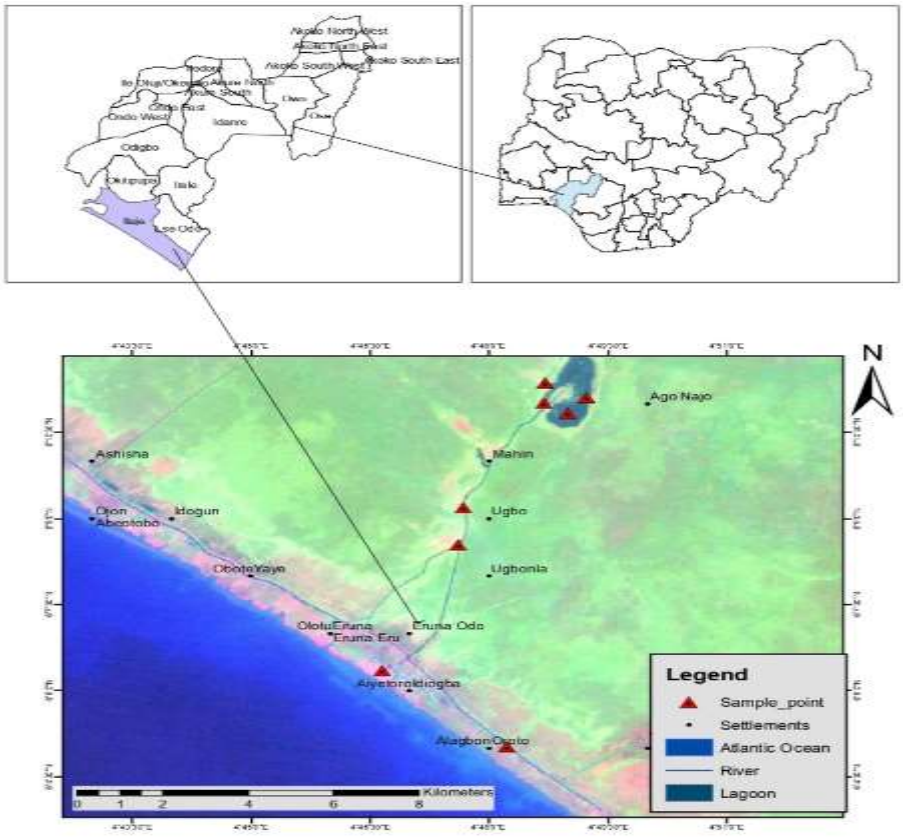

Fig 1: Map of sampling stations at Mahin lagoon and its adjoining creeks

The lagoon is famous as a fishing hub. Communities are sited around it for economic purposes, and a section of it serve as transportation route from Igbokoda to communities on the coastline (Figure 1). Mahin Lagoon represents a mixed and dynamic ecosystem, considering its proximity to the ocean and associated tidal influences. It is fed by the adjoining creeks connected to a 29 km long river channel which drains to the sea. The western flank of the lagoon used to be the major transportation route from Igbokoda to the coastal communities (Akinrinade *et al.*, 2016).Eight (8) stations were sampled in the course of this study. The site selection is based on the population/aggregation of fishing families/possible anthropogenic inputs, geographic distribution, catch volume and species diversities of the fish catches in the area.

Determination of Physicochemical Parameters: The water temperature was determined in-situ with mercury in glass thermometer while dissolved oxygen, salinity and pH were also determined in-situ with Horiba water Checker (model U-10).

Samples were collected with 1L sampling bottles and transported in ice chest to the Chemistry Laboratory of the University of Lagos for the determination of phosphate, ammonia, sulphate and nitrate according to American Public Health Association (2000) while the heavy metals (Cd, Pb, Cr, Cu, Zn, Co, Ni and Fe) analysis was done according to Thomas and Mohaideen (2015), using ACCUSYS 211 Atomic Absorption Spectrometer (AAS).

Statistical Analysis: Data were subjected to descriptive statistics (to determine means and standard deviations) on the Statistical Package for Social Sciences (20.0).

The means were compared with the recommendations of Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO) while the following indices were used to determine the pollution status of the lagoon and its adjoining creeks:

Single-Factor Pollution Index (Pi): The Single-Factor Pollution Index (Pi) was calculated as:

$$P_i = \frac{C_i}{S_i}$$ (Yan *et al.*, 2015)

Where: P_i is the pollution index of pollution indicator, C_i is the concentration of the pollution indicator in water (mg/l); S_i is the permissible limit for the pollution indicator in water.

According to Li *et al.* (2010), the single-factor pollution index (P_i) is classified into five grades, (Table 2).

Table 1: Standards for single-factor pollution index (*Pi*)

Pi	Pollution grades
< 0.4	Non-pollution
0.4 - 1.0	Slight pollution
1.0 - 2.0	Medium polluted
2.0 - 5.0	Heavy polluted
>5.0	Serious polluted

Comprehensive Pollution Index (CPI): The Comprehensive Pollution Index (CPI) was calculated as:

$$CPI = \frac{1}{n}\sum_{i=1}^{n}\frac{C_i}{S_i}$$ (Tao *et al.*, 2011)

Where: CPI = the comprehensive pollution index, C_i = concentration of the pollution indicator *i* (mg/l), S_i = permissible limit for the pollution indicator *i* in water, n = the number of analysed pollution indicators.

CPI is classified according to Tao *et al.* (2011) into five water quality levels (Table 3).

Table 2: Classification of surface water quality based on CPI

Values	Water Quality Grades
< 0.2	Cleanness
0.21 - 0.4	Sub-cleanness
0.41 - 1.0	Slight pollution
1.01 - 2.0	Moderate pollution
> 2.01	Severe pollution

Human health Risk Assessments: Inhalation, ingestion and dermal absorption of surface water are some of the important pathways of trace metals entrance into human body (USEPA, 2004). The dermal pathways, ingestion and hazard quotients (HQs) associated with corresponding heavy metals were assessed using a model of risk assessment. The exposure dose was calculated according to USEPA (2004) using:

$$D\ (ingestion) = \frac{Cw \times IRW \times EF \times ED}{BW \times AT}$$

and

$$D(dermal) = \frac{Cw \times SA \times Kp \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where: IRW is drinking water ingestion rate (2 L/day). Cwrepresents average concentration of heavy metals in water. EF indicates exposure frequency (350 days/year). ED stands for exposure duration (54 years equivalent to the average age lifetime in Nigeria). AT stands for average time for carcinogens and non-

carcinogens (19710). BW represents body weight (60 kg). SA represents exposed skin area (18000 cm^2). Kprepresents dermal permeability constant in cm/hr, ET is exposure time 0.6 h/day. CF is unit conversion factor; for water, it is equal to 1 L/1000 cm^3.

The hazard quotient (HQ) was therefore calculated as:
$HQs = \frac{D}{RfD}$

Where: RfD is the reference dose for different heavy metals (mg/kg/day), which is based on US risk based assessment.

RESULTS AND DISCUSSION:

Physicochemical parameters of surface water of Mahin lagoon and its adjoining creeks: Information on the physico-chemical properties of Mahin lagoon and its adjoining creeksare presented in Table 3 and 4. The study revealed that average temperature was 27.79±0.96°C with a ranged of 26.00 °C - 30.00°C. The average salinity, conductivity, pH, DO and BOD was 7.55±9.28‰,15.23±17.63µS/cm, 7.74±6.57, 7.65±0.99mg/L and 10.91±4.44mg/L respectively (Table 3). The table also revealed that nitrate ranged between 2.33mg/L and 14.67mg/L with a mean of 8.00±3.67mg/L while phosphate and sulphate had means of 3.88±1.55mg/l and 8.60±5.01mg/l respectively. It was further revealed in Table 3 that Zn, Pb, Fe, Cu, Cr, Ca, Ni and Co had means of7.15±6.31mg/L, 0.04±0.21mg/L, 10.63±6.02mg/L, 1.16±1.72mg/L, 0.02±0.00mg/L, 0.01±0.08mg/L, 0.28±0.45mg/L and 0.26±0.44mg/L respectively. Table 4 revealed that some of the physicochemical parameters: temperature, salinity, conductivity, pH, DO and BOD, nutrients (nitrate, phosphate and sulphate) as well as the heavy metal (Zn, Pb, Fe and Ni) varied significantly ($P<0.05$) across the season, with higher value recorded in the wet season than in the dry season, except in temperature and pH which had higher values in the dry season.

Table 3: Minimum and maximum range in Physicochemical parameters of Mahin lagoon and its adjoining creeks (June 2019 to April 2021).

Parameters	Minimum	Maximum	Range	Mean ±SD	Standard (WHO, 2003; FEPA, 2003)
Water Temperature (°C)	26.00	30.00	4.00	27.79±0.96	30
DO (mg/L)	6.00	11.33	5.33	7.65±0.99	5.5
Salinity	0.04	32.33	32.29	7.55±9.28	15
Conductivity (µS/cm)	0.00	67.00	67.00	15.23±17.63	1000
pH	5.33	9.00	3.67	7.74±6.57	6.6
BOD (mg/L)	5.30	19.00	13.70	10.91±4.44	5
Phosphate (mg/L)	1.00	8.00	7.00	3.88±1.55	0.3
Nitrate (mg/L)	2.33	14.67	12.34	8.00±3.67	5
Sulphate mg/L)	2.00	18.00	16.00	8.60±5.01	250
Zinc (mg/L)	0.00	25.00	25.00	7.15±6.31	3
Lead (mg/L)	0.00	1.33	1.33	0.04±0.21	<1
Iron (mg/L)	5.67	37.00	31.33	10.63±6.02	0.3
Copper (mg/L)	0.00	4.33	4.33	1.16±1.72	1
Chromium (mg/L)	0.00	0.08	0.08	0.02±0.00	<1
Cadmium (mg/L)	0.00	0.67	0.67	0.01±0.08	<1
Nickel(mg/L)	0.00	1.00	1.00	0.28±0.45	<1
Cobalt (mg/L)	0.00	1.00	1.00	0.26±0.44	<1

Table 4: Seasonal variation in Physicochemical parameters of Mahin lagoon and its Adjoining creeks (June 2019 to April 2021).

Parameter	Dry season	Wet season	T stat	T crit	P-value
Temperature (°C)	$28.47±0.67^b$	$27.12±0.68^a$	-11.39	1.98	0.00
Salinity (‰)	$13.85±9.44^b$	$1.37±1.96^a$	-14.28	1.98	0.00
Conductivity (µS/cm)	$28.06±16.93^b$	$2.63±3.13^a$	-19.45	1.98	0.00
pH	$7.60±0.76^b$	$7.72±9.30^a$	-23.05	1.98	0.00
DO (mg/l)	$7.86±2.47^a$	$8.02±0.42^b$	11.85	1.98	0.00
BOD (mg/l)	$14.14±3.34^b$	$6.88±0.65^a$	-33.16	1.98	0.00
Nitrate (mg/l)	$4.88±1.36^a$	$11.26±2.15^b$	32.42	1.98	0.00
Phosphate (mg/l)	$3.13±1.24^a$	$4.72±1.39^b$	11.33	1.98	0.00
Sulphate (mg/l)	$4.30±1.25^a$	$13.03±3.20^b$	37.17	1.98	0.00
Zinc (mg/l)	$2.60±1.70^a$	$11.85±5.85^b$	12.63	1.98	0.00
Lead (mg/l)	$0.46±1.21^b$	$0.07±0.08^a$	-3.92	1.98	0.00
Iron (mg/l)	$3.27±1.82^a$	$13.75±7.27^b$	11.90	1.98	0.00
Copper (mg/l)	$0.07±0.08^a$	$2.43±1.78^a$	10.89	1.98	0.00
Chromium (mg/l)	$0.02±0.06^a$	$0.03±0.07^a$	-0.10	1.98	0.92
Cadmium (mg/l)	$0.07±0.11^a$	$0.06±0.08^a$	-1.58	1.98	0.12
Nickel (mg/l)	$0.22±0.13^a$	$0.53±0.20^b$	12.28	1.98	0.00
Cobalt (mg/l)	$0.25±0.14^a$	$0.45±0.28^a$	3.52	1.98	0.00

Mean value with same superscripts along the rows were not significantly different (p>0.05).

Single-Factor Pollution Index: The Single-Factor Pollution Index of Mahin lagoon and its adjoining creeks is presented in Table 5. In dry season the table revealed that sulphate (0.02), Cu (0.06) and Cr (0.08) fell within the category of non-pollution. The table also showed that temperature (0.95), salinity (0.53), conductivity (0.85), Zn (0.57) and Ca (0.54) fell with the group of slight pollution. The table also revealed that pH (1.15), DO (1.19) and Nitrate (1.03) fell within the category of medium pollution. The table further revealed that BOD (2.98) and Fe (11.86) fell within the categories of heavy pollution and serious pollution respectively. In wet season, the table revealed that salinity (0.05), conductivity (0.07) and Cr (0.13) fell within the group of non-pollution. The also showed that temperature (0.9) and Pb (0.65) fell within the category of slight pollution. Moreover, the table revealed that pH (1.17), DO (1.34), BOD (1.34) and Cd (1.03) fell within the group of medium pollution. The table further showed that Nitrate (2.25), Zn (2.37) and Cu (2.43) fell within the group of heavy pollution. However, Phosphate (15.75) and Fe (45.82) indicated serious pollution.

Table 5: Single-factor pollution index of heavy metals in the surface water of Mahin lagoon and its adjoining creeks (Jun 2019 to April 2021).

Parameters	Dry	Interpretation	Wet	Interpretation
Temperature (ºC)	0.95	Slight pollution	0.9	Slight pollution
Salinity (‰)	0.53	Slight pollution	0.05	Non pollution
Conductivity (µS/cm)	0.85	Slight pollution	0.07	Non pollution
pH	1.15	Medium pollution	1.17	Medium pollution
DO (mg/l)	1.19	Medium pollution	1.34	Medium pollution
BOD (mg/l)	2.98	Heavily polluted	1.38	Medium pollution
Nitrate (mg/l)	1.03	Medium pollution	2.25	Heavily polluted
Phosphate (mg/l)	9.68	Seriously polluted	15.75	Seriously polluted
Sulphate (mg/l)	0.02	Non pollution	0.05	Non pollution
Zinc (mg/l)	0.57	Slight pollution	2.37	Heavily polluted
Lead (mg/l)	1.18	Medium pollution	0.65	Slight pollution
Iron (mg/l)	11.86	Seriously polluted	45.82	Seriously polluted
Copper (mg/l)	0.06	Non pollution	2.43	Heavily polluted
Chromium (mg/l)	0.08	Non pollution	0.13	Non pollution
Cadmium (mg/l)	0.54	Slight pollution	1.03	Medium pollution
Nickel (mg/l)	10.31	Seriously polluted	26.56	Seriously polluted
Cobalt (mg/l)	0.52	Slight pollution	0.89	Slight pollution

Comprehensive Pollution Index (CPI) of the Surface Water of Mahin Lagoon: The comprehensive pollution index (CPI) Mahin lagoon and its adjoining creeks as presented in Table 6. In dry season the CPI values ranged from 2.04 (Ayetoro) to 3.08 (Mahin 4) which indicated severe pollution across the stations with a mean value of 2.52. While in wet season the CPI for wet season ranged from 4.63 (Ayetoro) to 8.43 (Mahin 4) which also indicated severe pollution across the stations with a mean value of 5.98. The comprehensive pollution index revealed that the surface water of Mahin lagoon and its adjoining creeks were severely polluted in both dry and wet seasons (CPI >2).

Table 6: The comprehensive pollution index (CPI) of the surface water of Mahin lagoon and its adjoining creeks (Jun 2019 to April 2021).

Stations	Dry	Classification	Wet	Classification
Mahin 1	2.58	Severe pollution	5.66	Severe pollution
Mahin 2	2.31	Severe pollution	6.01	Severe pollution
Mahin 3	2.47	Severe pollution	6.54	Severe pollution
Mahin 4	3.08	Severe pollution	8.43	Severe pollution
Ugbo	2.39	Severe pollution	5.09	Severe pollution
Ugbonla	2.4	Severe pollution	5.33	Severe pollution
Ayetoro	2.04	Severe pollution	4.63	Severe pollution
Oroto	2.87	Severe pollution	6.16	Severe pollution
Mean	**2.52**	**Severe pollution**	**5.98**	**Severe pollution**

Human health Risk Assessments: Hazard Quotients (HQ dermal and HQ ingestion) of the Surface Water of Mahin Lagoon and its Adjoining Creeks: The Hazard Quotients (HQ dermal and HQ ingestion) obtained for the result of heavy metals parameters tested for water samples collected from Mahin lagoon and its adjoining creeks were presented in Table 7. The mean values of the Hazard Quotients (HQ dermal) for dry season were: Zn (4.92E-03), Pb (4.82E-05), Fe (1.36E-02), Cu (9.17E-04), Cr (3.45E-03), Cd (1.39E-03), Ni (1.43E-02) and Co (3.57E-03) while for wet season the values were: Zn (2.05E-02), Pb (2.67E-05), Fe (5.27E-02), Cu (3.49E-02), Cr (5.61E-03), Cd (2.20E-03), Ni (3.67E-02) and Co (4.83E-03). The HQ (dermal) obtained for all the metals were less than 1 (< 1) across station and season, indicating no risk hazard

quotient to human's health. Likewise, the mean values of the Hazard Quotients (HQ ingestion) for dry season were: Zn (3.04E-04), Pb (9.40E-04), Fe (1.62E-04), Cu (5.10E-05), Cr (6.40E-07), Cd (1.28E-03), Ni (3.30E-04) and Co (4.14E-04). While for wet season the mean values were: Zn (1.26E-03), Pb (5.20E-04), Fe (6.28E-04), Cu (1.94E-03), Cr (1.04E-06), Cd (2.04E-03), Ni (8.49E-04) and Co (7.10E-04). The mean values HQ (ingestion) obtained for all the metals were less than 1 (< 1) across stations and seasons, indicating no risk hazard quotient to human's health.

Table 7: The Hazard Quotients (HQ dermal and HQ ingestion) of the surface water of Mahin lagoon and its adjoining creeks (Jun 2019 to April 2021).

	HQ (dermal)		HQ (ingestion)	
Parameter	**Dry season**	**Wet season**	**Dry**	**Wet**
Zinc	4.92E-03	2.05E-02	3.04E-04	1.26E-03
Lead	4.82E-05	2.67E-05	9.40E-04	5.20E-04
Iron	1.36E-02	5.27E-02	1.62E-04	6.28E-04
Copper	9.17E-04	3.49E-02	5.10E-05	1.94E-03
Chromium	3.45E-03	5.61E-03	6.40E-07	1.04E-06
Cadmium	1.39E-03	2.20E-03	1.28E-03	2.04E-03
Nickel	1.43E-02	3.67E-02	3.30E-04	8.49E-04
Cobalt	3.57E-03	6.15E-03	4.14E-04	7.10E-04

Water is one of the most important and abundant compounds of the ecosystem. All living organisms on earth need water for their survival, growth and development. The physicochemical characteristics of Mahin lagoon and its adjoining creeks showed spatial, monthly and seasonal variations in the parameters. However, quality of the water may be of concern for the beneficial users due to the pollution status revealed by the pollution indices. In the present study, the physic-chemical characteristics of the surface water of Mahin lagoon and its adjoining creek were significantly different ($p<0.05$) across stations and seasons. The temperature (27.79±0.96) fell within the optimal water temperature of 28^0C – 30^0C, within which maximal growth rate, efficient food conversion, best condition of fish, resistance to disease and tolerant to toxins (Pollutants) are enhanced (Ekubo and Abowei, 2011). This was also corroborated by the findings of Loto and Ajibare (2021), who reported the mean temperature of the Lagos lagoon to be 25.33±1.75°C. The average pH, DO, Salinity and conductivity were within the permissible limit, except for the high value of BOD in in both dry and wet seasons, which is an indication of organic pollution in the environment. The values of BOD measured in the water samples were slightly higher than the less or equal to 5 (<or =5mg/l) stated by IEPA (2001) for the protection of aquatic life in unpolluted natural waters but falls within the range observed by Oyhakilome *et al.* (2012), in the Owena multi-purpose dam of Ondo State, Nigeria. The high values obtained in this study for nitrate, phosphate and sulphate could be due an indication of nutrients from agricultural run-off, which was also in accordance with the findings of Lawson, (2011). The study further revealed that Pb, Zn, Cu and Hg had means values were also within the permissible limit, except for Zinc with a value slightly higher than the permissible limit. The single-factor pollution index (Pi) of the surface water of Mahin lagoon and its adjoining creek showed some levels of pollution of the waters, from slight pollution to severe pollution, which could be as a result of anthropogenic activities along the coastal communities. Particularly, nitrate, Zn and Cu indicated heavy pollution only in wet season. While phosphate, Fe and Ni indicated sever pollution in both dry and wet season. However, the comprehensive pollution index (CPI)(which reflects the extent of overall pollution) of the study area revealed that the water was severely polluted with all the values greater than 2 (CPI <2) across stations and seasons. This is in accordance with the report of Yan et. al. (2015), on the identification of polluted risky regions and assessment of water quality based on GIS and field observations in Honghe river watershed, China. This was also corroborated by the findings of Loto and Ajibare (2021), on the pollution assessment of the Lagos lagoon. Despite the fact that the comprehensive pollution index (CPI) revealed that the water was severely polluted, yet through the assessment of human health risk, there was no any hazard quotient associated with the use of the water, whether through dermal or ingestion. This further agreed with the findings of Loto and Ajibare (2021), on Pollution assessment of Lagos lagoon. However, care must be taken to prevent future health risk. The human health risk assessment of the surface water for hazard quotients associated with the corresponding heavy metals revealed that there were no hazard quotient HQ both for dermal or ingestion. Since all the values were less than 1 (HQ < 1) in both dry and wet season.

*Conclusion***:** The physicochemical characteristics of surface water varied significantly across seasons and stations. The mean values of some of the parameters were within the acceptable limits, while some

exceeded the limit. Despite the revealed pollution status of the water, this study revealed no health hazard associated with the usage of the water either through dermal contact or ingestion. Further studies should be conducted to identify specific sources of pollution, monitor and care must be taken to avoid future health risk as a result of continuous pollution of the water.

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