

Assessment of Freshwater River Health Using Macroinvertebrate Diversity and Physico-Chemical Parameters

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Abstract: Freshwater ecosystems are among the most valuable natural resources because they support biodiversity, agriculture, fisheries, and human civilization. However, rapid urbanization, industrialization, agricultural runoff, and anthropogenic disturbances have severely degraded river ecosystems and water quality. The present study focuses on assessing freshwater ecosystem health using macroinvertebrate diversity as a biological indicator in association with physico-chemical parameters of water. Macroinvertebrates are highly sensitive to environmental disturbances and therefore serve as reliable indicators of ecological integrity and pollution status in aquatic habitats. The study evaluates the diversity, abundance, and distribution of macroinvertebrate communities in selected freshwater ecosystems and correlates these findings with environmental variables such as temperature, pH, dissolved oxygen, biological oxygen demand, turbidity, conductivity, alkalinity, and nutrient concentration. Sampling was carried out seasonally using standard biological and physicochemical assessment techniques. Diversity indices including Shannon-Wiener diversity index, Simpson's index, and biotic indices were employed to determine ecological health and pollution tolerance levels. The results revealed considerable variation in macroinvertebrate composition across different sites depending on pollution load and habitat condition. Sensitive taxa such as Ephemeroptera, Plecoptera, and Trichoptera were dominant in less disturbed areas, while pollution-tolerant groups including Chironomidae and oligochaetes were abundant in impacted regions. The study demonstrates that macroinvertebrate-based biomonitoring provides an effective, economical, and long-term approach for evaluating freshwater ecosystem sustainability. The findings emphasize the importance of conserving river ecosystems and implementing sustainable management strategies for maintaining biodiversity and water quality.

Keywords: Macroinvertebrates, Ephemeroptera, Plecoptera, Trichoptera, Chironomidae.

1. Introduction

Freshwater ecosystems are among the most significant natural resources supporting life on Earth. Water constitutes nearly two-thirds of the Earth's surface and plays an indispensable role in biological metabolism, ecological balance, and human civilization[1]. Although water is abundant globally, only a small fraction is available as freshwater suitable for human consumption and ecosystem functioning. According to Santra (2005), only 2.5% of the Earth's total water is freshwater, while the remaining 97.5% exists as saline water in oceans. Freshwater resources are distributed among rivers, lakes, groundwater, glaciers, and biological systems, making them extremely valuable for sustaining biodiversity and human welfare.

Rivers and streams represent dynamic lotic ecosystems characterized by continuous water flow, nutrient transport, and habitat heterogeneity[2]. These ecosystems provide habitat for a wide variety of aquatic organisms and support multiple ecosystem services including irrigation, fisheries, drinking water supply, recreation, hydropower generation, and agriculture [3]. Freshwater ecosystems also regulate ecological processes such as nutrient cycling, sediment



transport, and food web interactions. However, increasing anthropogenic pressures including urbanization, industrialization, agricultural runoff, deforestation, sand mining, sewage discharge, and idol immersion activities have substantially degraded freshwater habitats and reduced biological diversity [4].

Water quality degradation directly influences aquatic biodiversity and ecosystem functioning. Physical and chemical alterations in water bodies affect species composition, productivity, and trophic interactions within aquatic ecosystems [5]. Freshwater habitats are highly vulnerable to nutrient enrichment, eutrophication, sedimentation, heavy metal contamination, and organic pollution caused by human activities [6]. Such disturbances alter dissolved oxygen concentration, pH, turbidity, conductivity, and nutrient availability, thereby affecting the survival and distribution of aquatic organisms [7].

Macroinvertebrates are among the most widely used biological indicators for assessing freshwater ecosystem health because they respond sensitively to environmental changes and pollution stress [8]. These organisms occupy different trophic levels and play crucial roles in decomposition, nutrient recycling, and energy transfer within aquatic food webs. Since different macroinvertebrate taxa exhibit varying degrees of pollution tolerance, their diversity and abundance provide valuable information regarding ecological integrity and water quality [8]. Sensitive groups such as Ephemeroptera, Plecoptera, and Trichoptera are generally associated with clean water conditions, whereas pollution-tolerant organisms dominate degraded habitats.

Biomonitoring using macroinvertebrate communities has gained importance because conventional physicochemical methods provide only short-term information about water quality at the time of sampling. In contrast, biological communities integrate environmental conditions over time and offer a comprehensive assessment of ecosystem health [9]. Therefore, combining biological indicators with physicochemical analysis provides a reliable approach for evaluating freshwater ecosystem sustainability and pollution status.

The present study aims to investigate freshwater biodiversity using macroinvertebrate assemblages and to correlate biological diversity with physicochemical characteristics of river ecosystems. The study contributes to understanding ecological health, biodiversity conservation, and sustainable management of freshwater resources in the context of increasing environmental degradation.

Many researchers choose the less costly approach of evaluating and monitoring water quality by employing biotic parameters since it is more cost-effective and time-efficient than the physicochemical technique, which is costly due to the high cost of chemicals and materials [10]. It has been common practice to employ biological markers to evaluate the effects of degradable organic pollutants on lotic ecosystems [11]. Biologists frequently use macroinvertebrates as one of the many biological markers [12]. To varied degrees; these creatures are impacted by poor water quality. They may be divided into three categories: pollution intolerant (sensitive), moderately tolerant, and pollution tolerant. Because they cling to riverbeds, the immobile macroinvertebrates are unable to flee hostile environments and will perish if the water quality falls below what they can tolerate [13]. They respond rapidly to changes in their surroundings and are simple to sample and manipulate [14].

Many species were classified based on a variety of trophic criteria, including the plant:animal ratio in the diet, feeding mechanism, food size, food acquisition behavior, and energy and substance transfers, after a thorough review of the literature on the trophic characteristics of these macroinvertebrates [15]. Following analysis of data from rivers with varying geographic distribution, it was determined that each group should include individuals

who serve a specific purpose in any undisturbed riverine macroinvertebrate population. The macroinvertebrates are anticipated to react to changes in the water body since they are a community that is essential to the aquatic ecosystem's operation. The ability of various macroinvertebrate species to withstand pollution varies [16]. The macroinvertebrate biodiversity of polluted streams will eventually decline. By eliminating macroinvertebrates that cannot withstand pollution, more resources will be available for tolerant creatures to survive and procreate. They reflect the health of the ecosystem because they provide distinct trophic guilds and consumer levels in the food web, which are intimately linked to ecological activities. However, little is known about their contribution to biomass production and their function in the dynamics of the aquatic environment [17]. Compared to marine ecosystems, freshwater habitats are more varied and richer in taxa. The greater economic, visual, and culinary appeal of marine macroinvertebrates may be the reason for their increased attention. Freshwater macroinvertebrates, on the other hand, are more important yet have received less attention. They require more scientific investigation because of their important functions in veterinary and public health [18].

In terms of ecology and taxonomy, macroinvertebrates are a very varied collection of creatures with a wide range of sizes, forms, habitats, and behaviors [19]. These communities might be terrestrial, semi-aquatic, or aquatic. Due to their well-documented reactivity to both organic and inorganic pollution, they are commonly employed in biomonitoring investigations of flowing streams [20]. In the food web, they are typical elements of communities at various trophic levels. Depending on how they feed, they can be divided into several functional groups, such as shredders, which consume living tissue; collectors, or filter feeders, which consume decomposing organic matter; grazers, or scrapers, which consume algae, diatoms, or other materials; and predators, which consume other animals. They are crucial components in the nutrient recycling process in bodies of water. According to Nautiyal et al. (2004), scrapers are the organisms that are most frequently observed adhering to rocks, scraping off, and consuming algae. By filter-feeding or acquiring materials from substrates, collectors ingest fine particle organic matter (FPOM), which is typically detritus. Shredders use maceration to eat coarse particle organic matter (CPOM), which includes detritus and aquatic plants. Lastly, live creatures—usually other macroinvertebrates—are the food source for predators. Trophic structure changes show how a group reacts to disruption or an excess of a specific food supply. As a result, they are crucial components of water bodies' nutrient recycling.

2. Literature Survey

Numerous studies accountings for different variables have been conducted throughout the history of water quality evaluation. The majority of the research appeared to be more concerned with physicochemical factors on a broader scale than with biological ones, especially those pertaining to macroinvertebrates. In the majority of lotic ecosystems, the integration of both of these elements—including the principles of species diversity, population dynamics, habitat quality, species richness, and interrelationships on a wide scale has not yet been finished. This is due to the fact that macroinvertebrates are still relatively new as bio-indicators of water quality. Several studies have demonstrated that changes in environmental circumstances, as well as the structure and function of an aquatic ecosystem, have an impact on the variety and productivity of macroinvertebrates. Numerous researchers have noted that macroinvertebrate fauna offer a useful tool for determining the temporal and geographical quality of water both now and in the past.

In order to examine the water quality of the Cekerek stream in Turkey, Duran and Suicmez (2007) examined the relationships between 55 species of benthic macroinvertebrates and physicochemical parameters. They assessed organic pollution using the Gammarus: Asellus (G: A) ratio and five European biotic indices: the Extended Trent Biotic Index (ETBI), North Carolina Biotic Index (NCBI), Chandler Score (CS), Belgium Biotic Index (BBI), and Revised Biological Monitoring Working Party (Rev BMWP) Score. The biological and physicochemical data they saw showed an overall Class-I water quality at seven sites, with the exception of PO₄, NH₃-N, NO₃, and NO₂, which were found to be higher, most likely as a result of urban sewage and agricultural runoff. Ephemeroptera, Plecoptera, Trichoptera, and Gammarus sp. predominated at these locations, but Asellus sp. was uncommon, indicating that the stream conditions were clean.

Higher invertebrate abundance and richness are indicators of a healthy aquatic environment, according to Wade et al. (2004), who conducted a thorough study of Australian wetlands and offered the use of invertebrates to evaluate water quality. Their abundance and richness can be altered by natural occurrences. The richness and quantity of aquatic invertebrates are influenced by a wide range of dynamic variables, including as temperature, pollution, increasing salinity, draught, and pH.

Dinakaran and Anbalagan (2007) evaluated the diversity trends among various sample sites within protected and unprotected regions and emphasized the human influences on aquatic insects in six streams of the South Western Ghats (India). They focused on whether the primary reason of aquatic insects' presence or absence is anthropogenic influences or physicochemical causes. They used Correspondence Analysis (CA) to examine the faunal structure and computed the Shannon Weiner diversity index, Simpson's diversity index, Pielou evenness index, and Margalef richness index. They calculated the Biological Monitoring Working Party (BMWP) index to assess the biotic integrity of communities and used Principal Component Analysis to ascertain the association between faunal changes and physicochemical factors. Although biotic indexes and richness were lower in the channelized section of the protected area than in the non-channelized section, the study found that the protected areas were healthier and showed high diversity due to the good water quality. However, the overall higher BMWP score, richness, and abundance of EPT taxa suggested that the stream was pristine. By contributing to the intricate food webs, zoobenthos play a crucial role in freshwater ecosystems, according to Covich et al. (1999), who also noted the impact of zoobenthic species on energy flows and nutrient cycling during the conversion of live plants and dead organic material into prey items for larger consumers.

The majority of the functional feeding groups rely on allochthonous organic matter, according to Galdean et al. (2001), who examined the diversity of macroinvertebrates in Brazil's altitudinal lotic ecosystems. They found that moss clumps are important for the structure and distribution of macroinvertebrates.

Benthic macroinvertebrates were used by Sharma et al. (2008) to evaluate the Ninglad stream's water quality. Because of tributary emptying and self-purification, they employed NEPBIOS and NSFQI, which classified stations I and II as having water quality classes III and II, respectively. They believed that, in comparison to the physicochemical technique, the NEPBIOS is a rapid and cost-effective evaluation tool.

3. Research Methodology

Aquaculture, industry, irrigation, residential usage, biodiversity protection, and other factors all depend on the water quality of an aquatic ecosystem. For the purpose of managing and

improving a body of water, data on its physical, chemical, geological, and biological characteristics should be gathered. The current study is based on the monthly variance in these characteristics. Therefore, an effort was undertaken to assess the acceptability of the water from the Vainganga River under investigation based on these water quality indicators.

Area of Study:

The current study was conducted in aquatic environments at five points along the Vainganga River, which flows through the Gondia region of Maharashtra State, India. The district of Gondia spans 5640.51 square kilometers, extending from 20° 39" to 21° 38" N and 79° 27" to 80° 42" E.

Five sample locations were chosen along the Vainganga River, which flows through the Gondia district between latitudes 21° 22" and 21° 38" N and longitudes 79° 47" and 80° 29" E, at an elevation of around 300 to 325 meters above sea level. As shown in Table 1, the water samples were taken from five different sampling locations.

The Vainganga River is the biggest sub-basin of the Godavari River and one of its principal tributaries. Because of its importance due to irrigation and the economy, it serves as the district's backbone and pivot. For those residing within its catchment area, which spans 61093 square kilometers, it serves as a lifeline. It begins in the Satpura range's Mahadeo hills in Madhya Pradesh's Seoni district, where it runs for over 150 km before entering Gondia district at site 1 (Dangorli). At site 3 (Chandori), it bends south and then west, creating a depression that divides the districts of Gondia on its eastern bank and Bhandara on its western bank. Its whole research span was around 120 kilometers long. Along the alluvium on sandy, loamy red and clayey black soil, its water runs over the multi-habitat beds that are made up of rocks, boulders, cobbles, silt, clay, sand, pebbles, gravels, etc. There are several tiny rapids and pools in this shallow, medium-flowing river. With the exception of the wet months, the catchment area is largely clean. A range of habitats, including pools, runs, vegetative regions, and riffles, were included in each sampling site and were deemed typical. The sedimentary, muddy banks include several types of soil particles. Its watershed is characterized by varying degrees of household, industrial, agricultural, and human activities.

Along its catchment region, the river mostly collects surface runoffs from streams, floodplains, forests, and communities, as well as agricultural and urban runoffs. It receives the discharge of the tributaries Bagh, Bawanthadi, and Chulbandh. In the research region, there are no significant chemical industries located on its bank. The lakes and/or streams that are close to the river are where the majority of the companies in this district discharge their wastewater. Along with fishing, other activities along the river under observation include cleaning clothing, caring for animals, cremating dead people, etc.

Description of the Site

Site 1:

This location is located at 21° 59'4.03" N and 80° 19' 34.75" E, close to the hamlet of Dangorli. This is where the Vainganga River meets its tributary Bagh as it enters the Gondia district. This location is around 29 kilometers from Gondia City, the district headquarters, and 318 meters above mean sea level (amsl). Agricultural area, forests, streams, and settlements upstream of the Vainganga and Bagh rivers in the north and east, respectively, provide it with runoff water. It is where human remains are cremated, clothing, animals, and automobiles are washed, and idols are submerged (Plate I).

Site 2:

This location is around 35 kilometers from site 1 and 20 kilometers from Gondia city. At an elevation of 316 meters above sea level, the settlement of Dhapewada is situated on its river at coordinates $21^{\circ} 53'12.13''$ N and $80^{\circ} 29' 48.79''$ E. The communities along its bank, as well as many streams and forests, provide it with runoff water. Since a fair is held there once a year, it is the location of congruence. Other popular activities at this location include washing garments and animals and immersing idols (Plate II).

Site 3:

This location, which is 287 meters above sea level, is close to the settlement of Chandori (Kh) at $21^{\circ} 50'44.97''$ N and $79^{\circ} 95' 34.41''$ E. Here, the Vainganga River and its tributary the Bawanthadi meet. This location is around 32 kilometers from site-II and 40 kilometers from the city of Gondia. Water for this location comes from the Bawanthadi River, as well as runoff from nearby farms, streams, forests, and communities. Villagers from both sides use canoes to cross the river. At this location, operations include washing livestock and clothing, growing fruits and vegetables, and cremating human remains (Plate III).



Figure 1: Site 1 views (where it meets the tributary Bagh)



Figure 2: Perspectives of Site 2 (Congregation site)



Figure 3: Site 3 views (where it meets the tributary Bawanthadi)

4. Conclusion

The current study collected 62024 macroinvertebrate individuals from five distinct locations along the Vainganga River, representing 133 species across 71 families and 15 of 3 phyla. This data provides important insights into the macroinvertebrate ecosystem. Mollusca and Annelida were the next most dominating phylums, after Arthropoda. Ninety-seven species, fifty-seven families, and eleven orders make up the Arthropoda. In contrast to Annelida, which had two orders, six families, and fifteen species, Mollusca had two orders, eight families, and twenty-one species. This figure was sufficient to demonstrate a stable and balanced ecosystem with better water quality and greater variety in the Vainganga River. With Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, and Hemiptera emerging as numerous, dominating, and sensitive faunal groups that comprised the rich and stable environment, Arthropods dominated. The river Vainganga's virgin character is suggested by the molluscans, which are the second most numerous categories, followed by the fewest number of annelids.

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