BHARATI INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY

RESEARCH & DEVELOPMENT (BIJMRD)

(Open Access Peer-Reviewed International Journal)

DOI Link : https://doi.org/10.70798/Bijmrd/03110023

Available Online: www.bijmrd.com|BIJMRD Volume: 3| Issue: 11| November 2025| e-ISSN: 2584-1890

River Health and Mining Based Contamination: An Analytical Study Based on Chemistry, Physical Habitats and Biological Integrity

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Abstract:

Mining is a substantial component of the evolving economy, widely regarded as both indispensable and socially detrimental. It is a significant factor in causing air and water pollution and has a lasting effect on their overall quality. The Ganga is revered as one of India's most sacred and venerated rivers, and is considered to be the birthplace of Indian culture. The main objectives of the present study are to investigate the concentrations of contaminants in both the flowing water and deposits of the River Ganga. By employing technical developments like the "Water Quality Index" (WQI), "Atomic Absorption Spectroscopy" (AAS) and the "Index of Biotic Integrity" (IBI), the study acquire essential knowledge on the magnitude and consequences of pollution on both human well-being and the integrity of ecosystems. Using the WQI, it evaluate many factors such as heavy metal concentrations, microbiological presence, and pH levels to gain a thorough picture of water's purity and the degree of pollution resulting from mining activity. Rivers worldwide have been contaminated with substantial quantities of potentially toxic metals as a result of widespread human involvement and the expansion of manufacturing and agriculture. Furthermore, toxic metal remnants that possess the capacity to cause harm can accumulate in soil, microorganisms, aquatic vegetation, and organisms in rivers that have been contaminatedwater quality and the extent of contamination caused by mining activities. Due to extensive human activities and the growth of industrial and agricultural output, significant amounts of potentially harmful metals have been released into rivers worldwide.

Keywords: *River Health; Water Quality Index (WQI); Index of Biotic Integrity (IBI); Atomic Absorption Spectroscopy (AAS).*

1. Introduction

Rivers and streams offer various ecological services, such as providing clean water in adequate quantity and quality for agricultural, industrial, and residential purposes. They also serve as important habitats for submerged, wetlands, and migratory organisms, and support fisheries and recreational activities for humans in an ecologically sound way [1,2]. The process of development, industrialization, and intense agricultural cultivation has had a detrimental impact on the structure and function of river and stream ecosystems. As a result, the quality of water has significantly deteriorated and the overall integrity of these ecosystems has been compromised [3]. The assessment of the health of river and stream ecosystems is receiving increased attention from scholars worldwide and has emerged as a crucial and progressively significant topic in environmental management globally, particularly in Australia [4], Korea [5], and India.

The Ganga River is the most significant river system in India, characterized by a highly evolved ecology and possessing significant socioeconomic and ecological importance. The water supply serves a population of almost 450 million inhabitants, resulting in a density of nearly 550 people per square kilometer [6]. The Ganga basin has a high population density, with an average of 520 inhabitants per square kilometer [7].

The basin supports a population of almost 300 million individuals in the countries of India, Nepal, and Bangladesh [8]. The basin of the Ganga River, known for its abundant heritage, cultural, and religious significance, encompasses an approximate area of 1,060,000 square kilometers, making it the sixth largest in the world. The river system encompasses around 25% of the Indian subcontinent’s landmass. The Ganga River in India flows through 29 cities classified as class I, 23 cities classified as class II, and around 50 towns. This has resulted in the continual degradation of Ganga water due to the direct release of industrial waste, agricultural runoff, and human activities along the riverbank. This activity results in the buildup of household, industrial, and economic garbage in the river [9].

Direct diagnosis of natural health in rivers and streams isn’t possible due to the influence of external variables such as water supply, hydrology, physical features, riparian zones, and ecosystems[10].Prior research on the evaluation of stream health has mostly concentrated on the several elements that contribute to water purity [11]. Nevertheless, subsequent research has indicated that this approach is inadequate for assessing the ecological well-being of the freshwater ecosystem.

In order to tackle this issue, two significant methodologies have been employed to assess the conservation well-being of the river. There are two indices used to measure pollution levels: the IR spectroscopy, and WQI, which is based on fish populations. The WQI classic was initially proposed by Beach and subsequently refined by numerous researchers in various global locations to assess the chemical well-being condition of the ecosystem [12].

Rivers are very vulnerable ecosystems worldwide [13], facing a multitude of challenges on a global scale. The ingestion of wastewater resulting from human activity has a detrimental effect on aquatic ecosystems. Organic pollution in rivers fosters the growth of microbes, resulting in a decline in oxygen levels and disruption of the entire river ecosystem[14]. The proliferation of river projects and subsequent fragmentation of river systems has a profound impact on the composition of habitats, functioning of ecosystems, and processes, hence constituting a severe threat to biodiversity [15]. The confluence of industry, urbanization, climate change, and human-induced disruptions has inflicted substantial damage onto the exceedingly fragile riverine systems [16]. It is a well-established fact that human activities and influences have a substantial effect on the chemical and physical characteristics of streams which consequently impacts the biodiversity of aquatic ecosystems.

1.1 Contamination in River

The contamination of hefty metals in river water and sediments has been a significant environmental concern, particularly in the past decade. This is due to the abundance, long-lasting nature, and harmful effects of these metals[17-18].The rapid development of cities has led to a significant increase in heavy metal contamination in river water and surface sediments. This is mostly due to the lack of adequate measures to maintain water and sediment quality and hygienic infrastructure in line with population growth and urbanization. The presence of heavy metals in the environment is mostly attributed to both natural and human activities [19].

Anthropogenic activities and natural processes release a significant amount of toxic heavy metals into the environment, leading to contamination in aquatic ecosystems [20]. Geologist corrosion, industrialized metal disposal, and metal leakage from rubbish, solid waste piles, humans and animal waste are significant contributors of heavy metals. In addition, the presence of metal pollutants in aquatic ecosystems can be attributed to the negative impacts of uncontrolled urbanization and disorganized industrial development [21]. These activities have the potential to produce significant amounts of pollutants in sediment and water, leading to pollution in the aquatic environment.

1.2 Mining based contamination

River faces a dual danger from climate change and rising pollution levels, which have emerged as a significant global sustainability problem [22]. In the present situation, since the need for freshwater is increasing, the availability of clean and disease-free water is becoming more limited [23]. Anthropogenic activities can lead to the presence of trace elements, including heavy metals, in both surface and groundwaters. The health of rivers and the trophic conditions within them are mostly influenced by regional seasonality, particularly in the Asian monsoon region. Prior research has demonstrated that Asian lotic wetlands are greatly influenced by the flow caused by the season, which has a considerable impact on the composition of fish [24]. During this time, the fast flow of rivers decreases the amount of time that water stays in an aquatic system, known as “Water Residence Time” (WRT). This has a direct impact on the level of nutrients, biological material, and the accessibility of light, which in turn affects the productivity of sestonic chlorophyll-a (CHL-a) [25]. Likewise, the flow caused by the monsoon can significantly affect the movement of fish communities.

Mining, while crucial and essential for human progress in society, speeds up natural processes and raises the probability of releasing harmful materials at elevated rates in nearby regions. The production of substantial quantities of solid waste and discharges resulting from mining operations poses a significant risk of contaminating soils and water bodies due to the potential dispersion of trace metals by natural forces such as wind and rain, as well as accidental events [26]. Mining is often regarded as one of the most environmentally detrimental human activities due to various factors.

The mining activity is situated in a highly ecologically vulnerable region in Moatize due to its proximity to waterways. The local population in this region utilizes river water for various uses like as irrigation, agriculture, livestock rearing, and human necessities like drinking and cooking, without subjecting it to any form of treatment. Furthermore, a majority of households, namely over 65%, rely on water sourced from unguarded boreholes and rivers. Riverside farmlands are cultivated utilizing conventional methods that incorporate animal manure together with fertilizers and insecticides to grow crops such as maize, the squash, potatoes, nuts, and veggies.

This study examines how mining contamination affects river health. It focuses on chemical composition, physical environments, and biological well-being. This study seeks to understand the intricate links between quarrying and riverbed ecosystem degradation. The goal is to better understand the complex mechanisms that regulate river health in mining-affected areas. This research finds solutions to environmental harm and resource sustainability. The text encompasses the overview of the study, focusing on the Introduction of “River Health and mining based contamination”. The work provides a comprehensive review of the study, with a specific focus on the Introduction section which examines the relationship between river health and contamination caused by mining activities. The paper offers an extensive literature review and presents a methodology that utilizes complete research methods to analyze the presence of pollutants in a river. The text additionally includes the findings and examination gained from the study. Lastly, it provides conclusion of the study.

2. Review of Literature

Mamun et al., (2022) [27] assessed the ecological condition of a temperate riverover a period of ten years (2011–2020). The composition of water chemistry, trophic indicators, and tolerance guilds were mostly shaped by the patterns of “Land Use and Land Cover” (LULC). The impacts of LULC as well as water quality on the relationships between trophic levels and tolerance of fish communities, as well as the assemblages and structures of these communities, and the overall health of the river, were assessed using models based on linear regression and “Canonical Correspondence Analysis” (CCA). The results suggested that the decline and fluctuation of ecological river health were mainly impacted by the land use pattern and the installation of tangible obstacles related to the Asian monsoon.

Ouma et al., (2022)[28] determined that the increase in heavy-metal production in the South African (SA) region worsened the adverse effects on regarding the well-being of both humans and the environment.Significant advancements were achieved in the development of “Rapid Bioassessment Schemes” (RBS) for SA aquatic environments. Significant advancements were achieved in the creation of RBS for SA aquatic environments.

Akindele et al., (2023) [29] aimed to assess the “Biological Water Quality”(BWQ) of this river, which holds historical and global significance, through the use of ecotoxicological methods. Specimens were gathered from 3 ecological compartments during both the arid and rainy seasons within the portion of the river that traversed the UNESCO site. Hence, it is advisable to divert the incoming waste discharges away from the river or another water-based source.

SangeethaMohanachandran et al., (2023) [30]observedthe different assemblages of living species that was essential for assessing the overall health of a river. Assessing the extent of deterioration was crucial in order to determine the appropriate measures for river restoration. An assessment was conducted to evaluate the ecological status of the Tapti River in Central India. The evaluation utilized a fish-based “Index of Biotic Integrity” (IBI) approach. The study highlighted the importance of applying efficient management and mitigation techniques to restore the health and prosperity of the aquatic environment.

MariolaKrodkiewska et al., (2022) [31]evaluated the ecological state of rivers located in the Oder river and Vistula basins, which are affected by coal extraction activities. This study utilized microorganisms as indicators of water emissions, measuring their biological reaction. The streams in the most industrialized region of this area were determined to exhibit more unfavorable characteristics. The findings unveiled significant disparities in the limits associated with river salinity and loads of nutrients in the examined rivers.

Lee-Ann S. et al., (2020) [32] utilized a multi-indicator method to evaluate and compare the ecological health of the contaminated rivers that flowed into the very nutrient-rich Roodeplaat Dam. Both abiotic factors and biological indicators suggested that this ecosystem was affected by several adverse influences. The findings indicated that metals, faecal coliform bacteria, and elevated nutrient levels contaminated all three rivers, resulting in the saturated condition of the receiving impoundment.

Rico-Sánchez et al., (2022) [33] asserted that mining significantly contributed to pollution on a global scale, causing substantial disruptions to the ecosystem. The study assessed the ecological harm caused by mining activities by analyzing aquatic “Macroinvertebrates Assemblages” (MA). Three distinct environmental conditions were discovered, each associated with different microorganisms. Many families of apparently sensitive MA were limited in the past due to excessive levels of heavy metals, fertilizers, and salt.

MdMamun et al., (2020)[34] analyzed the microbial and biologic state of the creek was assessed using the many-metric “Water Pollution Index” (WPI) and IBI models. Furthermore, the results from the nutritive and endurance indicator analyses were consistent with the analytical data. The result of the study suggested that pesticide pollution had a direct impact on the overall health of biological ecosystems.

WenqiGaoet al., (2023) [35] emphasized the significance of taking into account seasonal influences when identifying major river ecological indicators. The IBI approach was used for managing river ecosystems. The findings enhanced our understanding of the ecological well-being and established appropriate guidelines for managing the Yangtze River. These findings might have been relevant to other major rivers in various locations.

3. Methods and Materials

3.1 Study Area

The Ganga River is a significant river basin in India, encompassing approximately 26% of the nation's territory, which is around 8,61,404sq km. It is the biggest river reservoir in India as a percentage of catchment areas. The Ganga River structure extends across India, Nepal, and Bangladesh. The Ganges River begins its journey at Gomukh, the endpoint of the Gongotri Glacial in the Himalayas. Upon the melting of the ice from these glaciers, it gives rise to the pristine waters of the Bhagirathi River. Research carried out in 1983 on water specimens collected from the upper portion of the Ganga at Patna has verified. The metropolis of Patna, which spans an area of 100 square kilometers, is divided into five regions: "Digha, Beur, Saidpur, Pahari, and Karmalichak". The former Pahari Zone of Patna has been divided into two zones, namely Zone-IV A-S and V, according to the current sewage scheme. This area contains a "Sewage Treatment Plant" (STP) located at the Pahari STP site, which has a capacity of 25 "Million Liters per Day" (MLD). The first 65 kilometers of the river, where there is little influence from tides, were examined using four sampling locations that were about equally spaced apart (Figure 1).

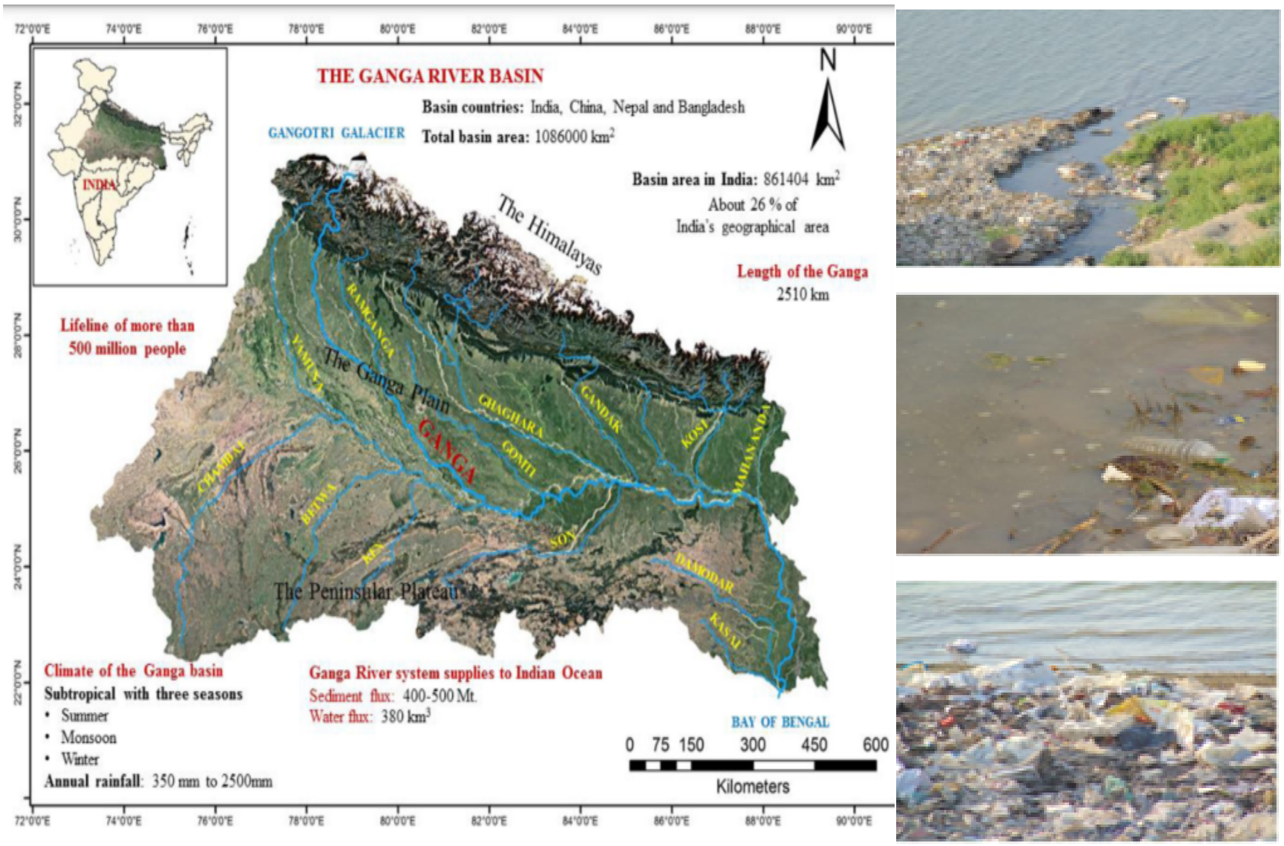

Figure1:Map of India with sediment sampling at Ganga River.

3.2 Environmental Threats to Ganga River Basins

We are currently in the anthropocentric, a newly defined geological period characterized by the significant influence of human activities on the planet's ecosystems[36]. The term "Anthropocene" denotes the epoch in

Earth's history during which human beings have emerged as a substantial geological force, signifying a shift from the Holocene epoch. Across the globe, numerous experts support the idea that the beginning or intensification of the Industrial Revolution marks the commencement of the Anthropocene [37]. Although the Ganga River offers a range of advantages, it is in an unhealthy state. The Ganga River ecology is under threat from various factors including a population explosion, urbanization, intensive agriculture, and industrialization. These drivers pose risks such as flow alteration, excessive harvesting, contamination, microbiological invasion, global warming, and destruction.

3.3 Sampling and data analysis

The samples of groundwater were gathered from multiple public and tube wells, taking into account factors such as main villages, agricultural patterns, and rock types. Figure 1 displays the sites where groundwater samples were taken. The water samples were stored in 500-milliliter pre-cleaned polyethylene bottles. Prior to collection, the glass containers were rinsed with the corresponding samples. The water quality kit was utilized to measure the EC, pH, and TDS at the site. The amount of cations and anions were determined using the procedures specified by APHA. The precision of the water quality variables was evaluated by computing the "Ionic Balance Error" (IBM) using the subsequent equation:

$$\text{IBM}=[(\sum cations - \sum anions) \div (\sum cations + \sum anions)] \times 100(1)$$

The concentrations of all both cations and anions were measured in meq/L. The computed ionic balance error fell within the acceptable range of ± 11%.

3.4 An Ecohydrological strategy to manage the Ganga River in an integrated manner

"Integrated Water Resource Management"(IWRM) is a methodical strategy that enables the coordinated progress and governance of water, land, and related resources. Our goal is to maximize the financial and social well-being in a just manner, while also maintaining the long-term sustainability of vital ecosystems. It is a holistic strategy that considers the entire river basin as the foundation for all planning activities. It incorporates knowledge from several fields of study and emphasizes the importance of communication and collaboration between both stakeholders and decision-makers [38]. Ecohydrological practices refer to ecological strategies that enhance the long-term viability of river ecosystems and the overall welfare of humans by effectively managing "Water Resources, Biodiversity, Ecosystem Services, and Resilience" (WBSR)

3.5 Water Quality Index (WQI) Model

The evaluation of the water's purity primarily requires an understanding of parameters. A standard is acknowledged for each parameter. The integration of complex data and the creation of a score in defining water quality problems promote comprehension of such issues. By disregarding the specific characteristics, the WQI has the benefit of evaluating the level of water quality.

The WQI is a widely utilized method for evaluating the quality of groundwater and determining its suitability for different applications, such as drinking and irrigation. The Study estimated the relative weights (wi) for some parameters including pH,$(C_2H_4)_n$, $(C_{10}H_8O_4)_n$, Ca2, etc. using the eq 2.

$$\text{Wi}= W_i/\sum_{i=0}^{n} W_i \qquad (2)$$

4. Result and Discussion

4.1 Identification of micro plastics (ATR-FT-IR spectroscopy)

It has become a crucial method for identifying MP and evaluating the health of rivers, as well as detecting contamination caused by mining activities. It can precisely determine the types and origins of MP pollution by examining the IR spectra of MP collected from sediments in rivers. ATR-FT-IR scanning emerged as an essential technique for identifying MP and assessing river health, as well as detecting mining-related contaminants. Through the analysis of the infrared spectra of MP obtained from river sediments, the types and sources of MP pollution can be accurately identified.

Table 1: Typical FT-IR absorption peaks for various types of microplastics found in the Ganga river

Polymer	**Wavenumber (cm^-1)**	**Peak Assignment**
Polyethylene	2916, 2848, 1463	CH2 stretching and bending
Polypropylene	2951, 2870, 1458	CH3 stretching and bending
Polystyrene	3025-3080, 1028	Aromatic C-H stretching and C=C stretching
PET(Polyethylene Terephthalate)	1720, 1295, 1085	C=O stretching and C-O-C stretching

Table 1 Serves as a fundamental guide for analyzing FT-IR spectra of microplastics discovered in the Ganga River. It highlights the distinctive peak intensities linked to various polymer types.

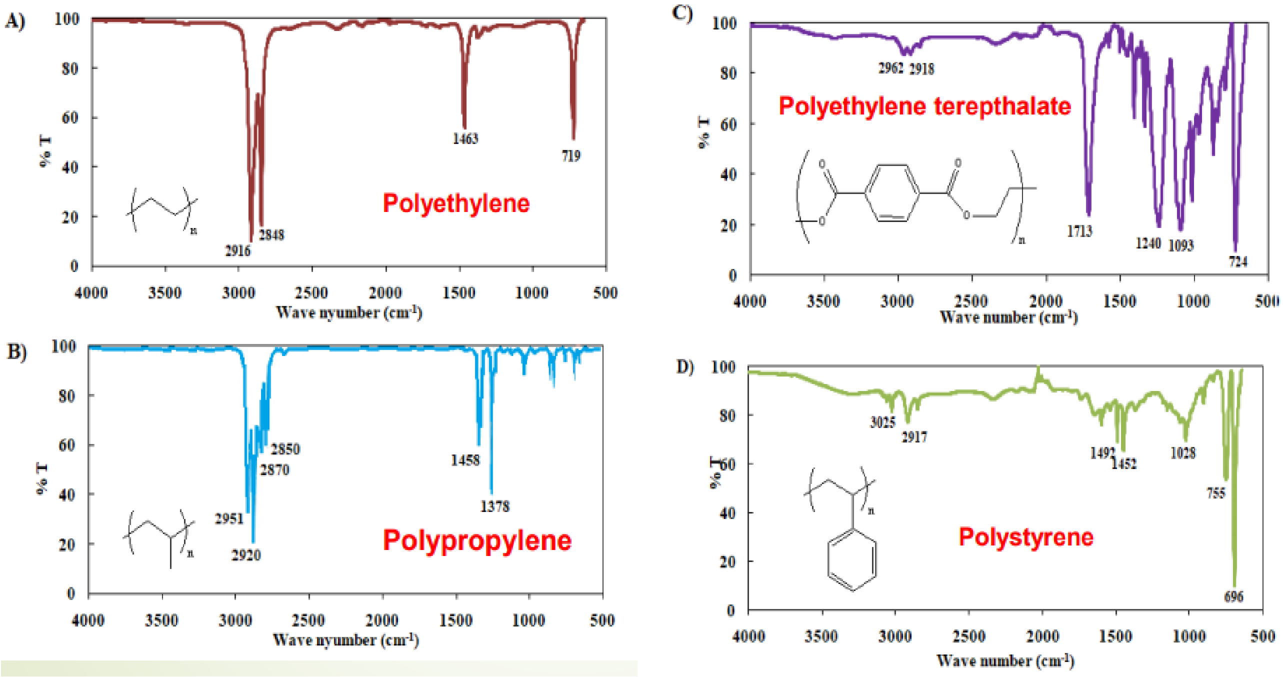

Figure 2: FT-IR spectrum of Microplastic found from Ganga

The findings of ATR-FT spectroscopy is shown in Figure 2 which contains the 4 different graphs showing the presence of different type of microplastic like polyethylene, polypropylene, polystyrene, polyethylene terephthalate in Ganga. The graph is plotted against T% and wave number(cm^{-1})

4.2 Metal analysis using “Atomic Absorption Spectroscopy” (AAS)

Table 2: Heavy metals using AAS at various wavelengths for different samples

Sample	Element	Wavelength (nm)	Concentration (ppm)
Sample 1	Chromium (Cr)	357.9	4.1
	Cadmium (Cd)	229.6	3.6
	Lead (Pb)	284.2	5.2
Sample 2	Lead (Pb)	283.3	7.8
	Cadmium (Cd)	228.8	2.9
	Chromium (Cr)	357.9	3.5
Sample 3	Lead (Pb)	283.3	6.5
	Cadmium (Cd)	228.8	4.3
	Chromium (Cr)	357.9	5.9

In Table 2&Figure 3 three samples (sample 1, 2, and Sample 3) taken from different locations along the Ganga River were examined for the existence of lead, cadmium, and chromium using (AAS) at their respective wavelengths. The levels of these toxic metals are documented in the table. These measurements aid in the surveillance of water quality and the identification of probable sources of pollution in the river.

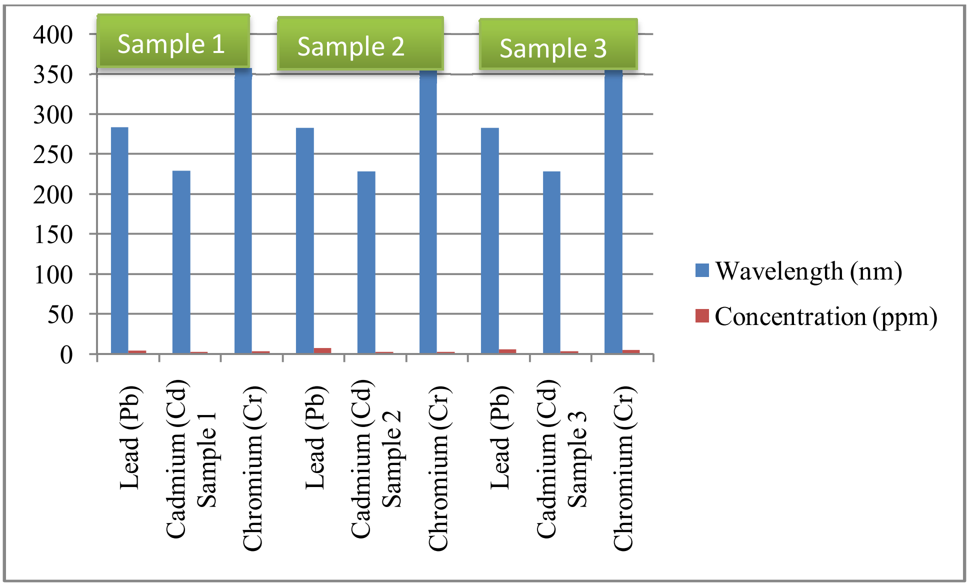

Figure 3:Heavy metal analysis by AAS

4.3 WQI based health and mining contamination

A WQI is employed to condense the assessment of water purity into a solo mathematical value, facilitating comprehension and communication of the overall condition of a water body. When evaluating the effects of mining contamination on water eminence and the resulting health risks, the WQI is especially useful for measuring the impact of mining activities on quality and the consequent health hazards connected with contaminated water.

Table 3: WQI based health and mining contamination

Parameter	**Health-based Contamination (WQI)**	**Mining-based Contamination (WQI)**
pH	7	6
Dissolved Oxygen (DO)	8	6
Chemical Oxygen Demand (COD)	6	8
Biochemical Oxygen Demand (BOD)	5	6
Total Suspended Solids (TSS)	6	7
Heavy Metal Concentrations (e.g., Lead, Mercury, etc.)	4	8
Total Coliform Count	4	6
Dissolved Heavy Metal Concentrations	5	8

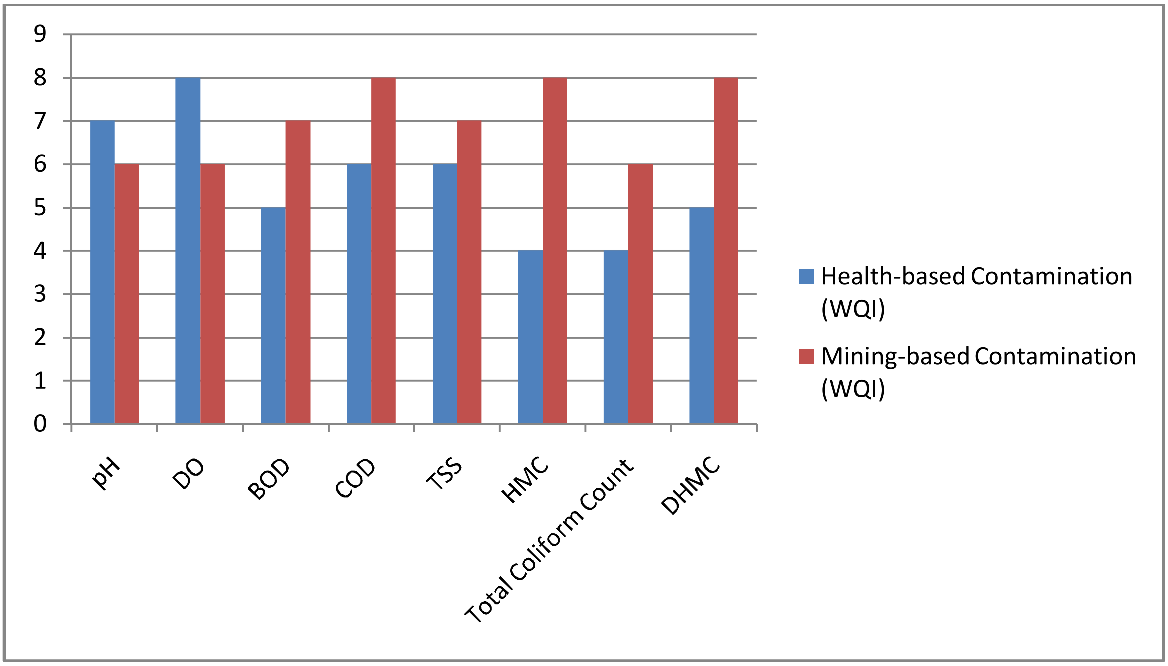

Figure 4: Showing Health based and Mining based contamination

Table 3 and Figure 4 display the WQI values, ranging from 1 to 10. A value of 1 indicates very low water quality, while a value of 10 indicates good water quality. A higher WQI implies greater water quality for each measure. Contamination related to health The WQI values are typically lower when compared to contamination caused by mining activities, indicating the more immediate and direct health hazards associated with metrics.

5. Conclusion

The Ganga River, which is vital for the livelihood of millions of people in India, is confronted with a formidable problem arising from contamination caused by both health-related issues and mining activities. The WQI and IBI are technological tools that provide important information on the extent of contamination and its many effects. By utilizing the WQI, we are able to analyze a multifaceted representation of water quality, taking into account factors such as heavy metals, microbiological content, and pH levels. These characteristics serve as indicators of potential health hazards and the degree of pollution caused by mining activities. Meanwhile, IBI focuses on studying the environmental condition of the river by using the number and variety of invertebrate genera as indicators to measure the effects of contamination. By combining WQI and IBI evaluations, we may obtain a thorough picture of the current state of the Ganga river. This knowledge can then be used to develop targeted actions to reduce pollution sources and restore the overall health of the river ecosystem. Nevertheless, it is crucial to maintain constant watchfulness and engage in cooperative endeavors to observe alterations, counteract persistent stresses, and guarantee the revival of the Ganga, so protecting its essential significance for both the environment and local populations.

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Citation: **Sarkar. M.,** (2025) “River Health and Mining Based Contamination: An Analytical Study Based on Chemistry, Physical Habitats and Biological Integrity”, *Bharati International Journal of Multidisciplinary Research & Development (BIJMRD)*, Vol-3, Issue-11, November-2025.