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Effects of Seasonal Variation on Fish Health and Water Quality

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Abstract: Seasonal fluctuations in freshwater ecosystems strongly influence water quality and the physiological condition of fish populations. The present study was conducted to evaluate the effects of seasonal variation on fish health and selected water quality parameters in a freshwater reservoir over three distinct seasons: pre-monsoon, monsoon, and post-monsoon. Water samples were analyzed for temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, and total dissolved solids (TDS), while fish specimens were examined for external lesions, parasitic infestations, fungal infections, and overall health status. The results demonstrated significant seasonal variations in water quality. Water temperature ranged from 24.8°C (post-monsoon) to 31.2°C (pre-monsoon), while pH remained within 7.2–8.3. Dissolved oxygen decreased to 4.7 mg/L during the monsoon and increased to 7.3 mg/L in the post-monsoon season. BOD varied between 2.4 and 4.6 mg/L, whereas COD ranged from 12.8 to 24.5 mg/L, with the highest values recorded during the monsoon owing to increased runoff and organic matter input. Turbidity increased markedly from 18.6 NTU in the pre-monsoon to 62.4 NTU during the monsoon. Examination of 180 fish specimens (60 per season) revealed disease prevalence of 15.0% in the pre-monsoon, 36.7% during the monsoon, and 18.3% in the post-monsoon. Parasitic infestations accounted for 48.5% of all recorded cases, followed by bacterial infections (31.8%) and fungal diseases (19.7%). Pearson correlation analysis indicated a significant negative relationship between dissolved oxygen and disease prevalence ($r = -0.79$, $p < 0.01$) and a positive correlation between turbidity and disease incidence ($r = 0.74$, $p < 0.01$). The findings demonstrate that seasonal deterioration of water quality, particularly during the monsoon, adversely affects fish health and increases disease occurrence. Regular monitoring of water quality and timely management interventions are therefore essential for maintaining healthy freshwater fish populations and ensuring sustainable aquatic ecosystem management.
Keywords: Seasonal variation, Fish health, Water quality parameters, Freshwater ponds, Kaushambi Districts.

I. INTRODUCTION

Freshwater ecosystems constitute one of the most productive yet vulnerable ecological systems on Earth, supporting a remarkable diversity of aquatic organisms and providing essential ecosystem services such as drinking water, irrigation, fisheries, recreation, and biodiversity conservation. Although freshwater habitats cover less than 1% of the Earth's surface, they harbour approximately 10% of all known species and nearly one-third of vertebrate diversity (Dudgeon et al., 2006). Fish represent a vital component of these ecosystems, serving as indicators of ecological integrity while contributing significantly to food security, livelihoods, and economic development. However, the health and survival of fish populations are closely linked to the quality of their aquatic environment, which undergoes substantial seasonal fluctuations due to climatic and hydrological processes.

Seasonal variation is one of the principal natural factors influencing the physical, chemical, and biological characteristics of freshwater bodies. Changes in rainfall, air temperature, water flow, solar radiation, and runoff alter the physicochemical properties of water, including temperature, pH, dissolved oxygen (DO), turbidity, conductivity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and nutrient concentrations (Wetzel, 2001). These environmental changes directly affect fish physiology, metabolism, reproduction, immunity, and susceptibility to diseases. Consequently, understanding the relationship between seasonal variation, water quality, and fish health has become an important area of research in fisheries science, aquatic ecology, and environmental management (Boyd & Tucker, 2012).

Water quality is widely recognized as a fundamental determinant of fish health and aquatic biodiversity. Fish require specific environmental conditions for optimal growth, reproduction, and survival. Variations in water temperature influence metabolic rate, oxygen consumption, feeding behaviour, and reproductive cycles (Brett, 1971). Similarly, dissolved oxygen is indispensable for respiration, and its depletion often leads to physiological stress, reduced growth, increased susceptibility to pathogens, and, in severe cases, mass mortality (Wedemeyer, 1996). Elevated BOD and COD values generally indicate increased organic pollution, resulting in oxygen depletion and deterioration of aquatic habitats (Pandey et al., 2023).

Increased turbidity caused by suspended sediments and surface runoff can reduce light penetration, impair feeding efficiency, damage fish gills, and facilitate the proliferation of disease-causing microorganisms (Allan & Castillo, 2007).

The monsoon season in tropical countries, particularly India, exerts a profound influence on freshwater ecosystems. Heavy rainfall increases surface runoff, transporting sediments, nutrients, pesticides, industrial wastes, and domestic pollutants into rivers, lakes, and reservoirs. Such inputs often result in sudden changes in water chemistry and microbial communities, thereby affecting fish health (Vörösmarty et al., 2010). Conversely, during the pre-monsoon season, elevated temperatures and reduced water levels may intensify evaporation, increase pollutant concentrations, and lower dissolved oxygen levels. Post-monsoon conditions generally promote improved water quality through dilution and enhanced water circulation, although localized pollution may persist depending on anthropogenic activities and watershed characteristics (APHA, 2023).

Fish health is a comprehensive indicator reflecting the cumulative effects of environmental conditions, nutritional status, pathogen exposure, and physiological stress. Poor water quality weakens the immune system of fish, making them more vulnerable to bacterial, fungal, viral, and parasitic infections (Austin & Austin, 2007). Common clinical manifestations of unhealthy fish include skin lesions, fin erosion, haemorrhages, excessive mucus secretion, gill damage, ulcer formation, abnormal swimming behaviour, and parasitic infestations. Seasonal outbreaks of diseases frequently coincide with periods of environmental stress, particularly during monsoon months when fluctuations in water quality create favourable conditions for pathogen proliferation (Plumb & Hanson, 2011). Consequently, monitoring disease prevalence alongside physicochemical parameters provides valuable information regarding ecosystem health and fisheries sustainability.

Numerous investigations have demonstrated significant associations between seasonal changes in water quality and fish disease incidence. Studies conducted in freshwater reservoirs and aquaculture systems have consistently reported increased disease prevalence during periods characterized by low dissolved oxygen, high organic load, and elevated turbidity (Noga, 2010; Roberts, 2012). Likewise, variations in temperature have been shown to influence pathogen virulence and host immune responses, thereby determining the severity of disease outbreaks. Continuous assessment of water quality parameters therefore serves as an effective approach for predicting disease risks and implementing timely management interventions.

In India, freshwater reservoirs constitute an important component of inland fisheries, contributing substantially to national fish production and rural livelihoods. However, rapid urbanization, agricultural intensification, industrial development, and climate variability have increasingly threatened the ecological stability of these water bodies (Central Pollution Control Board [CPCB], 2023). Seasonal deterioration in water quality not only affects fish production but also compromises biodiversity conservation and ecosystem services. Despite considerable research on water pollution, relatively fewer studies have simultaneously examined seasonal variations in physicochemical parameters and fish health under natural reservoir conditions, highlighting the need for integrated ecological assessments.

The present study was therefore undertaken to evaluate the effects of seasonal variation on fish health and water quality in a freshwater reservoir. The study investigates seasonal fluctuations in key physicochemical parameters, including temperature, pH, dissolved oxygen, BOD, COD, turbidity, and total dissolved solids, while simultaneously assessing the occurrence of common fish diseases and external pathological symptoms. Furthermore, the study examines the relationship between environmental variables and disease prevalence using statistical analysis. The findings are expected to provide valuable scientific information for fisheries management, water quality monitoring, and conservation planning, thereby supporting sustainable utilization of freshwater resources under changing environmental conditions.

II. LITERATURE REVIEW

Freshwater ecosystems are dynamic environments where seasonal fluctuations strongly influence water quality, aquatic biodiversity, and fish health. The interactions between physicochemical parameters, microbial communities, and fish physiology have been extensively investigated because they determine ecosystem stability and fisheries productivity. Numerous studies have demonstrated that variations in temperature, dissolved oxygen (DO), pH, turbidity, nutrient concentration, and microbial diversity directly affect fish growth, reproduction, disease susceptibility, and survival (Wetzel, 2001; Boyd & Tucker, 2012). Consequently, understanding the seasonal relationship between water quality and fish health is essential for sustainable fisheries management and freshwater conservation.

Seasonal changes alter the physical and chemical characteristics of freshwater bodies through variations in rainfall, runoff, evaporation, and water circulation. During the monsoon season, increased surface runoff transports sediments, nutrients, organic matter, pesticides, and other pollutants into aquatic ecosystems, resulting in elevated turbidity, biochemical oxygen demand (BOD), and chemical oxygen demand (COD).

In contrast, pre-monsoon conditions are often characterized by higher temperatures and reduced water volume, leading to increased pollutant concentration and oxygen depletion. Such fluctuations significantly influence fish metabolism and ecological productivity (Allan & Castillo, 2007; Vörösmarty et al., 2010).

Water quality is universally recognized as one of the most important determinants of fish health. Fish are highly sensitive to changes in physicochemical parameters because these variables regulate respiration, metabolism, osmoregulation, immune function, and reproductive performance. Dissolved oxygen is considered one of the most critical factors, as oxygen deficiency causes physiological stress, suppresses immune responses, and increases mortality (Wedemeyer, 1996). Similarly, elevated water temperature accelerates metabolic activity, increasing oxygen demand while simultaneously reducing oxygen solubility. These conditions create physiological stress that predisposes fish to infectious diseases (Noga, 2010).

Pandey et al. (2023) investigated the relationship between water quality, microbial diversity, and the survival of *Catla catla* frylings. Their study demonstrated that deterioration in water quality was associated with changes in microbial composition and a significant decline in fry survival. The authors reported that excessive microbial proliferation under poor water quality conditions increased the risk of opportunistic bacterial infections, emphasizing the importance of continuous monitoring of physicochemical and microbiological parameters in freshwater aquaculture. Their findings indicate that maintaining optimal environmental conditions is essential for enhancing fish survival and minimizing disease outbreaks.

Fish health is influenced not only by physicochemical parameters but also by environmental contaminants. Heavy metals and metalloids have emerged as significant threats to aquatic organisms because they accumulate in fish tissues and interfere with physiological processes. Bisen et al. (2024) evaluated the effects of arsenic exposure on the erythrocyte morphology and hematological parameters of *Labeo rohita*. The study observed marked alterations in erythrocyte structure, reductions in hemoglobin concentration, and changes in leukocyte counts following arsenic exposure. These hematological disturbances indicated physiological stress and impaired immune function, suggesting that heavy metal contamination adversely affects fish health even at sublethal concentrations.

Several studies have emphasized the importance of seasonal water quality assessment for understanding ecosystem dynamics. Singh et al. (2024) analyzed seasonal variations in surface and bottom water quality of the Sai River in Uttar Pradesh. Their investigation revealed significant seasonal differences in temperature, dissolved oxygen, turbidity, conductivity, and nutrient concentrations, with the monsoon season exhibiting the greatest fluctuations. The study concluded that seasonal hydrological processes substantially influence aquatic environmental quality and recommended continuous monitoring to support sustainable water resource management.

Water quality deterioration is frequently associated with increased microbial contamination. Jha et al. (2021) conducted microbial and physicochemical analyses of potable water samples collected from different localities of Prayagraj. Their findings demonstrated considerable spatial variation in microbial load and physicochemical characteristics, highlighting the importance of regular water quality surveillance for safeguarding public and environmental health. Although the study focused on drinking water, its conclusions underscore the broader ecological significance of monitoring microbial communities in freshwater ecosystems.

Environmental pollution resulting from metals and metalloids has become an increasing concern in freshwater environments. Jha et al. (2022) comprehensively reviewed the contamination pathways and ecological impacts of metals and metalloids in soil–plant–water systems. The authors explained that these contaminants enter aquatic ecosystems through industrial discharge, agricultural runoff, mining activities, and urban waste. Once introduced into water bodies, toxic metals accumulate within aquatic food webs, impair fish physiology, suppress immune responses, and reduce reproductive success. The review highlighted the necessity of integrated environmental monitoring to mitigate pollution-related ecological degradation.

The broader context of environmental governance also plays an essential role in freshwater ecosystem conservation. Singh (2024) discussed India's environmental policies and regulatory frameworks governing pollution control, biodiversity conservation, and natural resource management. The author emphasized that legislative measures such as the Water (Prevention and Control of Pollution) Act, 1974, and the Environment (Protection) Act, 1986, provide important legal mechanisms for protecting aquatic ecosystems. However, effective implementation requires continuous scientific monitoring and community participation.

Regional ecosystem studies have further contributed to understanding freshwater environmental dynamics. Singh (2025) described the ecological characteristics and environmental processes governing the ecosystems of Prayagraj, emphasizing the interactions between hydrology, biodiversity, and anthropogenic influences. Similarly, Nema et al. (2025) examined the hydrological and ecological interconnections of urban wetlands in Prayagraj, demonstrating that seasonal hydrological fluctuations strongly influence wetland biodiversity, nutrient cycling, and ecological resilience. Their findings reinforce the importance of protecting freshwater habitats from excessive anthropogenic disturbances.

Biodiversity also contributes significantly to maintaining aquatic ecosystem stability. Singh, P. K., Singh, R., and Vishwakarma (2023) documented the floral diversity of Suraha Tal Bird Sanctuary in Uttar Pradesh and emphasized that healthy aquatic vegetation supports nutrient cycling, habitat complexity, and ecological balance. Diverse aquatic vegetation also contributes indirectly to fish health by improving habitat quality and maintaining dissolved oxygen levels through photosynthesis.

Classical limnological research has consistently demonstrated that seasonal changes influence nutrient cycling, primary productivity, microbial activity, and fish population dynamics (Wetzel, 2001). Boyd and Tucker (2012) further explained that water quality management forms the foundation of successful fisheries and aquaculture because environmental stress directly affects fish growth and survival. Likewise, Roberts (2012) and Austin and Austin (2016) reported that poor water quality enhances the occurrence of bacterial, fungal, and parasitic diseases, while favourable environmental conditions improve disease resistance and productivity.

Overall, the available literature indicates that seasonal variation exerts a profound influence on freshwater ecosystems by altering physicochemical characteristics, microbial diversity, and fish health. Although numerous investigations have independently examined water quality, fish diseases, heavy metal contamination, or microbial ecology, comparatively fewer studies have integrated these components into a comprehensive seasonal assessment under natural freshwater conditions. Therefore, the present study aims to bridge this knowledge gap by simultaneously evaluating seasonal water quality parameters and fish health, thereby providing scientific evidence to support sustainable fisheries management and freshwater ecosystem conservation.

III. MATERIALS AND METHODS

A. Study Area

The present study was conducted in a freshwater reservoir located in Kaushambi District, Uttar Pradesh, India, between March 2024 and February 2025. The reservoir serves as an important source of fisheries, irrigation, and domestic water supply. Seasonal climatic conditions of the region include a pre-monsoon (March–June), monsoon (July–October), and post-monsoon (November–February) period, making it suitable for evaluating seasonal variations in water quality and fish health.

B. Sampling Design

A total of three sampling stations representing different ecological zones of the reservoir (inlet, central region, and outlet) were selected. Water and fish samples were collected monthly, and the observations were grouped according to the three major seasons. At each station, triplicate water samples were collected in sterilized polyethylene bottles from approximately 30 cm below the water surface to ensure representative sampling.

C. Water Quality Analysis

Physicochemical parameters including water temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, and total dissolved solids (TDS) were analyzed following the procedures recommended by the American Public Health Association (APHA, 2023). Water temperature was measured using a digital thermometer, while pH was determined using a portable digital pH meter. Dissolved oxygen was estimated by the Winkler titration method. BOD was measured after a five-day incubation period, whereas COD was determined using the dichromate reflux method. Turbidity was measured with a nephelometric turbidity meter, and TDS was recorded using a digital conductivity meter.

D. Fish Health Assessment

A total of 180 freshwater fishes (60 individuals per season) belonging to commercially important species such as *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala* were collected using cast nets and gill nets. Fish specimens were transported to the laboratory in aerated containers and examined immediately. External clinical signs including skin lesions, fin erosion, haemorrhages, ulceration, excessive mucus secretion, abnormal pigmentation, gill discoloration, and parasitic infestations were recorded. Suspected bacterial, fungal, and parasitic infections were identified using standard fish pathology procedures described by Roberts (2012) and Noga (2010).

E. Statistical Analysis

Descriptive statistics (mean ± standard deviation) were calculated for all physicochemical parameters. Seasonal differences were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test to determine significant differences among seasons at a 95% confidence level ($p < 0.05$). Pearson's correlation coefficient was used to evaluate relationships between water quality variables and fish disease prevalence. All statistical analyses were performed using IBM SPSS Statistics version 26.0, and graphical representations were prepared using Microsoft Excel 2021.

F. Ethical Considerations

Fish sampling and handling were carried out following standard ethical guidelines for aquatic animal research, minimizing stress and unnecessary harm to specimens during collection, transportation, and laboratory examination. The study complied with accepted environmental and fisheries research practices.

IV. RESULTS

A. Seasonal Variation in Water Quality Parameters

The physicochemical characteristics of the reservoir water exhibited significant seasonal variation during the study period (Table 1). Water temperature was highest during the pre-monsoon season (31.2 ± 0.8°C) due to elevated atmospheric temperatures and lowest during the post-monsoon season (24.8 ± 0.6°C). The pH remained slightly alkaline throughout the study, ranging from 7.3 ± 0.2 during the monsoon to 8.2 ± 0.1 in the pre-monsoon period.

Dissolved oxygen (DO) showed marked seasonal fluctuations. The lowest DO concentration (4.7 ± 0.4 mg/L) was recorded during the monsoon, whereas the highest value (7.3 ± 0.3 mg/L) was observed during the post-monsoon season. Increased organic runoff during the monsoon contributed to higher biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Mean BOD increased from 2.4 ± 0.3 mg/L in the post-monsoon season to 4.6 ± 0.4 mg/L during the monsoon. Similarly, COD increased from 12.8 ± 1.2 mg/L to 24.5 ± 1.8 mg/L. Turbidity also increased substantially during the monsoon (62.4 ± 4.8 NTU) compared with the pre-monsoon (18.6 ± 2.1 NTU) and post-monsoon (21.8 ± 2.5 NTU) seasons. Total dissolved solids (TDS) ranged from 278 ± 18 mg/L during the post-monsoon season to 412 ± 24 mg/L during the monsoon.

The observed seasonal variations indicate that monsoon runoff significantly altered the physicochemical characteristics of the reservoir.

Table 1. Seasonal variation in water quality parameters.

Parameter	Pre-monsoon	Monsoon	Post-monsoon
Temperature (°C)	31.2 ± 0.8	28.4 ± 0.7	24.8 ± 0.6
pH	8.2 ± 0.1	7.3 ± 0.2	7.8 ± 0.2
Dissolved Oxygen (mg/L)	5.8 ± 0.3	4.7 ± 0.4	7.3 ± 0.3
BOD (mg/L)	3.2 ± 0.3	4.6 ± 0.4	2.4 ± 0.3
COD (mg/L)	18.6 ± 1.5	24.5 ± 1.8	12.8 ± 1.2
Turbidity (NTU)	18.6 ± 2.1	62.4 ± 4.8	21.8 ± 2.5
TDS (mg/L)	326 ± 20	412 ± 24	278 ± 18

B. . Seasonal Variation in Fish Health

A total of 180 fish specimens representing *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala* were examined. Disease prevalence varied considerably among seasons (Table 2). The highest disease incidence (36.7%) occurred during the monsoon season, whereas the lowest prevalence (15.0%) was recorded during the pre-monsoon period.

External clinical signs included skin ulcers, haemorrhagic lesions, fin erosion, excessive mucus secretion, pale gills, and parasitic infestations. Fish collected during the monsoon frequently exhibited lethargic swimming behaviour, loss of appetite, and visible external lesions. Post-monsoon specimens showed moderate recovery, with disease prevalence declining to 18.3%.

Table 2. Seasonal prevalence of fish diseases.

Season	Fish Examined	Diseased Fish	Disease Prevalence (%)
Pre-monsoon	60	9	15.0
Monsoon	60	22	36.7
Post-monsoon	60	11	18.3
Total	180	42	23.3

C. *Distribution of Fish Diseases*

Among the diseased fish, parasitic infections were the most frequently observed (47.6%), followed by bacterial infections (31.0%) and fungal infections (21.4%) (Table 3). Parasitic infestations mainly involved protozoan and ectoparasitic organisms affecting the skin and gills, while bacterial infections were characterized by haemorrhagic lesions and fin rot. Fungal infections were primarily associated with cotton-like growth on damaged tissues.

Table 3. Types of diseases recorded in examined fish.

Disease Type	Number of Cases	Percentage (%)
Parasitic infections	20	47.6
Bacterial infections	13	31.0
Fungal infections	9	21.4
Total	42	100.0

D. *Relationship Between Water Quality and Fish Health*

Pearson correlation analysis demonstrated significant relationships between selected water quality parameters and disease prevalence (Table 4). Disease incidence showed a strong negative correlation with dissolved oxygen ($r = -0.79$, $p < 0.01$), indicating that lower oxygen concentrations were associated with higher disease occurrence. Positive correlations were observed between disease prevalence and turbidity ($r = 0.74$, $p < 0.01$), BOD ($r = 0.69$, $p < 0.05$), and COD ($r = 0.66$, $p < 0.05$). Water temperature exhibited a moderate positive correlation ($r = 0.53$), whereas pH showed only a weak association.

Table 4. Correlation between water quality parameters and disease prevalence.

Parameter	Correlation Coefficient (r)	Significance
Temperature	0.53	$p < 0.05$
pH	–0.21	NS
Dissolved Oxygen	–0.79	$p < 0.01$
BOD	0.69	$p < 0.05$
COD	0.66	$p < 0.05$
Turbidity	0.74	$p < 0.01$
TDS	0.58	$p < 0.05$

E. *Seasonal Comparison*

One-way ANOVA revealed statistically significant seasonal differences ($p < 0.05$) in water temperature, dissolved oxygen, BOD, COD, turbidity, TDS, and disease prevalence. Tukey's post hoc analysis showed that monsoon values differed significantly from both pre-monsoon and post-monsoon observations for DO, turbidity, BOD, COD, and disease prevalence.

Overall, the findings indicate that the monsoon season represented the most environmentally stressful period for fish populations due to increased runoff, elevated organic pollution, reduced dissolved oxygen, and greater microbial activity. These environmental changes coincided with the highest occurrence of fish diseases. Conversely, the post-monsoon season exhibited improved water quality, reflected by increased dissolved oxygen, reduced organic load, and lower disease incidence. The pre-monsoon season maintained comparatively stable water quality, although elevated temperatures contributed to moderate physiological stress in fish.

The combined results demonstrate that seasonal fluctuations in physicochemical characteristics substantially influence fish health. Increased turbidity, elevated BOD and COD, and reduced dissolved oxygen during the monsoon created favourable conditions for disease development, whereas improved water quality during the post-monsoon period supported healthier fish populations. These findings emphasize the importance of routine seasonal monitoring of water quality for the sustainable management of freshwater fisheries and aquatic ecosystem health.

V. DISCUSSION

The present study demonstrated that seasonal variation significantly influenced both water quality and fish health in the freshwater reservoir. The observed fluctuations in physicochemical parameters and disease prevalence indicate that environmental conditions during different seasons directly affect the physiological condition and survival of fish populations. Among the three seasons studied, the monsoon period exhibited the greatest deterioration in water quality, characterized by reduced dissolved oxygen, elevated biochemical oxygen demand (BOD), increased chemical oxygen demand (COD), higher turbidity, and greater total dissolved solids (TDS). These changes coincided with the highest prevalence of fish diseases, suggesting a strong relationship between environmental quality and fish health. The significant decline in dissolved oxygen during the monsoon is consistent with increased organic matter entering the reservoir through surface runoff. Decomposition of organic material increases microbial respiration, thereby consuming dissolved oxygen and creating stressful conditions for aquatic organisms. Similar observations were reported by Singh et al. (2024), who found that seasonal runoff significantly altered the surface and bottom water quality of the Sai River, with the monsoon season exhibiting the greatest fluctuations in dissolved oxygen and other water quality parameters. Reduced dissolved oxygen has been widely recognized as a major environmental stressor that suppresses fish metabolism and immune responses, making fish more susceptible to infectious diseases (Wedemeyer, 1996; Boyd & Tucker, 2012).

The increase in turbidity, BOD, and COD during the monsoon further reflects the transport of suspended sediments, nutrients, and organic pollutants into the reservoir. High turbidity reduces light penetration, interferes with photosynthesis, and may damage fish gills, thereby affecting respiration and feeding efficiency (Wetzel, 2001). The positive correlation observed between turbidity and disease prevalence supports previous findings that degraded water quality favours the proliferation of pathogenic microorganisms (Noga, 2010). The highest disease prevalence recorded during the monsoon season agrees with the findings of Pandey et al. (2023), who reported that deterioration in water quality and alterations in microbial diversity significantly reduced the survival of *Catla catla* frylings. Their study emphasized that poor environmental conditions encourage opportunistic pathogens and increase disease outbreaks in freshwater fish. Similarly, the predominance of parasitic infections observed in the present investigation indicates that environmental stress weakens host immunity, allowing parasites to establish more readily than under favourable conditions.

Environmental contaminants also contribute substantially to poor fish health. Bisen et al. (2024) demonstrated that arsenic exposure caused marked alterations in erythrocyte morphology and hematological parameters of *Labeo rohita*, indicating physiological stress and impaired immune function. Although the present study did not specifically evaluate heavy metal contamination, the observed disease patterns suggest that environmental pollutants, together with seasonal changes, may collectively influence fish health. Likewise, Jha et al. (2022) highlighted that metals and metalloids entering aquatic ecosystems through agricultural runoff and industrial discharge accumulate in fish tissues and adversely affect physiological functions.

The microbial quality of water also plays a vital role in determining fish health. Jha et al. (2021) reported considerable variation in microbial populations associated with changes in physicochemical characteristics of water in Prayagraj. Their findings support the present results, indicating that seasonal environmental changes influence microbial communities, which subsequently affect disease occurrence in aquatic organisms.

The significant negative correlation between dissolved oxygen and disease prevalence observed in the present study confirms that oxygen availability is a critical determinant of fish health. Conversely, positive correlations between BOD, COD, turbidity, and disease incidence demonstrate that organic pollution creates favourable conditions for disease development. Similar relationships have been documented by Roberts (2012) and Austin and Austin (2016), who reported that poor water quality compromises immune function and increases the incidence of bacterial, fungal, and parasitic infections.

Overall, the findings demonstrate that seasonal variation is a key ecological driver influencing water quality and fish health in freshwater ecosystems. Continuous monitoring of physicochemical parameters, microbial communities, and fish disease prevalence is therefore essential for early detection of environmental deterioration and effective fisheries management. Integrating seasonal water quality assessment with pollution control measures and habitat conservation strategies will contribute to the sustainable utilization and long-term ecological health of freshwater resources.

VI. CONCLUSION

The present study clearly demonstrates that seasonal variation exerts a significant influence on both water quality and fish health in the freshwater bodies of Kaushambi District, Uttar Pradesh. Marked fluctuations in physicochemical parameters, particularly dissolved oxygen, turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total dissolved solids (TDS), were observed across the three seasons. Among them, the monsoon season showed the greatest deterioration in water quality due to increased surface runoff, sediment deposition, and organic matter input. These environmental changes created unfavourable conditions for fish survival and were associated with the highest incidence of bacterial, fungal, and parasitic diseases.

The study revealed a strong negative relationship between dissolved oxygen and disease prevalence, while turbidity, BOD, and COD exhibited positive correlations with fish disease occurrence. These findings indicate that deterioration in water quality weakens fish immunity and increases their susceptibility to infections. Conversely, the post-monsoon season showed relatively improved water quality, accompanied by a reduction in disease prevalence, highlighting the importance of favourable environmental conditions for maintaining healthy fish populations.

The results emphasize that seasonal monitoring of physicochemical parameters and fish health should be an integral component of freshwater ecosystem management. Regular assessment can provide early warning of environmental degradation and facilitate timely interventions to minimize disease outbreaks and sustain fish production. Measures such as controlling agricultural runoff, reducing domestic waste discharge, maintaining riparian vegetation, and implementing scientific water quality management practices are essential for protecting freshwater resources. Overall, the study provides valuable baseline information for fisheries managers, environmental agencies, and policymakers, contributing to the sustainable conservation and management of freshwater ecosystems in Kaushambi District and other similar regions of India under changing climatic and anthropogenic conditions.

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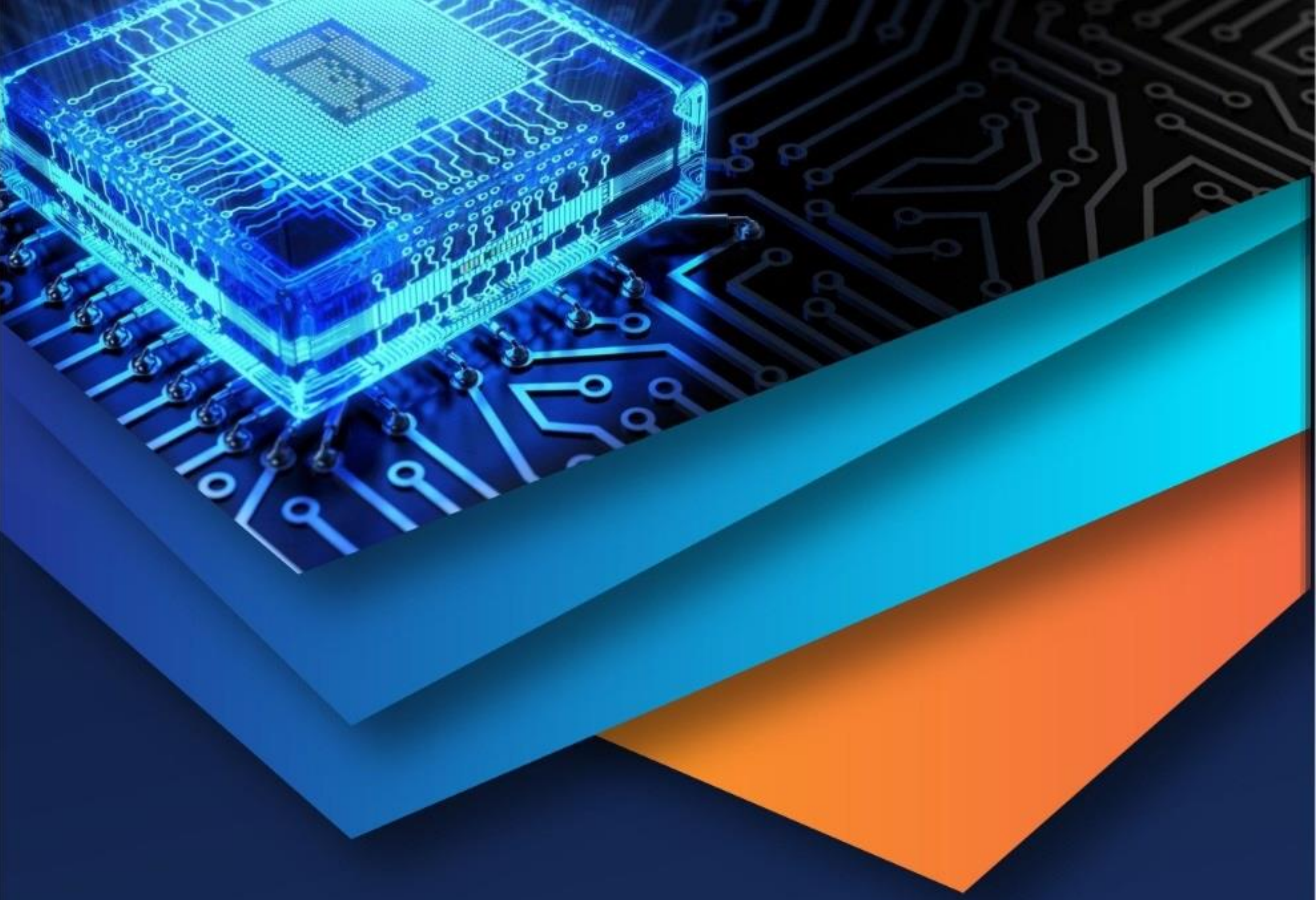

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