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ASSESSMENT OF PHYSICOCHEMICAL WATER QUALITY INDICATORS IN POLLUTED AQUATIC ECOSYSTEMS

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Abstract
Anthropogenic activities are causing environmental pollution to aquatic ecosystems and this type of pollution has the potential to alter the water quality and stability of the ecosystem considerably. The analysis of physicochemical indicators and toxic pollutants is thus needed to study the dynamics of pollution in the water bodies. The current research examined the parameters of physicochemical water quality and heavy metals in the water bodies of aquatic ecosystems based on a dataset of 1000 observations taken in five sites of monitoring. The important parameters analyzed were the pH, turbidity, temperature, dissolved oxygen, biochemical oxygen demand, and the concentrations of lead, mercury and arsenic. Descriptive and comparative analyses have been done to assess the variability of water quality indicators and how each of them is associated with the level of pollution at the monitoring sites. The findings indicated that the water conditions were mostly neutral and slightly alkaline with a mean pH of 7.25 and an average turbidity of 10.22 NTU, which is a range of suspended solids. Dissolved oxygen was 5.93 mg/L and biochemical oxygen demand was 5.48 mg/L, which indicated moderate conditions of organic pollution. The traces of heavy metals were also detected in different locations, which indicates a possible level of contamination in the observed environments. The combination of the analysis of physicochemical indicators and metal content gave a full picture of the pollution trend and the environment. These indicators should be closely kept and monitored continuously to help in the sound management of the environment and the health of aquatic ecosystems.

Keywords: *Aquatic Ecosystems, Water Quality Indicators, Heavy Metal Contamination, Physicochemical Parameters, Aquatic Pollution Monitoring*

1. Introduction

Aquatic ecosystems are significant elements of the natural habitat and they provide crucial ecological services comprising of nutrient recycling, habitat creation and maintenance of biodiversity. The ecosystems are also important to sustain the human livelihoods through water, fisheries, agriculture and recreational services. However, in the presence of high rate of industrialization, population explosion, urban settlement, and aggravated farming activities, there is a tremendous burden on freshwater systems all over the world. As a result, there is increased levels of pollution of most rivers, lakes and other water bodies that are threatening the ecosystem and sustainability of water resources. These ecological problems include pollution caused by the suspended solids, organic and heavy metals that have been reported as the most serious factor in the decline of the water quality of the aquatic environments [1].

Physicochemical parameters have been widely adopted as significant parameters in the determination of the water quality and environmental conditions of water bodies. Parameters such as pH, turbidity, temperature, dissolved oxygen (DO) and biochemical oxygen demand (BOD) play an important role in the determination of significant information on the water bodies' chemical and physical characteristics. These indicators help the researcher and the environmental managers in defining the causes of the pollution, evaluating the ecological condition and monitoring the evolution of the environment over time. To illustrate this, the dissolved oxygen rate may be used to determine the presence of organic pollution and activities and turbidity may be used to determine the presence of suspended particles in the water by natural processes or as a result of human activities. Therefore, an organized analysis of physicochemical pointers has become an important tool of defining the environmental state of aquatic ecosystems and establishing the potential risks of pollution [2].

Along with the physicochemical indicators, the heavy metal pollution has been a major environmental concern in most of the freshwater systems. Of particular concern are the metals like lead, mercury, and arsenic, which may remain within the aquatic environment over a long period, accumulating in the sediments, aquatic organisms and food chains. These pollutants are usually industrial effluent, mining, agricultural effluent, and urban effluent. Heavy metals, after being dumped into the water bodies, can lead to ecological toxicity and can also be a risk to the health of human beings due to contaminated water sources or through the consumption of aquatic food [3]. It is already demonstrated that heavy metal contamination may have a significant impact on the water quality and the functioning of ecosystem, which is why it is necessary to monitor and evaluate metal concentrations in the water on a regular basis [4].

A number of recent studies have reported the importance of the application of the physicochemical indicators and the heavy metal analysis in the determination of pollution of water in the freshwater systems. In order to give an example, the study of the water quality of rivers has shown that the rates of heavy metals concentration along with the states of physicochemical indicators could present the more detailed vision of the processes of pollution and environmental risks [5]. Similarly, the studies that have been carried out in various water bodies have shown that human-induced activities are likely to raise the levels of metals and distorted values of water quality that equally affects the ecological balance of aquatic habitats [6]. These findings help to highlight the fact that; water quality assessment involves a multidimensional response which involves chemical indicator and toxic contaminants.

Another recent research has also investigated the spatial and temporal distribution of heavy metal in freshwater ecosystems and rivers. The results of these studies have shown that the levels of pollution may vary greatly at different locations of monitoring; this has been attributed to the difference in the environmental conditions, the land-use processes and human activities [7]. The studies on the contaminated water bodies, including the mining-affected areas and riverbeds within cities, have demonstrated the fact that the distribution structures of the heavy metals might be extremely influential on the overall water quality and ecological risks [8]. These geographical disparities are therefore worth knowing to identify the hotspots of pollution and develop effective policies concerning the environmental control.

As a result of the growing concern surrounding the problem of water pollution, several research studies have been carried out in the measurement of the quality of water using the integrated indices and pollution evaluation methods. Indicatively, one study has found out that a syndromic analysis of physicochemical indicators and heavy metal concentration can be applied to determine the intensity of pollution and help determine the remediation efforts in polluted river systems [9]. Similarly, assessments on the tropical freshwater systems have also emphasized that it is necessary to monitor different parameters of water quality as a technique of protecting aquatic life in addition to the important role of ensuring safe water resource that is used by humans [10].

Although the literature on aquatic pollution is growing rapidly, it is still necessary to have detailed studies that would assess a variety of physicochemical indicators and the heavy metal pollutants at the same time and across the monitoring sites. Most past studies were either on individual parameters of water quality or on individual pollutant of interest, which can be restrictive in the general interpretation of environmental pollution processes. A more united evaluation method is hence required so as to give a better picture of the pollution modes and the state of the environment that influence aquatic ecosystems.

Here, the current research will consider the assessment of physicochemical water quality parameters and contamination of heavy metals in the water bodies to gain a clearer insight into the trends of pollution and environmental status. The investigation of several indicators and pollution rates in various monitoring points is a contribution to the overall knowledge of the process of water quality and helps to design better methods of monitoring the environment and managing it.

Objectives of the Study

1. To evaluate key physicochemical water quality indicators and heavy metal concentrations in aquatic ecosystems in order to assess pollution conditions and environmental status.
2. To examine the relationships between water quality parameters and pollution levels across monitoring locations to understand spatial patterns of aquatic pollution.

2. Materials and Methods

2.1 Study Design

This was a quantitative observational study that used physicochemical parameters of water quality to measure pollution in water bodies. The data on water quality measurements performed at various monitoring points were analyzed to determine the patterns of environmental pollution and the state of ecosystems. The approach aimed at examining the main physicochemical parameters which are usually applied to assess the aquatic pollution and environmental contamination. It was observed that variations in water quality indicators and pollution status were identified using observational data, which represented various sampling locations and time points. Such a design allowed assessing in an orderly manner the physicochemical properties linked to contaminated aquatic systems and aided interpretation of the environmental factors influencing the ecological well-being of the ecosystem.

2.2 Dataset Description

The sample size analyzed in the model was 1000 data on the measurement of water quality in five aquatic monitoring locations [11]. Each observation consisted of the physicochemical parameters and the concentrations of heavy metal which were utilized in order to determine the pollution conditions in aquatic ecosystems. Such variables as measurement time, at which the sample was taken, pH, turbidity, water temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), lead level, mercury level, arsenic level, as well as an indicator of the extent of pollution characterised the data set. These were significant environmental factors that were normally utilized in the water quality monitoring and pollution evaluation study. The data was a complete sample of physicochemical conditions that prevailed in different aquatic locations.

2.3 Water Quality Indicators
Various physicochemical indicators were evaluated in order to establish pollution degree in aquatic environments. The indicators included: the pH, turbidity, temperature, dissolved oxygen (DO), the biochemical oxygen demand (BOD) which are highly used in assessing the conditions of the water quality and ecology in the water body. The heavy metal levels, including lead, mercury, and arsenic were also taken to establish the potential pollution of the anthropogenic sources of contamination. Such parameters were vital in terms of chemical parameters, degree of organic pollution and toxic pollution of water bodies. The analysis of these indicators in general allowed defining the general state of physicochemical factors, the impact of which on the well-being of aquatic ecosystems.

2.4 Data Preparation
It was verified that the data was complete, consistent and suitable in the analysis of the environment. The entire observations involving water quality and pollution indicators were organized depending on the sampling site and sampling time. The variables were also explored to test potential inconsistency and also ensure that all physicochemical indicators were well represented in the data. The observations were summarized in terms of location of observation so that a comparative analysis of the water qualities conditions could be done. This was then accompanied with the generation of descriptive summaries which explained the distribution of physicochemical parameters and heavy metal concentrations across different aquatic monitoring locations which formed the study.

2.5 Analytical Approach
The method of analysis was aimed at analyzing physicochemical water quality parameters and its correlation with pollution condition in water bodies. The distribution and variability of the physicochemical parameters in the dataset were analyzed by descriptive statistical summaries. A comparative assessment was done to determine the variations in water quality indicators between the locations of monitoring. The samples of heavy metals were analyzed to determine the possible patterns of contamination. Moreover, the association between physicochemical variables and the levels of pollution were assessed to establish the extent to which environmental indicators depicted the state of pollution in the aquatic ecosystems. These studies gave a combined insight into the dynamics of physicochemical pollution.

2.6 Environmental Interpretation
These results were explained with references to the environmental bioscience and health of aquatic ecosystem. Alteration in physicochemical status and heavy metals concentrations served to actualize the meaning on pollution condition in water bodies. The changes in the parameters of turbidity, dissolved oxygen and biochemical oxygen demand were considered to be the indicators of the stress in the environment and the intensity of the pollution. The presence of heavy metals was viewed as the signifier of the potential anthropogenic pollution of the quality of water. The synthesis of physicochemical indicators and the degree of the pollution provided the research with the information on the environmental situation and the changing trends of the pollution, which is leading to the instability of aquatic ecosystems.

3. Results

3.1 Descriptive Characteristics of Water Quality Indicators
The dataset contained 1000 records of physicochemical water-quality measures in five aquatic monitoring sites. Table 1 summarizes the descriptive characteristics of these indicators. The average pH was 7.25 with a standard deviation of 1.02 with the minimum reading of 5.52 and the highest reading of 8.99, which showed that the water was generally neutral but slightly alkaline. The turbidity ranged between 0.50 and 19.97 NTU, and the average was 10.22 NTU, indicating a variation in suspended particulate matter. The average temperature of the water was 24.97 °C, with a range, 15.00 °C to 34.99 °C. Biochemical oxygen demand averaged 5.48 mg/L and dissolved oxygen averaged

5.93mg/L, indicating moderately good conditions of organic pollution in the monitored aquatic environments.

Table 1. Descriptive statistics of physicochemical water quality indicators in aquatic ecosystems

Parameter	Mean	Standard Deviation	Minimum	Maximum
pH	7.25	1.02	5.52	8.99
Turbidity (NTU)	10.22	5.63	0.50	19.97
Temperature (°C)	24.97	5.76	15.00	34.99
Dissolved Oxygen (mg/L)	5.93	2.29	2.00	9.98
Biochemical Oxygen Demand (mg/L)	5.48	2.60	1.01	9.99
Lead (mg/L)	0.00996	0.0057	0.00013	0.01999
Mercury (mg/L)	0.00098	0.00057	0.00001	0.00199
Arsenic (mg/L)	0.00986	0.0055	0.00051	0.01992

3.2 Heavy Metal Contamination in Aquatic Ecosystems

The heavy metal levels were found in all the monitoring sites, which showed that contamination is possible in the aquatic systems. The average concentration of lead was 0.00996 mg/L, and the levels of mercury were 0.00098 mg/L, with the range being 0.00001mg/L to 0.01992 mg/L (Table 2). These findings reveal the existence of trace heavy metals in the sampled water bodies and denote the possibility of environmental pollution, which could affect the quality of the ecosystems and the environmental health in the long-term.

Table 2. Distribution of heavy metal concentrations in aquatic ecosystems

Heavy Metal	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
Lead	0.00996	0.00013	0.01999
Mercury	0.00098	0.00001	0.00199
Arsenic	0.00986	0.00051	0.01992

3.3 Variation in Water Quality Across Monitoring Locations

The indicators of water quality showed moderate changes throughout the five monitoring sites. There were 210 observations in location L1, 190 observations in location L2 and L3, 206 observations in location L4 and 204 observations in location L5. The highest values of average turbidity were L2 (10.88 NTU) and L5 (10.87 NTU), whereas L3 had lower values of turbidity (9.13 NTU). Table 3 shows that the mean biochemical oxygen demand was 5.26 mg/L at L3, and 5.65mg/L at L1. This indicated some spatial variation in dissolved oxygen with the highest mean DO (6.07mg/L) in L5 and 5.85mg/L in L4, meaning that there is a slight difference in aquatic pollution indicators between sites.

Table 3. Distribution of observations across monitoring locations

Location	Number of Observations
L1	210
L2	190
L3	190
L4	206
L5	204
Total	**1000**

3.4 Relationship Between Water Quality Indicators and Pollution Levels

There were three types of pollution, with 915, 79, and 6, respectively, being pollution level 2, level 1, and level 0. Overall, the average pollution was 1.91 ± 0.31, which means that the largest number of observations were related to high pollution status. The records of increased levels of pollution were usually recorded with increased turbidity parameters averaging approximately 10.22 NTU and biochemical oxygen demand averaging 5.48 mg/L, as indicated in Table 4. Dissolved oxygen levels on the other hand were 5.93 mg/L in average indicating a propensity towards depletion of oxygen in a more polluted environment. These trends indicate that there is a connection between physicochemical indicators and pollution levels in water bodies.

Table 4. Distribution of observations across pollution levels

Pollution Level	Number of Observations
0	6
1	79
2	915

3.5 Overall Assessment of Aquatic Pollution Status

The combined analyzes of physicochemical indicators gave a general picture of the pollution trend in the sampled aquatic ecosystems. The variability of turbidity (0.50 to 19.97 NTU) and moderate levels of dissolved oxygen (2.00 to 9.98 mg/L) and biochemical oxygen demand (1.01 to 9.99 mg/L) also showed that there was a variation in the level of environmental stress among water bodies. The heavy metal levels, such as lead (0.00996 mg/L mean) and arsenic (0.00986 mg/L mean), also attested the occurrence of contamination across the sites. In general, the dataset was indicating that most observations were related to moderate to high levels of pollution, indicating the environmental pressures on the quality of the aquatic ecosystem.

4. Discussion

The present study was used to evaluate physicochemical indices of water quality and the concentration of heavy metal to obtain the picture of the trend pollution in water ecosystems. The descriptive analysis showed that the levels of pH were generally held in nearly neutral conditions, which suppressed the fact that extreme acidity and alkalinity did not develop as a significant stressor in the environments observed. Nonetheless, the turbidity figures were important and appropriate since they revealed change in suspended matter and potential causes of pollution in the various locations. The biochemical oxygen demand was 5.48 mg/L and the average of dissolved oxygen was 5.93 mg/L which indicated a moderate level of pressure of organic pollutant in the waters. The presence of lead, mercury and arsenic will also show that there is a trace metal contamination, which may be brought about by anthropogenic sources such as industrial and agricultural discharge or urban wastewater. Overall, these trends in turbidity, oxygen demand, and metal values indicate that the physicochemical indicators could provide much data about the amount of environmental stresses on the water ecosystems.

The trends in this research are in line with other studies which have revealed the correlation between physicochemical parameters and the dynamics of aquatic pollution. A comparable research carried out in investigating the presence of heavy metal pollution in the river Ravi showed that high levels of metals were linked with pollution of the environment and ecological hazards [12]. The studies devoted to monitoring datasets of freshwater ecosystems have also shown the significance of using physicochemical indicators along with assessments of heavy metals to analyze the level of aquatic pollution efficiency [13]. The studies of drinking water sources in relation to the environmental alterations showed that the amounts of heavy metals may largely impact the quality of water and environmental protection [14]. The analysis of riverine systems has also validated the view that turbidity, biochemical oxygen demand, and heavy metal contamination are usually used as the most significant events of the pollution levels in water bodies [15]. Further studies examining megacity river systems revealed that anthropogenic processes may be the cause of spatial variability in distribution of heavy metals and water quality situations [16]. The overall impact of these researches is to recommend the significance of physicochemical monitoring as one of the most important methodologies of evaluating water body contamination.

Despite the fact that the present analysis has provided certain understanding, certain limitations have to be acknowledged. First, it was primarily physicochemical indicators and heavy metal information, and not a set of biological parameters, such as microbial diversity, aquatic organisms, or ecological communities responses. This implied that the study focused more on the environmental signalers rather than the real biological impacts on the water on aquatic life. Second, the data was not extended over a long period, and it does not allow concluding on the long-term tendencies in the environment or any seasonal changes in the pollution rates. Thirdly, the analysis has been grounded on the monitoring variables which were available and could not consider other variables in the environment, such as hydrology, land use patterns, and the sources of the pollution. These limitations represent the fact that further studies that would imply the application of a broader range of environmental and biological variables can provide a more comprehensive understanding of the mechanisms of aquatic ecosystem pollution. This study can be applied to make important conclusions on the environmental bioscience and water resources management. The results suggest that, physicochemical indicators, in combination with the measurements of the heavy metals, present a convenient and effective methodology of establishing the nature of the pollution in water. Turbidity, dissolved oxygen, biochemical oxygen demand and metal concentrations are the most common parameters that are observed since they allow the researcher and environmental managers to create vision of the initial signs of an ecology experiencing stress and the likelihood of contamination. Further, the complex of different indicator results enables conducting a more comprehensive examination of the condition of the environment within aquatic ecosystems. These findings prove the relevance of frequent water quality management efforts, particularly in the regions where anthropogenic pressure is growing. The stress on the implementation of monitoring strategies and the introduction of environmental assessment could contribute to the improvement of the action with regard to pollution control and assist in enhancing the health of the aquatic ecosystem.

5. Conclusion

Assessment of parameters of physicochemical water quality and the level of heavy metals provided useful data on the degree of pollution in aquatic life. Significant fluctuations in the parameters of turbidity, dissolved oxygen and biochemical oxygen demand were observed thereby demonstrating that there were movements in suspended matter, organic pollution as well as oxygen levels between points of monitoring. These are the indicators that are known very well to be good indicators of environmental stress of the aquatic environment. Moreover, the observation of such heavy metals as lead, mercury, and arsenic shows that anthropogenic processes are possible, and the situation can be deteriorated due to the contamination that can affect the ecological sustainability and the quality of water. The combined analysis of several physicochemical indicators and concentrations of heavy metals provided a holistic view of the dynamics of pollution of the aquatic environment. In this way, the detection of environmental conditions can be more detailed as opposed to the assessment using the single indicators. The interaction effect of various water quality variables gives useful information in determining patterns of pollution and assessing the ecological status of aquatic environments. Sustainability of aquatic ecosystems encompasses the need to maintain sustainable aquatic ecosystems through constant monitoring and good environmental management practices. Frequent monitoring of physicochemical indicators and the level of contaminants may help to identify the initial symptoms of the negative impact on the environment and take the necessary steps to control the level of pollution. Enhancing surveillance systems and encouraging sustainable environmental measures are thus necessary measures towards conserving water resources and contributing to sustainability in the ecosystem.

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