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Evaluating the impact of physico-chemical and bacteriological water quality on river ecosystem health and aquatic biodiversity

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Abstract
In flowing waters, living balance is closely linked to level of purity and changes are frequently reflected in the ranges of populations. Along with the presence of bacteria, such as the fats or waste associated bugs, there are other variables to consider, including temperature, pH (acidity), dissolved oxygen, an amount of nitrogen and phosphorus present, or the degree of cloudiness. All together these make up if a creature has favourable conditions to survive or not. The study will involve multivariate statistical modeling, together with ecological indices, which will then be used to analyze how biodiversity, particularly that of fish, macroinvertebrates and plankton, change in relation to changes in various environmental factors. Dissolved oxygen decreases as BOD (biological oxygen demand) increases with nutrient enrichment and there are low dissolved oxygen environments in which vulnerable organisms would not fare well. At the same time, if coliforms are detected as being higher than normal, it also indicates the possibility of sewage backup or farm-derived runoff, posing risks to both the environment and people. Water quality indices are combined with other tools such as species richness and diversity to create models that predict rivers' condition. Ways of which water quality degradation correlates with reduction in species appears clear; this indicates places where ecological damage increases in dramatic amounts. As a result of this, the findings from this study will be used to develop a framework for sustainable river use and play a role in conservation efforts and decisions on river management policy to restore and maintain healthy freshwater ecosystems.

Keywords: Temperature, pH, BOD (biological oxygen demand), conservation

Introduction
Rivers form one of the most useful freshwater ecosystems on Earth due to the large variety of ecological, social and economic functions. They are the source of drinking, irrigation, animal farming, fisheries, industrial processing and domestic consumption, provide support to the riverine communities recreation, culture and livelihoods. Ecologically, rivers are not just running bodies of water but multifaceted biological communities that support a wide range of biological communities and regulate key environmental processes. These ecosystems support the presence of microorganisms, phytoplankton, zooplankton, benthic invertebrates, fish, amphibians, and riparian organisms, which interact to stabilize and make the ecosystem productive. These interactions help rivers to transform nutrients, break down organic matter, enhance primary productivity, and to transfer trophic energy, which is vital in ensuring that local biodiversity and ecosystem are kept in balance. Thus, to evaluate the health of rivers, one can not rely solely on the amount of water flowing there, but rather on the quality of the physical, chemical, and biological parameters of the flow. Over the past few decades, the degradation of the quality of river water has emerged as one of the biggest environmental problems all over the globe. The burden of the pollutants on freshwater systems has increased a lot due to the rapid urbanization, population increase, increase in industrial activities, intensification of farming activities, and improper waste-management practices. Sewage released into rivers by households contain high amount of organic matter, detergents, nutrients and disease causing organisms. Agricultural runoffs bring fertilizers, pesticides, sediments and animal wastes, whereas industrial discharges usually include heavy metals, poisonous chemicals, oils and other toxic substances. Moreover, there are diffuse non-point sources that also contribute to poor quality of river water like the stormwater runoff, open defecation, landfill leachates and soil erosion (Water SA, Jordaan & Bezuidenhout, 2013) [1]. All these inputs change the natural physicochemical structure of river water by augmenting nutrient levels, salinity, turbidity and suspended solids, as well as oxygen requirements. Consequently, this causes imbalance in the river ecosystems, both the abiotic environment and the biological communities which rely on the abiotic environment. The implications of the deterioration of such water quality are far-reaching and are connected in many ways. Nitrogen and phosphorus are the nutrients that increase nutrient loading and increase the rate of eutrophication, which may result in the excessive growth of algae and aquatic plants. In the event of these organisms dying and breaking down, microbial activity increases exponentially, leading to higher biological oxygen requirements and a decrease of dissolved oxygen in the water. Reduced dissolved oxygen leads to stressful or even fatal situations of fish and benthic fauna and other aerobic organisms. On the same note, high turbidity decreases light penetration, hence photosynthesis in submerged plants and phytoplankton and disturbs feeding, respiration and reproduction in aquatic organisms. Physiological stress in aquatic organisms may be further exacerbated by elevated temperature, changes in pH, and boosted conductivity, as well as the build-up of toxic substances in organisms. Under these conditions, which are frequently favored by the high levels of pollution in highly polluted systems, there is a

tendency to favor the presence of pollution-tolerant species and opportunistic pathogens, and the population of microbes which are adapted to organic enrichment, and disadvantage sensitive species, which may eventually become extinct (Scientific Reports, Khan et al., 2024) [2]. This change results in a decline in biodiversity, simplification of food webs and ecological processes. Conventional methods of river surveillance usually involve measuring individual water-quality parameters individually. As an example, dissolved oxygen, pH, turbidity, or count of coliform can be measured individually so as to ascertain whether a river is polluted or not. Such measurements although helpful do not fully represent the complexity of river ecosystems. Control of river health is through interplay of various environmental variables which work together concurrently at spatial and time scales. Physicochemical factors characterize the immediate environment of aquatic organisms where they obtain their food, grow, reproduce, and survive. Simultaneously, the bacteriological parameters give information on the source of contamination, organic pollution, fecal contribution and destabilization of the ecosystem. Thus, to effectively evaluate the river health a combined approach is needed to evaluate the interaction between these variables instead of considering them separately as indicators. Temperature, pH, dissolved oxygen, electrical conductivity, turbidity, total dissolved solids, biological oxygen demand, chemical oxygen demand, nitrate, phosphate, chloride, and ammonium are some of the physicochemical parameters that are of particular significance in establishing the ecological status of rivers. Temperature determines metabolic activity, solubility of oxygen, and rate of growth of the microorganisms. PH influences the enzyme activity, nutrient availability and the survival of aquatic creatures. Dissolved oxygen is an essential parameter of aerobic organisms and it is often termed as being one of the most significant measures of the health of aquatic ecosystems. The balance of nutrient concentrations controls the productivity level; however, overabundance of nutrient may disrupt the ecosystems via eutrophication. Conductivity and total dissolved solids indicate the ionic content and may indicate the salinity or stress of pollution. Turbidity, suspended solids impact the quality of water and quality of the habitat and the values of BOD and COD indicate the degree of organic and chemical pollution. A combination of these variables defines whether the environment is conducive or not to aquatic life (Ecological Indicators, Sharma & Gupta, 2018) [3]. The current paper examines the influence of key physicochemical and bacteria-related factors on aquatic biodiversity and river health, and the pathways through which water-quality indicators affect aquatic ecology. The aim is to offer an academic approach integrating research, monitoring and management.

Physico-Chemical Parameters and River Health

The first controllers of the water quality and biological aptness of river ecosystems are physicochemical variables. Temperature has an effect on the rate of metabolism, oxygen solubility, microbial growth and distribution of species. High temperature has the capacity to increase the rate of biochemical reactions, increase microbial activity, and exacerbate the oxygen stress, particularly high levels of organic pollution. Another important parameter is pH since it influences the availability of ions, enzyme activity, nutrient chemistry, and survival of organisms. Most freshwater organisms thrive only under a relatively small pH range, and any variation can decrease reproductive success, shift community structure, and prefer some types of microbes, like cyanobacteria, in eutrophic environments. PH in the Vaal River was found to be one of the main variables that affected the bacterial community structure. Dissolved oxygen is commonly considered as a core measure of river health as it is an indicator of the capacity of the water to maintain aerobic life. Reduction in oxygen interferes with the life of fish, macroinvertebrate community and the microbial equilibrium. High biological oxygen demand and chemical oxygen demand represent higher rates of organic matter decomposition and higher pressure of pollution, which usually results in a decrease in dissolved oxygen and results in the selection of pollution tolerant organisms. Low-BOD rivers tend to maintain a more favorable oxygen regime and healthy aquatic life than rivers that receive continuous loads of sewage or organic wastes (Ecological Indicators, Sharma & Gupta, 2018) [3]. Phosphate, nitrate and ammonium are nitrogenous nutrients that have a very strong impact on productivity and ecological status. In moderate amounts they facilitate the biological productivity, whereas high levels facilitate eutrophication, algal growth, microbial disequilibrium and loss of oxygen in the decomposition process. Nitrate, phosphate, ammonium, chloride and sulphate and total dissolved solids were implicated in spatial and seasonal changes in bacterial communities in multivariate analyses, suggesting a role of nutrient and ionic regimes in driving ecological changes. River condition is also influenced by electrical conductivity, total dissolved solids, turbidity, suspended solids and salinity-related ions. High conductivity and TDS tend to indicate dissolved salts and loads of pollutants, whereas turbidity inhibits light penetration, disrupts photosynthesis, gills benthic habitats and smothers the gills. Such stressors undermine the quality of habitat of most species of concern and they usually coincide with downstream human-induced disturbance (UK Centre for Ecology & Hydrology, 2021) [4].

Table 1: Physico-Chemical Parameters on River Health

Parameter	Type	Role in river health	Biodiversity impact
Temperature	Physico-chemical	Controls metabolism and oxygen level	High values stress aquatic life
pH	Physico-chemical	Regulates chemical balance	Extreme pH harms sensitive species
Dissolved Oxygen	Physico-chemical	Supports aerobic organisms	Low DO reduces fish and invertebrates
BOD	Physico-chemical	Indicates organic pollution	High BOD lowers oxygen availability
COD	Physico-chemical	Shows chemical pollution load	High COD degrades habitat quality
Conductivity	Physico-chemical	Reflects dissolved ions/salts	High levels can stress organisms
Turbidity	Physico-chemical	Measures water clarity	Reduces light and feeding efficiency
Nitrate	Physico-chemical	Nutrient for aquatic plants	Excess causes eutrophication

Phosphate	Physico-chemical	Drives algal growth	High levels trigger algal blooms
Total coliforms	Bacteriological	Show microbial contamination	Indicate poor ecological condition
Fecal coliforms / E. coli	Bacteriological	Show fecal pollution	Increase pathogen risk and stress biota
Heterotrophic bacteria	Bacteriological	Reflect decomposition activity	High counts suggest ecological imbalance

Ecological Indicators: Bacteriological Parameters

Bacteriological parameters gives the river an ecological parameter by providing a biological dimension to assess the river and is used to show the sanitary quality, organic pollution and ecological change. Typical indicators are total heterotrophic bacteria, total coliforms, fecal coliforms, and individual organisms like Escherichia coli, which are used to indicate fecal contamination by sewage or livestock (Maheswari, 2025) [9]. The importance of such contamination is based on not only the health of the people but also the integrity of aquatic ecosystem. Large bacterial loads frequently indicate that there was more organic substrate, nutrient, and waste. In polluted rivers, high levels of coliform and heterotroph bacteria are often associated with an increase in BOD, COD, nitrate, and phosphate levels. This tendency indicates that bacteriological contamination is not a one-sided issue but a component of a more general syndrome of ecological degradation. In addition to the traditional indicator bacteria, the organization of the entire bacterial community can also indicate ecological reactions to environmental gradients. The Cyanobacteria, Alphaproteobacteria, Betaproteobacteria, Gammaproteobacteria, Bacteroidetes, and the Actinobacteria groups were predominant freshwater communities in the Vaal River and varied in terms of abundance by season and water chemistry (UK Centre for Ecology & Hydrology, 2021) [4]. The analysis revealed that bacterial communities were largely dependent on pH, temperature, and levels of inorganic nutrients, whereas opportunistic pathogens were at low levels at certain downstream locations. These results confirm that microbial community structure can be used as a bioindicator of environmental disturbance. Due to a fast bacterial response to nutrients, flow and temperature, as well as pollution, the bacteria can monitor the ecological change earlier than some higher organisms. When stable physicochemical conditions and balanced microbial diversity characterizes a river, it is more likely to support healthy food webs and aquatic biodiversity as compared to rivers with pollution-related bacteria and extreme fecal contamination (Journal of Water Resource and Protection, Patra et al., 2010) [5].

Impacts on Aquatic Biodiversity

Aquatic life or aquatic biodiversity consists of phytoplankton, zooplankton, periphyton, macroinvertebrates, fish, amphibians and microbial groups. These communities are influenced by the quality of habitat, the amount of oxygen, balance of nutrition, flow regime and the level of contamination (Maheswari, 2025) [9]. The ecological tolerance limits cause biodiversity to decrease when physicochemical conditions shift beyond the ecological tolerance thresholds; death, sublethal stress, decreased reproduction, competitive exclusion. The low dissolved oxygen is particularly detrimental since aerobic organisms cannot survive and grow without oxygen. Excessive BOD and eutrophication associated with oxygen depletion is usually accompanied by fish kills, loss of sensitive benthic macroinvertebrates, and simplification of troic structure. Nutrient enrichment can also induce cyanobacteria blooms, altering the light climate, pH, and toxicity in certain instances and inhibiting other microbial and planktonic communities. Bacteriological pollution may additionally worsen the ecological quality by portraying sewage discharges, enhanced decomposition, and high hazard of pathogens. Though not every bacteria is detrimental, the ongoing process of contamination by feces entails a sign of chronic pollution, which changes the processes in the ecosystem and makes it less appropriate to inhabit by aquatic organisms and humans. Therefore, physicochemical and bacteriological stressors and not any one variable are likely to explain the loss of biodiversity in rivers (Zinabu et al., 2024) [6].

Modeling Framework

An efficient river-health model ought to incorporate sources of pollution, water-quality variables, microbial indicators, as well as biodiversity responses. The conceptual pathway starts with anthropogenic drivers that include sewage discharge, agricultural runoff, industrial effluents, and land-use change. These drivers alter physicochemical parameters, include nutrients, suspended solids, conductivity, BOD, COD, among other parameters. The second step of the model encapsulates bacteriological responses, such as an increased coliform density, an increased number of heterotrophs and changes in bacterial community structure. Principal component analysis, redundancy analysis, cluster analysis and diversity indexes techniques are appropriate multivariate techniques that can be used to determine the strongest relationships between environmental variables and microbial assemblage. These techniques can be used to identify the water-quality gradients that best describe ecological variation on a site-season basis (Maheswari, 2025) [9]. The end stage relates physicochemical and bacteriological variables to ecological outcomes including species richness, abundance, evenness, pollution-sensitive taxa and fish or macroinvertebrate guilds. Predictive model can be in a form of multiple regression, generalized linear models, structural equation models, water quality indices or machine-learning based on the data and the goal. In the case of biodiversity-oriented research, integrated models are particularly useful since they consider both direct effects, including oxygen stress on fish, and indirect effects, including nutrient-induced changes in microbial complexity, which modify food webs and habitat-suitability (Heliyon, Isa et al., 2020) [7].

Research and Management Implications

The practical interest of integrating models is in river monitoring and restoration. It assists in determining the areas of pollution hotspots, the areas of intervention priority and seasonal variation as opposed to chronic degradation. It also facilitates ecological risk assessment in the sense that the interaction of various stressors is demonstrated as opposed to considering the variables separately.

The most informative monitoring programs to use in river management should be a combination of:

- Physicochemical indicators, such as temperature, pH, DO, BOD, COD, conductivity, turbidity, TDS, nitrate, ammonium, and phosphate.
- Bacteriological indicators, e.g. total coliforms, fecal coliforms, E. coli as well as community-level microbial analysis where feasible.
- Biodiversity indices and indicators such as plankton diversity, benthic macroinvertebrate diversity, fish assemblages and scores of habitat condition.

This conjoined method enhances interpretation since a site can exhibit chemical moderation, and yet exhibit bacterial disturbances or losses of biodiversity. Similarly, the range of acceptable values of individual variables are not necessarily signs of ecological safety in cases where cumulative stress leads to changes in microbial structure and trophic functioning. Thus, river-health assessment ought to shift to the multi-metric ecological models rather than using single water-quality thresholds (Kumar et al., 2022) [8].

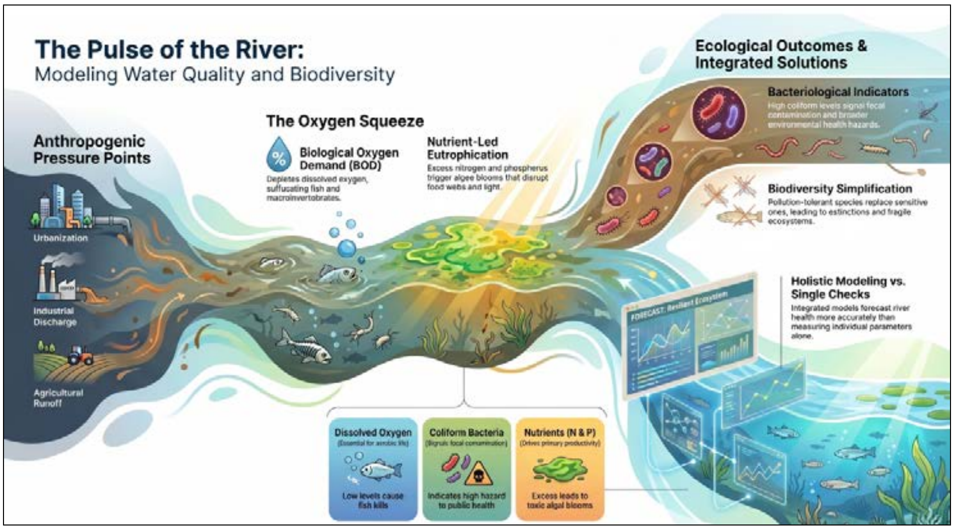

Fig 1: Modeling Water Quality and Biodiversity

Conclusion

Close to each other are the physicochemical and bacteriological parameters which are determinants of river health and aquatic biodiversity. The conditions of the habitats are directly determined by parameters like pH, temperature, dissolved oxygen, nutrients, conductivity, turbidity, BOD, and COD, and the ecological disturbance, organic loading, and pathways of contamination are identified using bacteriological indicators. River studies demonstrate that microbial communities are highly sensitive to pH, temperature, and inorganic nutrient gradients and are thus effective at indicating the condition of an ecosystem.

It is better to model such relationships to have a more robust foundation of understanding and management of freshwater ecosystems compared to individual parameter analysis. It is necessary to have a strong framework to link sources of pollution with water chemistry, biochemical responses, and biodiversity modalities across space and time. The conservation planning, pollution control, and restoration approaches based on such integrated models can foster healthy and biodiverse river systems under the increased anthropogenic pressure.

References

1. Jordaan K, Bezuidenhout CC. The impact of physico-chemical water quality parameters on bacterial diversity in the Vaal River, South Africa. Water SA,2013:39(3):385–396. http://dx.doi.org/10.4314/wsa.v39i3.7
2. Khan MU, Guo J, Gao Y, Zhi H, Wei S, Zhang K, et al. Evaluating a river’s ecological health: A multidimensional approach. Scientific Reports,2024:14:8847. https://doi.org/10.1038/s41598-024-59308-3
3. Sharma P, Gupta A. Towards developing a river health index. Ecological Indicators,2018:85:148–161.
4. UK Centre for Ecology & Hydrology. River water quality monitoring. In The sustainable water management handbook (Chapter 5), 2021. https://www.ceh.ac.uk/sites/default/files/2021-11/sustainable-water-guide-chap5-river-water-quality-v2.pdf
5. Patra AK, Sengupta S, Datta T. Water quality parameters and fish biodiversity indices as measures of ecological degradation: A case study in two floodplain lakes of India. Journal of Water Resource and Protection, 2010, 2(1). https://doi.org/10.4236/jwarp.2010.21010
6. Zinabu E, Negash W, Misgana M. Bacteriological quality and physicochemical analysis of the Kalte River in Wolaita Sodo Town, southern Ethiopia. Journal of Environmental and Public Health, 2024.
7. Isa MA, Allamin IA, Ismail HY, Usman A. Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, northwest Nigeria. Heliyon,2020:6(8):04773. https://doi.org/10.1016/j.heliyon.2020.e04773
8. Kumar SR, Susan V, Pachauri T. Water quality assessment based on physico-chemical and biological analysis of Khari River. Materials Today: Proceedings, 2022.
9. Maheswari R. Analysis of physico-chemical parameters and bacteriology study of river water. International Journal of Fisheries and Aquatic Studies, 2025, 13(5).