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Evaluation of the Organic Pollution Status of some Rivers in Edo State using Palmer's Pollution Index

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Abstract

Freshwater bodies are susceptible to organic contamination, which is mostly caused by human activities, and these activities can change the composition of the algal community in the receiving water bodies. Physico-chemical evaluation techniques can be quite costly and evaluate water bodies based on a variety of parameters. Biological assessments are sensitive to variations in water quality and provide less expensive options than conventional techniques. Palmer's algal pollution index was used in this study to evaluate the organic pollution condition of ten rivers in Edo State. In October 2020, samples of phytoplankton were taken for study from 10 distinct rivers in Edo State. The samples were examined microscopically and identified using relevant taxonomic texts. Out of the 20 algal genera identified by Palmer, sixteen (16) pollution-tolerant algae genera were implicated in this study. These were distributed between the divisions Bacillariophyta (*Gomophonema*, *Melosira*, *Navicula*, *Nitzchia*, and *Synedra*), Chlorophyta (*Ankistrodesmus*, *Closterium*, *Pandorina*, *Scenedesmus*, and *Stigeoclonium*), Cyanophyta (*Microcycstis*, *Oscillatoria*, and *Phormidium*) and Euglenophyta (*Euglena*, *Lepocinclis*, and *Phacus*). The phytoplankton data were used to calculate Palmer's algal pollution index, and the results revealed that 60% of the sampled rivers were in the confirmed high organic pollution range, 10% were in the probable high organic pollution range, and 30% were in the moderate pollution range. Using QGIS's Inverse Distance Weightage (IDW) Interpolation function, the organic pollution plot for the research area was created based on the findings of Palmer's Algal Pollution Index. Overall, this study showed that the rivers have a high level of organic enrichment and suggested routine river monitoring in order to develop suitable management plans for the preservation of these rivers.

1. Introduction

Aquatic ecosystems are widely affected by a variety of anthropogenic factors resulting from urbanization and human population explosion [1]. This has led to increased generation of wastes which majorly find their way into waterways via intentional disposal into these water bodies or from non-point sources. Freshwater bodies, in particular, are vulnerable to organic pollution, which arises primarily from anthropogenic activities such as industrial discharges, agricultural runoff, and domestic waste disposal.

Organic pollutants, including nutrients, pesticides, and various contaminants, can have detrimental effects on aquatic ecosystems, leading to the degradation of water quality, loss of biodiversity and compromised ecosystem services. So, detecting the organic pollution status of freshwater ecosystems is considered important. Typically, the assessment of the pollution status of water is typically achieved using physical and chemical methods [2]. However, the high cost and large number of parameters are drawbacks. These drawbacks can be overcome by employing biological monitoring which is a scientific and economically valid approach for monitoring programmes to assess water quality [3].

This approach use living organisms or their responses to determine the condition or changes of the environment. Biological monitoring can be a useful tool in assessing the health of freshwater ecosystems as biological communities can integrate variable exposure to pollution over time, thus reflecting the true health of freshwater ecosystems. Additionally, biological communities within these ecosystems can highlight short or long term shifts in water quality by the presence or absence of certain indicator species. Algae are particularly useful for bio-monitoring because of their role as the foundation of most aquatic food webs. Because of their short life spans, rapid reaction to pollutants, and ease of quantification, algae are one of the most rapid bio indicators of water quality changes [4]. Also, as a result of their heightened sensitivity, algae frequently communicate changes in environmental conditions by responding well before effects on higher trophic levels show C

In this study, an algal based pollution index - Palmer's pollution index (PPI) to determine the organic pollution status of some rivers in Edo State. This algal based index has been widely used as an inexpensive method for assessing pollution status of surface freshwaters in several studies [6, 7, 8, 9, 10, 11]. However, there is a dearth of studies on pollution assessment using biological methods like the Palmer's algal pollution index in Edo State. Hence, this study attempts to assess the organic pollution status of ten rivers in Edo State, Nigeria using Palmer's algal pollution index and also predict the organic pollution status of other rivers within the study area boundary using the Inverse Distance Weightage (IDW) Interpolation function of QGIS.

2. Methodology

2.1 Study area

This study cut across ten different rivers within and outside Benin City in Edo State, Nigeria. Benin City is located in the humid tropical rainforest belt of Nigeria and it is drained by three major river systems - Ikpoba River, the Ogba River and Owigie-Ogbovben River systems. The rivers involved in the study include: Ovia River, Ugbogor River, Igue-Edo River, Usen-Ada River, Eruvbi River, Ugonoba River, Okhuaihe River, Ikpoba River, Ikpe River and lastly Ogba River as shown in Figure 1. The catchments of these rivers is marked by the preponderance of anthropogenic activities such as bathing, clothes washing, car washing, fishing, cassava processing, sand mining, cultural worship and industrial effluent discharge.

2.2 Phytoplankton sample collection and analysis

Phytoplankton samples were collected from three stations across the ten rivers in October, 2020 for qualitative and quantitative phytoplankton analysis Qualitative samples were obtained by towing a phytoplankton net with a mesh size of 10µm across the rivers for at least 10 minutes. Quantitative samples were collected in 1L sample jars and concentrated before estimation of the phytoplankton population using the drop count method [12]. Samples were preserved in one milliliter of 40% formalin solution prior to analysis. Microscopic analysis commenced by placing two drop of the sample on a glass-slide with the aid of a dropper and a cover slip was lowered unto it. The prepared slides were viewed under an OLYMPUS compound research microscope and identified using numerous algal reference materials and keys [13, 14, 15, 16, 17, 18, 19, 20, 21, 22].

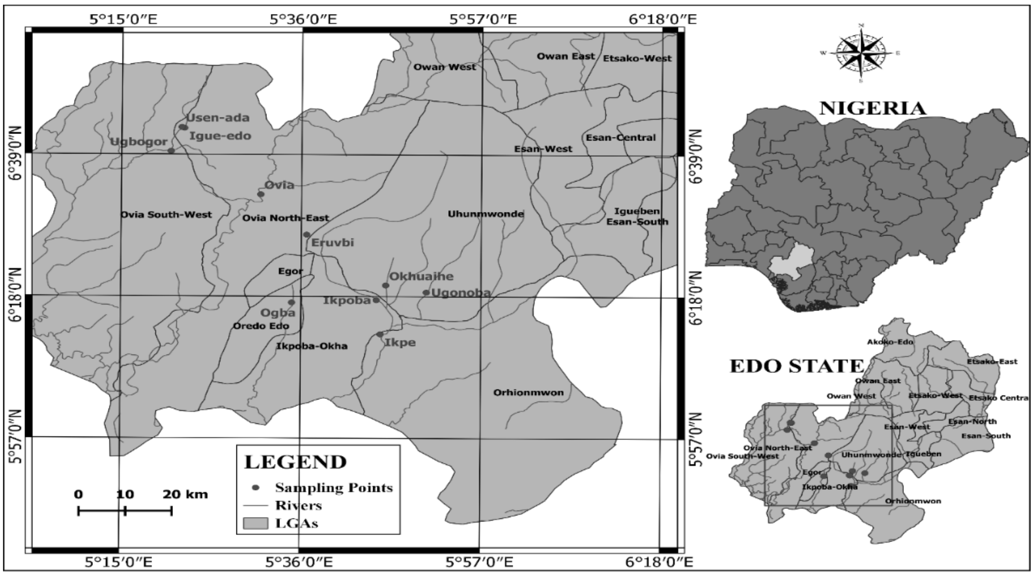

Fig. 1: Map of Study Area showing Sampled Rivers

2.3 Palmer's Algal Pollution Index

Phytoplankton recorded in this study was used in assessing the organic pollution status of the sampled rivers according to Palmer [23]. As indicated by Palmer, pollution tolerant algal genera were recorded if more than 5 individuals per ml were counted during quantitative estimation. A comprehensive rating of algae tolerating organic pollution and their index value as designated by Palmer [23] is depicted in Table 1.

Table 1: **Algal Genus Pollution Index Rating**

S/N	GENUS	INDEX
1	*Ankistrodesmus*	2
2	*Chlamydomonas*	4
3	*Chlorella*	3
4	*Closterium*	1
5	*Cyclotella*	1
6	*Euglena*	5
7	*Gomphonema*	1
8	*Lepocinclis*	1
9	*Melosira*	1
10	*Micratinium*	1
11	*Microcycstis*	1
12	*Navicula*	3
13	*Nitzschia*	3
14	*Oscillatoria*	4
15	*Pandorina*	1
16	*Phacus*	2
17	*Phormidium*	1
18	*Scenedesmus*	4
19	*Stigeoclonium*	2
20	*Synedra*	2

2.4 Inverse Distance Weightage (IDW) Interpolation

The QGIS Desktop version 3.8.2 was used to compute the Inverse Distance Weightage (IDW) Interpolation map and the pollution classification map of the study area using the results from Palmer's algal pollution index calculation.

3. Results and Discussion

3.1. Phytoplankton composition and distribution

Phytoplankton analysis revealed a total of 92 genera distributed within 37 families, 14 orders and 5 classes as shown in Table 2. Overall, the trend in taxa number by division was Bacillariophyta> Chlorophyta> Cyanophyta> Euglenophyta. A similar trend was reported by Iloba [10]. The dominance of Bacillariophyta in similar lotic freshwaters in Edo State has also been reported by Ekhator and Alika [24] and Akhere *et al*. [25].

Table 2: **Phytoplankton assemblage of the Sampled Rivers**

Divisions	Classes	Orders	Families	Genera
Bacillarophyta	Bacillarophyceae	2	17	49
Chlorophyta	Chlorophyceae	7	10	21
	Trebouxiophyceae	1	1	1
Cyanophyta	Cyanophyceae	3	8	15
Euglenophyta	Euglenophyceae	1	1	6
TOTAL	**5**	**14**	**37**	**92**

The spatial distribution of pollution tolerant genera is depicted in Table 3. *Navicula* and *Nitzschia* were the most widely occurring taxa (100% occuirrence) among the diatoms while *Closterium*, *Oscillatoria* and *Euglena* were most widely occurring (70% occurrence) with the Chlorophyta, Cyanophyta and Euglenophyta divisions respectively. The preponderance of *Closterium* and *Oscillatoria* in was similarly documented by Ekhator and Alika [24] in Osse River, Edo State.

3.2. Palmer's Algal Pollution Index

This study implicated 16 pollution tolerant algal genera out of the 20 algal genera designated by Palmer [23]. These were distributed between the divisions Bacillariophyta (*Gomophonema*, *Melosira*, *Navicula*, *Nitzchia*, and *Synedra*), Chlorophyta (*Ankistrodesmus*, *Closterium*, *Pandorina*, *Scenedesmus*, and *Stigeoclonium*), Cyanophyta (*Microcycstis*, *Oscillatoria*, and *Phormidium*) and Euglenophyta (*Euglena*, *Lepocinclis*, and *Phacus*). The results of the computation of Palmer's algal pollution index are depicted in Table 3 and Figure 2.

Table 3: Computation of Palmer's algal pollution index

Algal Genera	**Index Score**	**Eruvbi**	**Igue-Edo**	**Ikpe**	**Ikpoba**	**Ogba**	**Okhuaihe**	**Ovia**	**Ugbogor**	**Ugonoba**	**Usen-Ada**
Microcycstis	**1**	-	-	-	-	-	1	-	-	1	-
Oscillatoria	**4**	4	4	4	4	4	4	4	-	-	-
Phormidium	**1**	1	-	1	-	1	1	-	-	-	-
Chlamydomonas	**4**	-	-	-	-	-	-	-	-	-	-
Pandorina	**1**	-	-	-	1	-	-	-	-	-	-
Scenedesmus	**4**	-	-	-	-	4	-	-	-	-	-
Micratinium	**1**	-	-	-	-	-	-	-	-	-	-
Ankistrodesmus	**2**	-	-	-	2	-	-	-	-	-	-
Chlorella	**3**	-	-	-	-	-	-	-	-	-	-
Closterium	**1**	-	-	1	1	1	1	1	-	1	-
Stigeoclonium	**2**	2	2	-	-	-	-	2	-	-	2
Cyclotella	**1**	-	-	-	-	-	-	-	-	-	-
Melosira	**1**	-	-	1	1	-	-	1	1	-	-
Gomphonema	**1**	-	-	-	1	-	1	1	1	1	1
Navicula	**3**	3	3	3	3	3	3	3	3	3	3
Nitzschia	**3**	3	3	3	3	3	3	3	3	3	3
Synedra	**2**	2	-	2	-	2	-	2	2	2	2
Euglena	**5**	5	-	5	5	5	5	5	5	-	-
Phacus	**2**	-	2	-	-	-	2	-	2	-	-
Lepocinclis	**1**	-	-	-	-	-	1	-	-	-	-

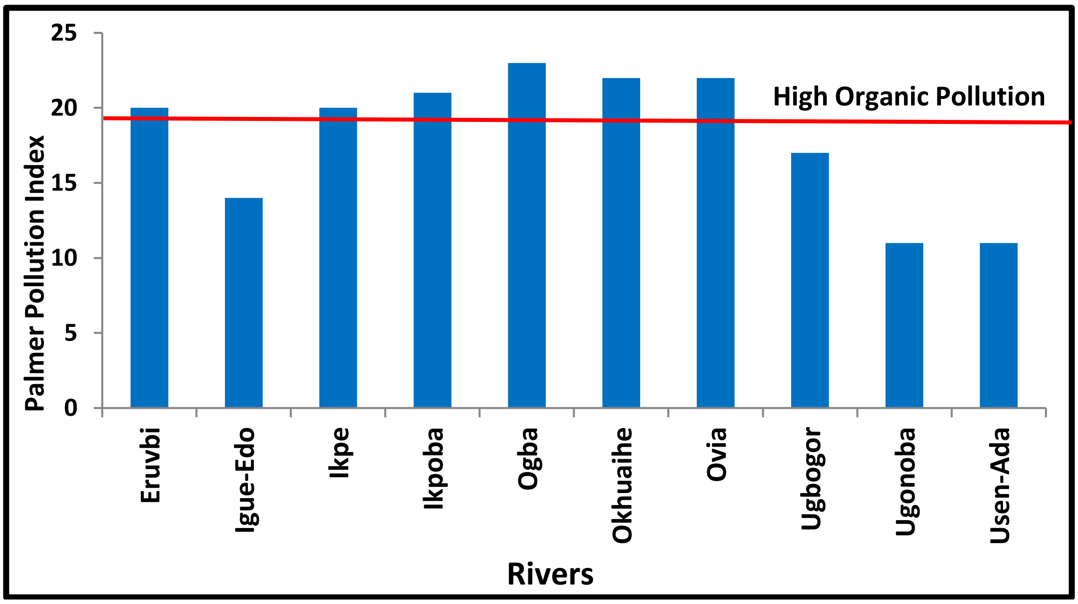

Fig. 2: Palmer's Algal Genera Pollution Index of the Sampled Rivers

According to Palmer's Algal Pollution Index, values between 0-10 indicate lack of organic pollution, 10-15 moderate pollution, 15-20 probable high organic pollution and 20 and above as confirmed high organic pollution. Based on the results of this study, 60% of the algal pollution index values fell in the confirmed high organic pollution range while 20% fell within the probable high organic pollution range and the remaining 20% of the index values represented moderate pollution. Similar studies by Iloba [10] also reported high organic pollution with index scores of 20 – 24, in 66.67% of the studied rivers in Delta State.

Palmer's Pollution index values were indicative of confirmed high organic pollution in all the rivers except in Igue-Edo River, Ugonoba River, and Usen-Ada River with moderate pollution and Ugbogor River with a probable high organic pollution. The highest pollution index score (23) was recorded in Ogba River and this is invariably linked to the presence of *Scenedesmus* in the river and the absence of this taxon in others. Also, the proximity of the river to the Ogba zoological garden and park coupled with the relatively high human traffic experienced by Ogba river and environs, may pose cause some degree of pollution resulting from point and non-point discharge into the river. In Benin City, rivers are widely seen as recipients for waste and effluent discharge and this practice can potentially increase the nutrient load of the receiving water bodies which can potentially alter the biotic community structure in such rivers. Under stressful conditions such as eutrophication, pollution tolerant algae may outcompete sensitive species, thus altering the algal community structure and disrupting the food chain.

Generally, genera like *Oscillatoria*, *Phormidium*, *Scenedesmus Closterium*, *Navicula*, *Euglena*, *Nitzschia*, and *Synedra* were responsible for the high levels of organic pollution recorded in this study as their presence is indicative of organic pollution as maintained by Palmer [23]. Palmer [23] had shown that phytoplankton genera such as *Oscillatoria*, *Navicula*, *Nitzschia*, *Euglena*, *Phacus* and *Ankistrodesmus* were found in organically polluted water and this is further reinforced by this present study, Kshirsagar [26] Salem *et al*. [1] and Iloba [10].

The organic pollution classification of the sampling points based on the spatial variation in Palmer's pollution index for the ten rivers is portrayed in figure 3.

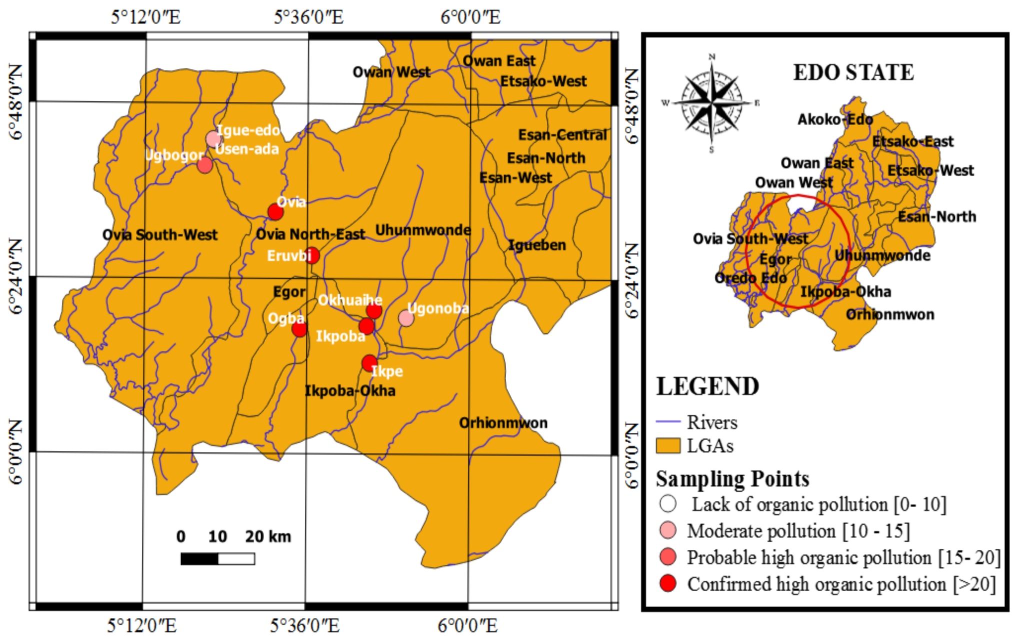

Figure 3: Thematic map of the organic pollution status of the different rivers

3.3. Inverse Distance Weightage (IDW) Interpolation

The pollution index score obtained for the ten rivers were utilized to compute the IDW Interpolation map (Figure 4) so as to predict the level of organic pollution of other rivers/areas within the study area boundary.

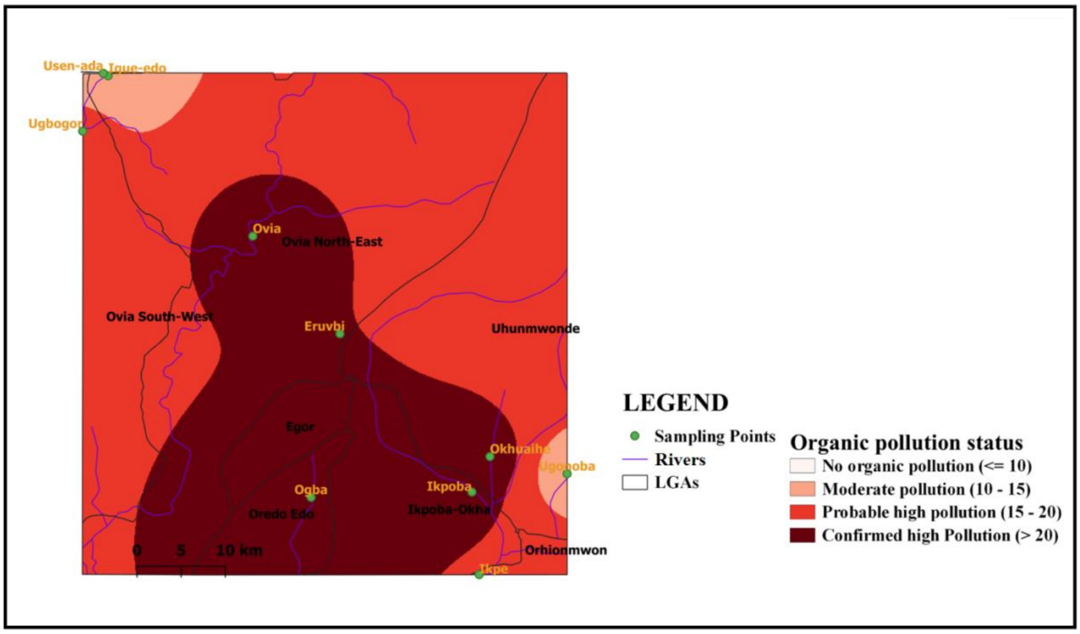

Figure 4: Inverse Distance Weightage (IDW) Interpolation map of the study area

It can be inferred from the map that areas around Usen-Ada River, Igue-Edo River and Ugonoba River will have moderate organic pollution while the areas surrounding Ovia River, Eruvbi River, Ogba River, Ikpoba River and Okhuaihe River will have confirmed high pollution. Ugbogor River on the other hand was found to fall under the probable high pollution area of the map. These results are in congruence with the results of the Palmer's pollution index. Furthermore, two local government areas namely Oredo and Egor fell entirely within the confirmed high pollution region of the map with the implication that rivers within these local governments will probably have confirmed high organic pollution. This is quite understandable as these two local government areas are located in the city center of Edo State and consequently are prone to anthropogenic influx of nitrogenous waste from industrial effluent, drainage pipes, urban discharge and domestic sewage systems which culminate to high organic pollution and eutrophication.

4.0 Conclusion

In conclusion, it can be inferred from this study that various degree of organic pollution exists in all the rivers. This study further reinstates the significance of algae in pollution assessment of water bodies and the pivotal role of predictive models like the Inverse Distance Weightage (IDW) Interpolation in water pollution assessment studies.

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