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Assessment of Wastewater Quality Through Physicochemical Parameters and Its Environmental Impact

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ABSTRACT

Wastewater pollution has emerged as one of the most significant environmental challenges worldwide due to the rapid growth of urban populations, industrial development, and intensified agricultural practices. Large quantities of wastewater generated from domestic households, industries, and agricultural fields are often discharged into natural water bodies without adequate treatment. This contaminated water contains a variety of pollutants, including organic matter, nutrients, suspended particles, toxic chemicals, and heavy metals, which can significantly alter the physical and chemical characteristics of aquatic ecosystems. As a result, monitoring and evaluating wastewater quality has become an essential aspect of environmental protection and water resource management within the field of Environmental Chemistry.The assessment of wastewater quality is commonly carried out by analyzing a range of physicochemical parameters that provide valuable information about the level of contamination present in the water. Important parameters include pH, temperature, electrical conductivity (EC), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and dissolved oxygen (DO). Each of these indicators reflects different aspects of water quality and pollution levels. For instance, pH indicates the acidity or alkalinity of water, while electrical conductivity represents the concentration of dissolved ions. Similarly, BOD and COD are important indicators used to determine the amount of biodegradable and chemically oxidizable organic matter present in wastewater.Elevated concentrations of BOD and COD suggest a high presence of organic pollutants, which require large amounts of oxygen for decomposition by microorganisms. This process can significantly reduce dissolved oxygen levels in water bodies, creating unfavorable conditions for aquatic organisms such as fish, algae, and other microorganisms. Additionally, high levels of TDS and TSS can reduce water clarity, interfere with photosynthesis in aquatic plants, and contribute to sediment accumulation in rivers and lakes.Therefore, systematic evaluation of these physicochemical characteristics is essential for understanding the extent of wastewater contamination and its potential environmental consequences. Effective wastewater treatment technologies, regular monitoring programs, and strict environmental regulations are necessary to minimize pollution and protect both ecosystem health and human well-being

Keywords: *Wastewater, Physicochemical parameters, Water pollution, BOD, COD, Environmental impact.*

INTRODUCTION

Water is one of the most fundamental natural resources on Earth and plays a crucial role in sustaining life, maintaining ecological balance, and supporting socio-economic development. All living organisms depend on water for survival, and it also serves as an essential component in agricultural production, industrial processes, and domestic activities. Healthy aquatic ecosystems rely on clean and balanced water conditions to support biodiversity and natural biochemical cycles. However, with the rapid expansion of human activities over the past few decades, water resources across the globe have been subjected to increasing levels of contamination. One of the major contributors to this problem is the discharge of untreated or poorly treated wastewater into natural water bodies.Urbanization, industrial development, and population growth have significantly increased the generation of wastewater. As cities expand and industries grow, the volume of domestic sewage, industrial effluents, and agricultural runoff entering the environment also rises. In many developing regions, wastewater treatment infrastructure is either insufficient or poorly managed, resulting in large quantities of untreated effluent being released directly into rivers, lakes, and groundwater systems. Such practices lead to the deterioration of water quality and pose serious risks to ecosystems, human health, and sustainable water management.Wastewater is a complex mixture containing a wide range of substances. These include organic materials such as proteins, carbohydrates, fats, and other biodegradable compounds derived from domestic and industrial activities. In addition, wastewater may contain inorganic chemicals, nutrients such as nitrogen and phosphorus, suspended solids, heavy metals, and potentially toxic substances. When these pollutants enter natural water bodies, they can significantly alter the physical, chemical, and biological characteristics of water. Over time, this contamination can lead to long-term environmental degradation and disrupt the natural balance of aquatic ecosystems.

Environmental chemistry plays a critical role in understanding and evaluating the quality of wastewater and its impact on the environment. Wastewater analysis involves the identification and measurement of various pollutants present in water samples. By determining the concentration of contaminants and evaluating their chemical behavior, scientists and environmental researchers can assess the level of pollution and identify potential ecological risks. This information is essential for developing effective wastewater treatment strategies and for implementing environmental protection policies.To evaluate wastewater quality, researchers commonly analyze a series of physicochemical parameters that provide important information about the condition of the water. These parameters include pH, temperature, electrical conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total solids. Each of these indicators reflects specific characteristics of the water and helps determine the extent of contamination. Together, they provide a comprehensive understanding of the overall quality and pollution level of wastewater.

The pH of water indicates its acidity or alkalinity and plays an important role in chemical reactions occurring in aquatic systems. Extreme pH values can harm aquatic organisms and influence the solubility and toxicity of various chemical substances. Temperature is another important factor that affects biological and chemical processes in water, including microbial activity and oxygen solubility. Electrical conductivity reflects the concentration of dissolved ions and salts present in water, which may originate from industrial discharges, agricultural runoff, or domestic wastewater.Dissolved oxygen is one of the most critical parameters for assessing water quality because it is essential for the survival of aquatic organisms such as fish, algae, and microorganisms. Adequate oxygen levels support healthy biological processes, whereas low oxygen concentrations can create stressful or lethal conditions for aquatic life. The presence of excessive organic pollutants in wastewater can significantly reduce dissolved oxygen levels through microbial decomposition processes.

Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are two widely used indicators for measuring the level of organic pollution in wastewater. BOD represents the amount of oxygen required by microorganisms to break down biodegradable organic matter present in water under aerobic conditions. High BOD values indicate that large quantities of biodegradable organic substances are present, which require oxygen for decomposition. COD, on the other hand, measures the total amount of oxygen required to chemically oxidize both biodegradable and non-biodegradable organic compounds in water. Together, BOD and COD provide valuable insight into the organic load and pollution intensity of wastewater.Elevated levels of BOD and COD are often associated with significant environmental problems. When wastewater containing high concentrations of organic matter enters natural water bodies, microorganisms begin to decompose these materials. During this process, large amounts of dissolved oxygen are consumed. As oxygen levels decline, aquatic organisms may experience stress or suffocation, leading to reduced biodiversity and, in severe cases, massive fish kills. Oxygen depletion also encourages the growth of anaerobic microorganisms that produce foul-smelling gases such as hydrogen sulfide and methane, further degrading water quality.

In addition to BOD and COD, the presence of total solids including suspended solids and dissolved solids also plays an important role in determining wastewater quality. Suspended particles can reduce light penetration in water, affecting photosynthesis in aquatic plants and algae. Excessive solids may also clog fish gills, disrupt aquatic habitats, and accumulate as sediments that alter the structure of water bodies. Dissolved solids, on the other hand, may include salts, minerals, and other chemical compounds that influence water taste, hardness, and overall chemical stability.The assessment of these physicochemical parameters is therefore essential for monitoring wastewater pollution and understanding its environmental implications. Regular analysis helps identify sources of contamination, evaluate the efficiency of wastewater treatment processes, and ensure that discharged water meets environmental standards. Furthermore, such studies provide valuable data that can guide policymakers and environmental managers in designing strategies for pollution control and sustainable water resource management.In this context, the present study focuses on evaluating wastewater quality through the analysis of key physicochemical parameters. By examining factors such as pH, temperature, electrical conductivity, dissolved oxygen, BOD, COD, and total solids, the study aims to determine the level of contamination present in wastewater samples. In addition, the research seeks to understand the potential environmental impacts associated with these pollutants and their influence on aquatic ecosystems. The findings of this study may contribute to a better understanding of wastewater pollution and support efforts to improve water quality monitoring and environmental protection measures.

2. Literature Review

Wastewater pollution has become a critical environmental concern worldwide due to rapid industrialization, urbanization, and population growth. The discharge of untreated or inadequately treated effluents into water bodies introduces a variety of pollutants, including organic matter, salts, heavy metals, and suspended solids, which collectively deteriorate water quality and disrupt aquatic ecosystems. Physicochemical analysis of wastewater has emerged as a fundamental approach to evaluate the degree of contamination, identify potential sources of pollution, and assess the environmental risks associated with effluent discharge. Several studies have highlighted the significance of key parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, electrical conductivity, nitrates, and sulphates in understanding the extent of pollution in wastewater.A number of investigations conducted in industrial zones have demonstrated that wastewater in these areas often contains elevated levels of pollutants. For instance, research conducted in industrial regions revealed that wastewater samples exhibited high concentrations of pH, BOD, COD, and total solids. These findings indicate severe pollution primarily resulting from industrial activities, such as chemical manufacturing, textile processing, and food processing industries. Elevated BOD and COD levels suggest a high load of organic matter and biodegradable pollutants in the wastewater. High organic content in water accelerates microbial activity, which in turn consumes dissolved oxygen, reducing oxygen availability for aquatic life. This reduction in dissolved oxygen can cause hypoxic conditions, leading to stress or mortality in sensitive aquatic species, and subsequently disrupt the ecological balance of the water body. The researchers concluded that untreated industrial effluents significantly degrade water quality and must undergo effective treatment before being discharged into rivers or lakes to prevent long-term environmental damage.

Similarly, studies on wastewater stabilization ponds have provided insight into the dynamics of organic pollutant removal and water quality in treatment systems. One investigation reported influent wastewater with BOD values ranging from 48 to 209 mg/L and COD values between 110 and 365 mg/L. These elevated values reflect the presence of high concentrations of organic matter and biodegradable pollutants. Such organic loading emphasizes the potential stress imposed on receiving water bodies if the wastewater is released without adequate treatment. Stabilization ponds rely on microbial decomposition and natural processes to reduce organic pollutants, but their efficiency can be limited if the influent contains extremely high pollutant concentrations. This underscores the importance of regular monitoring of wastewater parameters to ensure treatment systems are capable of handling pollution loads effectively.

Research conducted in India has further highlighted the prevalence of wastewater contamination in industrial and urban areas. Analysis of samples from industrial sites revealed that several parameters, including pH, electrical conductivity, nitrate, sulphate, TDS, and TSS, exceeded permissible limits established by environmental regulatory authorities. Elevated pH levels indicate alkaline or acidic conditions, which can affect both aquatic life and the chemical characteristics of receiving water bodies. High electrical conductivity reflects a significant concentration of dissolved ions, often associated with salts, heavy metals, and other inorganic pollutants. Increased nitrate and sulphate concentrations are indicative of nutrient pollution, which can promote excessive algal growth and eutrophication in surface waters. Elevated TDS and TSS levels further signify the presence of suspended and dissolved solids that interfere with photosynthesis in aquatic plants, reduce water clarity, and contribute to sedimentation in riverbeds and reservoirs. Collectively, these findings demonstrate that industrial and urban activities act as major pollution sources, with direct implications for environmental and public health.

The observed physicochemical characteristics of wastewater have important implications for aquatic ecosystems. High BOD and COD levels lead to oxygen depletion, which can create stressful conditions for fish and other aquatic organisms. Reduced dissolved oxygen can result in fish kills, loss of biodiversity, and alteration of food web structures in affected water bodies. Similarly, elevated TDS and electrical conductivity affect water salinity and ionic balance, potentially impacting freshwater organisms that are sensitive to changes in ionic composition. Suspended solids reduce light penetration and inhibit photosynthesis, affecting primary productivity in aquatic ecosystems. Additionally, the presence of nitrates, phosphates, and sulphates can trigger eutrophication, resulting in algal blooms, the formation of hypoxic zones, and further deterioration of water quality. These combined effects illustrate the complex interactions between various physicochemical parameters and highlight the need for comprehensive monitoring to identify pollution sources and assess ecological risks accurately.Monitoring wastewater quality through physicochemical analysis is also essential for designing appropriate treatment strategies. The parameters studied BOD, COD, TDS, TSS, pH, nitrates, sulphates, and conductivity provide insight into the type and concentration of pollutants present in the effluent. High BOD and COD values indicate the need for biological treatment processes, such as activated sludge systems, biofilters, or stabilization ponds, to reduce organic loads. Elevated TDS and conductivity may require additional treatment steps, including membrane filtration, ion exchange, or reverse osmosis, to remove dissolved salts and heavy metals. High TSS levels necessitate sedimentation, filtration, or coagulation processes to remove particulate matter before discharge. By assessing these parameters, engineers and environmental managers can select suitable treatment technologies, optimize treatment efficiency, and ensure that treated wastewater meets regulatory standards for safe discharge or reuse.

In addition to technological interventions, sustainable wastewater management requires regulatory enforcement and public engagement. Strict implementation of environmental laws and effluent discharge standards ensures that industries and municipalities are held accountable for pollution control. Environmental monitoring programs can track changes in water quality over time, identify pollution hotspots, and provide early warning of potential ecological hazards. Public awareness campaigns and education initiatives can promote responsible practices, such as reducing household chemical disposal, adopting cleaner production techniques in industries, and encouraging water reuse where feasible. By integrating scientific monitoring, regulatory frameworks, and community participation, the cumulative impacts of wastewater pollution can be effectively mitigated.

Furthermore, the reuse of treated wastewater offers an opportunity to reduce environmental stress and promote water sustainability. Treated effluents can be safely used for agricultural irrigation, industrial processes, or groundwater recharge, reducing the demand on freshwater resources. Reusing treated wastewater can also prevent nutrient and salt accumulation in natural water bodies, limiting eutrophication and maintaining ecological balance. This approach emphasizes the importance of a circular water management strategy, where wastewater is not merely treated as waste but as a resource that can contribute to environmental sustainability and economic development.

Collectively, the findings from these studies emphasize the critical role of physicochemical analysis in evaluating wastewater pollution. High levels of organic and inorganic pollutants, as indicated by parameters such as BOD, COD, TDS, TSS, and nutrient concentrations, highlight the serious environmental risks posed by untreated effluents. Effective monitoring and treatment of wastewater are essential to prevent water quality degradation, protect aquatic ecosystems, and safeguard public health. Additionally, sustainable management practices, regulatory compliance, and public awareness are key components of a holistic approach to environmental protection and water resource conservation.

In conclusion, wastewater from industrial and urban areas represents a significant source of environmental pollution. Elevated levels of physicochemical parameters, including organic matter, dissolved and suspended solids, salts, and nutrients, have direct implications for aquatic ecosystems, soil quality, and human health. Monitoring these parameters provides critical information for assessing pollution severity, identifying sources, and designing appropriate treatment strategies. Implementation of advanced treatment technologies, along with sustainable management practices, regulatory enforcement, and community engagement, can effectively mitigate the adverse effects of wastewater pollution. By adopting an integrated approach, it is possible to reduce environmental degradation, promote water reuse, and achieve long-term ecological sustainability. These studies collectively reinforce the importance of continuous research, monitoring, and strategic intervention to ensure that wastewater management supports both environmental health and socio-economic development.

3. Materials and Methods

3.1 Study Area

Wastewater samples were collected from selected domestic and industrial discharge sites located near urban areas. These sites represent common sources of wastewater pollution affecting surrounding ecosystems.

3.2 Sample Collection

Wastewater samples were collected in sterilized polyethylene bottles and transported to the laboratory for analysis. Samples were stored at low temperature to prevent changes in chemical composition before analysis.

3.3 Physicochemical Parameters Analyzed

The following parameters were analyzed:

pH – indicates acidity or alkalinity of water

Temperature – influences chemical reactions and biological activity

Electrical Conductivity (EC) – indicates the presence of dissolved ions

Total Dissolved Solids (TDS) – represents dissolved substances in water

Total Suspended Solids (TSS) – indicates suspended particles

Biological Oxygen Demand (BOD) – measures oxygen required for microbial decomposition of organic matter

Chemical Oxygen Demand (COD) – indicates oxygen required to chemically oxidize organic pollutants

Dissolved Oxygen (DO) – indicates oxygen availability for aquatic life

3.4 Analytical Methods

Standard analytical methods were used for water quality analysis:

pH measured using a digital pH meter

Temperature measured using a thermometer

EC measured using a conductivity meter

BOD determined by 5-day incubation method

COD determined using dichromate digestion method

TDS and TSS determined by gravimetric analysis

4. Results

The analysis of wastewater samples showed the following average values:

Parameter	Observed Value	Permissible Limit
pH	7.5 – 8.2	6.5 – 8.5
Temperature	25 – 30°C	< 40°C
EC	1200 – 1800 µS/cm	750 – 2000 µS/cm
TDS	800 – 1500 mg/L	500 – 1000 mg/L
TSS	120 – 250 mg/L	100 mg/L
BOD	150 – 350 mg/L	30 mg/L
COD	300 – 700 mg/L	250 mg/L
DO	2 – 4 mg/L	≥ 5 mg/L

The results indicate that BOD, COD, TDS, and TSS values exceeded permissible limits in several samples, suggesting significant wastewater contamination.

5. Discussion

The analysis of wastewater samples reveals elevated levels of key physicochemical parameters, which are indicative of substantial pollution arising from anthropogenic activities. Human activities such as industrial processes, domestic sewage disposal, agricultural runoff, and urbanization contribute significantly to the contamination of water bodies. The presence of these pollutants not only affects the chemical quality of the water but also disrupts the ecological balance and poses health risks to both aquatic life and humans who depend on these water resources.

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are among the most critical indicators of organic pollution in water. High BOD values suggest that the water contains large amounts of biodegradable organic matter, which stimulates the growth and activity of microorganisms. These microorganisms consume dissolved oxygen (DO) in the water as they metabolize the organic compounds. A significant reduction in DO levels can create hypoxic conditions, which are stressful or even lethal for aquatic organisms. Fish, in particular, are highly sensitive to low oxygen concentrations, and prolonged exposure can lead to mortality, affecting the entire aquatic food chain. COD, on the other hand, measures the total amount of organic compounds, both biodegradable and non-biodegradable, in the water. Elevated COD levels in the wastewater samples confirm the presence of persistent organic pollutants, which may not easily degrade naturally. This combination of high BOD and COD signifies that the water body is under severe organic loading, which could lead to eutrophication, algal blooms, and long-term ecological degradation if untreated wastewater is discharged.

Total Dissolved Solids (TDS) and Electrical Conductivity (EC) are other important parameters that provide insight into the concentration of dissolved salts and inorganic substances in wastewater. High TDS levels indicate the presence of minerals, salts, metals, and other dissolved ions, while EC is a measure of the water's ability to conduct electricity, which correlates with the ionic concentration in the solution. Elevated TDS and EC can have far-reaching consequences. For instance, when wastewater with high TDS is used for irrigation, it may reduce soil fertility by altering its chemical composition, affecting plant growth, and potentially causing soil salinization. Over time, salts can accumulate in the soil profile, leading to decreased agricultural productivity and loss of arable land. Additionally, high TDS and EC levels in water can pose a risk to groundwater quality, especially in areas where there is interaction between surface and subsurface water. Contaminated groundwater may serve as a source of drinking water, introducing potential health hazards to human populations, including gastrointestinal disorders, hypertension, and kidney problems.

Total Suspended Solids (TSS) is another crucial parameter observed at elevated levels in the wastewater samples. TSS refers to the particulate matter suspended in water, including silt, clay, organic debris, and microorganisms. High TSS concentrations reduce light penetration into the water column, which inhibits photosynthesis in aquatic plants and phytoplankton. This limitation on photosynthesis decreases oxygen production within the water body, compounding the effects of high BOD and COD on dissolved oxygen levels. Suspended solids can also carry adsorbed pollutants, including heavy metals and persistent organic compounds, which further exacerbate water quality deterioration. The deposition of these solids on riverbeds and lake bottoms can alter habitat structure, negatively impacting benthic organisms and disrupting the aquatic ecosystem.

The combination of these elevated physicochemical parameters indicates that untreated wastewater contains both organic and inorganic pollutants in concentrations that can severely impact aquatic ecosystems. Persistent organic compounds, nutrients, and dissolved salts interact synergistically to create unfavorable conditions for aquatic life. Fish kills, reduced biodiversity, and ecological imbalance are commonly observed in water bodies receiving untreated effluents. Furthermore, such wastewater may serve as a breeding ground for pathogenic microorganisms, raising public health concerns. Pathogens in untreated sewage can lead to waterborne diseases such as cholera, dysentery, and hepatitis, affecting local communities that rely on these water bodies for domestic or recreational purposes.

Given these implications, it is evident that proper wastewater treatment is not merely a regulatory formality but a critical environmental necessity. Treatment processes such as primary sedimentation, biological treatment, and advanced tertiary treatments can significantly reduce BOD, COD, TDS, EC, and TSS levels before effluent discharge. Primary treatment removes large suspended solids, reducing TSS, while secondary treatment, typically biological in nature, decomposes organic matter and lowers BOD and COD. Tertiary treatments, including filtration, chemical precipitation, and reverse osmosis, can address residual dissolved salts and heavy metals, ensuring that the water meets environmental standards. The implementation of these treatments mitigates the negative impacts on aquatic ecosystems, preserves biodiversity, and protects human health.

In addition, proper wastewater management has long-term socio-economic benefits. Treated wastewater can be safely reused for agricultural irrigation, industrial processes, and even groundwater recharge, promoting water conservation and sustainability. It also prevents contamination of downstream water bodies, preserving the ecological services they provide, such as fisheries, recreation, and nutrient cycling. Communities and policymakers must recognize the interconnection between wastewater quality and environmental health to ensure effective monitoring and treatment strategies are enforced.

In conclusion, the elevated levels of BOD, COD, TDS, EC, and TSS in the wastewater samples indicate significant anthropogenic pollution that threatens aquatic life, soil quality, and human health. High organic and inorganic loads lead to oxygen depletion, reduced photosynthesis, and ecological imbalance, highlighting the urgent need for comprehensive wastewater treatment. Implementing appropriate treatment processes ensures the protection of natural resources, promotes environmental sustainability, and safeguards public health. Therefore, effective wastewater management is a critical step toward reducing pollution, maintaining ecosystem integrity, and supporting sustainable development.

6. Conclusion

This study focused on assessing the quality of wastewater by examining key physicochemical parameters and evaluating their potential environmental consequences. The analysis indicated that several critical indicators, including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), and Total Suspended Solids (TSS), were present at concentrations exceeding recommended thresholds. These elevated levels reflect substantial contamination, primarily originating from human activities such as industrial discharges, domestic sewage, and urban runoff. The high concentrations of organic and inorganic pollutants in the wastewater suggest a strong potential to disrupt aquatic ecosystems and compromise water quality.The discharge of untreated or inadequately treated wastewater into rivers, lakes, and other water bodies can have severe ecological consequences. Elevated BOD and COD levels indicate that organic matter in the wastewater is rapidly consumed by microorganisms, which reduces dissolved oxygen (DO) in the water. Lower DO concentrations create stressful conditions for aquatic organisms and may result in fish mortality, reduced biodiversity, and altered ecosystem dynamics. Similarly, high TDS and TSS levels contribute to increased salinity and turbidity, limiting light penetration and interfering with photosynthetic activity in aquatic plants. Over time, the accumulation of salts and suspended solids can degrade soil quality when wastewater is used for irrigation and can potentially contaminate groundwater resources, posing risks to human health and agricultural productivity.

These findings underscore the urgent need for effective wastewater management strategies. Continuous monitoring of wastewater quality is crucial to identify pollution hotspots and prevent ecological degradation. Implementing advanced treatment technologies, including primary, secondary, and tertiary processes, can significantly reduce the concentrations of organic and inorganic pollutants, ensuring that treated effluents meet environmental safety standards.Furthermore, promoting sustainable wastewater management practices, enforcing strict environmental regulations, and increasing public awareness about the impacts of water pollution are essential steps toward preserving water resources. Educating communities about proper waste disposal and encouraging the adoption of environmentally friendly practices can reduce the anthropogenic burden on aquatic ecosystems. By combining technological, regulatory, and community-based approaches, it is possible to mitigate the adverse effects of wastewater pollution and safeguard both environmental and public health, contributing to long-term ecological sustainability.

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