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A Review of Hydro-Chemical Characteristics and Contaminant Sources in Surface Water Bodies of Jharkhand

Kumari Asha Verma
Research Scholar
Department of Chemistry
Faculty of Science
Radha Govind University, Ramgarh Jharkhand

Abstract

Jharkhand, a mineral-rich state with extensive industrial and mining activities, is increasingly facing surface water quality degradation due to both natural geochemical processes and anthropogenic pressures. The review synthesizes data on physico-chemical parameters such as pH, electrical conductivity, total dissolved solids (TDS), hardness, alkalinity, and major ions including calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, and fluoride. Several studies also report the presence of heavy metals like iron, manganese, arsenic, and lead, especially near mining zones and industrial clusters. Analysis of these findings reveals significant spatial and seasonal variations in water quality. Surface water in regions adjacent to coalfields, iron ore mines, and industrial zones often exhibits elevated contaminant levels, exceeding the permissible limits set by BIS and WHO standards. Major sources of contamination identified across studies include mine drainage, industrial effluents, agricultural runoff, and untreated domestic sewage. Further, previous studies have applied hydro-chemical facies analysis, Piper diagrams, and multivariate statistical techniques like Principal Component Analysis (PCA) and Cluster Analysis (CA) to understand the dominant water types and pollution mechanisms. These analytical approaches confirm that the water chemistry is influenced by both rock-water interactions and anthropogenic activities. The review highlights the urgent need for integrated water resource management, regulatory enforcement, and continuous monitoring to safeguard water quality. It also calls for greater community involvement and inter-agency collaboration in mitigating water pollution. The compiled findings serve as a valuable resource for environmental planners, researchers, and policymakers working toward sustainable surface water management in Jharkhand.

Key Words: Hydro-Chemical Analysis, Surface Water, Water Pollution.

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- **Introduction:**

Jharkhand, a state in eastern India, is endowed with abundant natural resources, including rivers, lakes, and reservoirs, which serve as critical surface water bodies for domestic, agricultural, and industrial purposes. However, rapid industrialization, mining activities, urbanization, and agricultural runoff have significantly impacted the hydro-chemical characteristics of these water bodies, raising concerns about water quality and sustainability. The surface water systems, including major rivers like the Damodar, Subarnarekha, and Koel, are vital for the region's socio-economic development but face challenges from contamination due to heavy metals, organic pollutants, and nutrient enrichment. Understanding the hydro-chemical properties of these water bodies is essential to assess their suitability for various uses and to identify contamination sources that threaten ecological and human health. Previous studies have highlighted key determinants such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), and heavy metal concentrations as critical indicators of water quality in Jharkhand. These studies also underscore the impacts of anthropogenic activities, such as mining and industrial effluents, alongside natural factors like geological weathering, on water chemistry. The contamination of surface waters has led to adverse effects, including reduced potability, impaired aquatic ecosystems, and health risks for communities dependent on these resources. This study synthesizes findings from prior research by scholars to evaluate the hydro-chemical characteristics of surface water bodies in Jharkhand, focusing on key determinants and their implications. By analyzing existing literature, it aims to provide a comprehensive understanding of water quality dynamics and contaminant sources.

- **Objectives**
  1. To evaluate the hydro-chemical characteristics of surface water bodies in Jharkhand based on key parameters such as pH, DO, BOD, TDS, and heavy metal concentrations.
  2. To identify the primary sources of contamination in surface water bodies and assess their environmental and socio-economic impacts.

- **Methodology**

This study is based on a systematic review of previous research conducted by scholars on the hydro-chemical characteristics of surface water bodies in Jharkhand. Relevant literature, including peer-reviewed articles, reports, and books, was collected from academic databases and institutional publications. The analysis focuses on studies that measured key water quality parameters (e.g., pH, DO, BOD, TDS, and heavy metals) and identified contaminant sources such as industrial effluents, mining activities, and agricultural runoff. Data from these studies were synthesized to evaluate spatial and temporal variations in water quality and to assess the impacts of contamination on ecosystems and human health. The methodology involves qualitative and quantitative comparisons of findings to highlight key determinants and their implications.

- **Review of Related Literature:**

A review of literature is a detailed summary and critical evaluation of existing research, including articles, books, and reports, relevant to a specific topic. It synthesizes key findings, methodologies, and gaps to establish the current state of knowledge. In scientific research, it plays a vital role, it provides context, showing how the study fits into the field. Similarly, it identifies gaps where further research is needed, justifying the study's purpose. A review of literature also informs a researcher about methodology by highlighting effective approaches and avoiding past errors. It supports the theoretical framework, grounding the research in established concepts. By preventing duplication, it ensures originality. It also aids in developing hypotheses based on prior trends or contradictions. Finally, a thorough review enhances the study's credibility by demonstrating the researcher's expertise. Thus, it is essential for building on existing knowledge, addressing gaps, and contributing meaningfully to science. Given the significance of the proposed research topic, a considerable amount of prior work has been conducted; the following are some notable studies that have contributed to this area-

1. **Chatterjee et. al. (2010)**, titled "Water Quality Assessment Near an Industrial Site of Damodar River, India," evaluates water quality parameters, focusing on coliform bacteria abundance at a point source of the Damodar River (24°26′ N, 86°53′ E), West Bengal, India, from 2004 to 2007. The site, impacted by mining and industrial effluents, was sampled monthly, revealing high levels of coliform bacteria, Escherichia coli and Streptococcus sp., ranging from 2,600 to 20,000 CFU/100 ml, with peak abundance during the post-monsoon period (September–December). A positive correlation ($r = +0.868$, $df = 34$) was observed between the two bacterial species, with their relative abundance expressed as y(E. coli) = 1.41x(Streptococcus) − 8.07. Principal Component Analysis identified three factors explaining the variance in environmental variables. Physicochemical parameters consistently exceeded WHO and regulatory standards, indicating polluted water. The presence of coliform bacteria highlights the need for effective pollution control at the source and remediation strategies to ensure safe domestic water use from the Damodar River at this site and downstream.
2. **Kumar and Singh (2020)** conducted a hydrogeochemical study of surface and subsurface water resources in the Raniganj coalfield area, Damodar Valley, India, analyzing 49 water samples to assess water quality and major ion chemistry. The study revealed that both groundwater and surface water were alkaline, with dominant anions following the order $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > F^-$, and cations as $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ in groundwater and $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ in surface water. The primary hydrogeochemical facies were Ca-Mg-HCO_3 and Ca-Mg-Cl for groundwater, and Ca-Mg-HCO_3, Ca-Mg-Cl, and Na-HCO_3-Cl for surface water. Gibbs plots, scatter plots, and ionic ratios indicated that water chemistry was controlled by rock weathering, sulphide oxidation, and ion exchange processes. Water quality assessment showed that 36% of groundwater and 21% of surface

water samples were of poor quality, with elevated levels of F^-, Ca^{2+}, Mg^{2+}, SO_4^{2-}, and total hardness exceeding Bureau of Indian Standards limits for drinking. High salinity, residual sodium carbonate, Kelley index, percent sodium, and magnesium hazard at some sites restricted irrigation suitability, necessitating effective water management strategies.

3. **Sinha (2021)** investigated heavy metal pollution in the Subarnarekha and Kharkai rivers near Jamshedpur and Ghatshila, India, focusing on the impact of industrial wastewater from steel and copper plants. Conducted from April 2004 to October 2006, the study analyzed surface sediments and wastewater discharge samples for heavy metals (Fe, Cr, Mn, Co, Ni, Cu, Zn, Cd, Pb) using Atomic Absorption Spectrophotometry (AAS). The fractional analysis of sediments identified metals in four phases: adsorbed/ion-exchangeable, oxide coating, organic solids, and crystalline. Only the first three phases were bioavailable, while the crystalline phase was not. The study found that the geochemistry of surface sediments provided a cumulative assessment of pollution, reflecting the impact of untreated domestic and industrial wastewater. Higher metal concentrations were observed near industrial discharge sites, particularly at Ghatshila's copper plant and Jamshedpur's steel plant. The results highlight the rivers' pollution load and its potential ecological impact, emphasizing the need for improved wastewater management to mitigate metal contamination and protect water quality.
4. **Maity & Maiti (2022)**, in a study titled *"Evaluation of Spatio-Temporal Variation of Water Quality and Source Identification of Conducive Parameters in Damodar River, India,"* investigates the water quality of the Damodar River, a highly polluted stretch in the Ganga River basin, West Bengal. Covering six years (2014–2019), the study analyzes 24 water quality parameters across 11 monitoring sites selected based on potential pollution sources. Multivariate statistical techniques, including Factor Analysis (FA), Cluster Analysis (CA), and Discriminant Analysis (DA), were employed to assess spatial and temporal variations. FA identified key seasonal parameters, while stepwise DA highlighted ammonia, dissolved oxygen (DO), potassium, temperature, total coliform, total fixed solids (TFS), and turbidity as primary contributors to seasonal water quality variations. CA grouped sampling stations into three clusters, revealing spatial variations influenced by ammonia, BOD, calcium, chloride, conductivity, DO, sodium, sulfate, temperature, alkalinity, TDS, hardness, TSS, and turbidity. The study notes higher pollution levels during the monsoon season due to combined point and non-point sources, with the middle course being more polluted due to urban and industrial activities. The Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) confirmed poor water quality across all sites and seasons, aligning with multivariate analysis results.
5. **Singh et al. (2017)**, In a study examined surface water contamination near the Jharia coalfield in Jharkhand, using a modified Water Quality Index (WQI) to assess water quality changes. Eighteen surface water samples were collected from

mining areas, analyzing nine parameters: pH, total hardness, calcium, magnesium, bicarbonate, chloride, nitrate, sulphate, and total dissolved solids (TDS). The cation dominance was $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$, and anions followed $HCO_3^{-} > SO_4^{2-} > Cl^{-}$. The WQI results indicated 17% of samples were in the "good" category, 61% in "poor," and 22% in "very poor." High WQI values were driven by elevated TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, and SO_4^{2-}, showing strong correlations among these parameters. Most water quality parameters exceeded Bureau of Indian Standards (BIS) limits, rendering the water unsafe for drinking without treatment. The study highlights that mining activities significantly contribute to surface water contamination, necessitating salinity control measures to ensure water suitability for human consumption and environmental sustainability.

6. **Prathap & Chakraborty (2020)** in his investigation analyzed surface water quality in Charhi and Kuju coal mining areas of Jharkhand, collecting samples from 31 locations to assess physical and chemical parameters. Statistical analyses, including ANOVA and Pearson correlation, revealed significant site-wise and seasonal variations in 6 and 13 of 15 parameters, respectively. Strong correlations were found between TDS-EC (r^2 = 0.74–0.99) and total hardness-HCO_3^{-} (r^2 = 0.95–0.98), with scatter plots showing positive interrelationships among Ca, Mg, and HCO_3^{-} across seasons. While the Water Quality Index (WQI) suggested good quality for most samples, the health water quality index indicated poor quality due to high metal concentrations (As, Fe, Mn, Se). The study underscores that, despite early-stage mining, contamination is increasing, particularly from heavy metals, posing risks to agricultural and domestic water use. These findings provide baseline data for managing pollution in similar mining regions globally.
7. **Pandey et al. (2023)** in his study monitored surface water quality in five dams (Hatia, Kanke, Getalsud, Galudih, Chandil) in Jharkhand's Subarnarekha river basin, assessing seasonal variations and land use impacts from 2016 to 2021. Water samples were analyzed for pH, dissolved oxygen, BOD, calcium, magnesium, hardness, TDS, suspended solids, alkalinity, and chlorine, compared against WHO and Indian standards. The Water Quality Index (WQI) indicated variable water quality, ranging from good to poor, suitable for human activities with pre-treatment. Land use land cover (LULC) analysis using ArcGIS showed 87–95% accuracy, revealing significant changes. NDWI indicated increased drought areas, and NDVI showed a massive decline in dense and moderate vegetation across all sites. These findings suggest that urbanization and mining are driving water quality deterioration and vegetation loss, necessitating improved land management practices to ensure sustainable water use and environmental health.
8. **Singh et al. (2013),** he evaluated surface water quality in the West Bokaro Coalfield, Jharkhand, using the Water Quality Index (WQI) to assess 14 samples from rivers and ponds. Parameters tested included pH, TDS, total hardness, turbidity, bicarbonate, alkalinity, calcium, magnesium, fluoride, chloride, nitrate, and sulphate. WQI values ranged from 36.2 to 125.5, with 28.6% of samples in the

"good" category, 42.9% "poor," and 28.6% "very poor." Approximately 71.5% of samples were unsuitable for direct consumption, requiring treatment. Mining activities were identified as a primary cause of water pollution, degrading both quality and quantity. The study highlights the urgent need for water treatment and pollution control measures to mitigate the impacts of mining on surface water resources, ensuring their suitability for drinking and other uses.

9. **Kumar et al. (2019)** In a study conducted a comparative analysis of surface water quality in Basagarh pond, Hatia, Jharkhand, during the pre-monsoon season of 2019, focusing on physico-chemical and microbiological parameters. Data from Table 1 and Figures 2–5 revealed seasonal fluctuations in water quality. Hardness, sodium, potassium, sulphate, alkalinity, and chloride levels increased from March to April, peaking in April (hardness: 284 mg/L, alkalinity: 36 mg/L) due to excessive summer evaporation, then decreased in May due to slight rainfall, and rose again in June. Dissolved oxygen (DO) decreased from March to April, while biochemical oxygen demand (BOD) increased, with both parameters rising in May due to rainfall and decreasing in June. Fluoride, iron, and arsenic concentrations slightly increased in April, with fluoride consistently exceeding IS 10500:2012 standards, rendering the water unsafe for drinking. Manganese levels remained stable. Microbiological analysis using the Most Probable Number (MPN) method showed high total and faecal coliform counts, indicating severe bacterial contamination. Temperature peaked in April, while pH remained stable (7.38–7.65), slightly dropping to 6.53 in June. Conductivity and turbidity peaked in May (294 µS, 49 NTU) due to rainfall. The study highlights that contamination from human activities and fluoride makes the water unsuitable for drinking, recommending regular monitoring, chlorination, or boiling to prevent waterborne diseases like cholera and hepatitis A.
10. **Kadave & Kumari (2025)** In a study assessed seasonal water quality and land use land cover (LULC) changes in the Subarnarekha watershed, Ranchi stretch, Jharkhand, highlighting the impact of agricultural runoff and climate change on water pollution. Water quality parameters, including acidity, alkalinity (ALK), total dissolved solids (TDS), hardness (H), dissolved oxygen (DO), biochemical oxygen demand (BOD), chlorides (Cl^-), electrical conductivity (EC), salinity (SAL), resistivity (RES), and pH, were analyzed using standard methods. During the monsoon season, acidity, alkalinity, hardness, chlorides, salinity, pH, and DO decreased, while EC, TDS, BOD, and resistivity increased compared to the pre-monsoon season. Post-monsoon, chloride levels were significantly elevated, and hardness peaked, while it was lowest during the monsoon. Statistical analyses, including hierarchical cluster analysis (HCA) and principal component analysis (PCA), confirmed high TDS, EC, chloride, and hardness issues. The Water Quality Index (WQI) indicated poor to unsuitable water quality across all sampling points in all seasons. LULC and Normalized Difference Water Index (NDWI) analyses revealed significant reductions in forest cover and water bodies due to rapid

urbanization. The study underscores the urgent need for afforestation, forest protection, and wetland conservation to mitigate pollution and preserve water resources in the Subarnarekha watershed.

11. **Giri et al. (2010)** in a study assessed metal contamination in the East Singhbhum region of Jharkhand, a highly mineralized zone with extensive copper, uranium, and other mining activities. Concentrations of metals (Fe, Mn, Zn, Pb, Cu, Ni) were measured in 10 groundwater and eight surface water locations across four seasons over one year near a proposed uranium mining site. Surface water metal ranges were Fe: 0.08–1.21 mg/L, Mn: 0.02–0.32 mg/L, Zn: 0.02–3.48 mg/L, Pb: 0.84–14 µg/L, Cu: 1.25–36 µg/L, and Ni: 1.24–15 µg/L. Groundwater ranges were Fe: 0.06–5.3 mg/L, Mn: 0.01–1.3 mg/L, Zn: 0.02–8.2 mg/L, Pb: 1.4–28 µg/L, Cu: 0.78–20 µg/L, and Ni: 1.05–20 µg/L. Only Fe and Mn exceeded India's drinking water standards. The Metal Pollution Index (MPI) was calculated, yielding values of 28 for groundwater and 10 for surface water, both well below the contamination threshold of 100, indicating no significant metal pollution. The study suggests that, despite mining activities, the water sources are relatively safe for these metals, though Fe and Mn levels require monitoring to ensure suitability for drinking.
12. **Kumar et al. (2008),** In a study investigated the physico-chemical properties of water in the Singhbhum thrust belt, Jharkhand, a region with significant uranium mining activity, to assess its suitability for irrigation and domestic use. The analysis focused on water samples from areas affected by mining, which generates millions of tons of tailings and poses radiation risks and environmental contamination. The water was found to be alkaline, with cationic chemistry dominated by sodium and magnesium (Na > Mg > Ca > K). Key parameters evaluated included the Sodium Absorption Ratio (SAR) and percentage sodium (% Na), both indicating that the water is suitable for domestic and irrigation purposes. Most physico-chemical parameters were within the maximum permissible limits set by the World Health Organization (WHO, 1984) for domestic, irrigation, and agricultural use. The study suggests that, despite the environmental challenges posed by uranium mining, the water quality in the region remains largely acceptable for its intended uses, though continuous monitoring is essential to manage potential contamination risks from mining activities.

- **Hydro-Chemical Characteristics of Surface Water Bodies in Jharkhand**

1. *Physicochemical Parameters*

Surface water bodies in Jharkhand, including rivers like the Damodar, Subarnarekha, and Kharkai, and various ponds and dams, exhibit diverse physicochemical characteristics influenced by regional geology and anthropogenic activities. The water is predominantly alkaline, with pH levels generally ranging from 6.53 to 7.65, though slight decreases occur during monsoon seasons due to dilution from rainfall. Total dissolved solids (TDS) and electrical conductivity (EC) are critical indicators, often elevated in mining areas, with TDS values frequently exceeding safe limits due to dissolved salts and minerals. Hardness, driven by calcium (Ca^{2+}) and magnesium (Mg^{2+}), peaks during pre-monsoon periods (e.g., 284 mg/L in some ponds) due to evaporation and decreases during monsoons. Alkalinity, primarily from bicarbonate (HCO_3^-), follows a similar trend, with high values (up to 36 mg/L) in summer months. Chloride (Cl^-) and sulphate (SO_4^{2-}) levels are significant, with chlorides peaking post-monsoon and sulphates correlating with mining activities. These parameters often exceed permissible limits set by Indian standards, rendering water unsuitable for drinking without treatment.

2. Seasonal Variations:

Seasonal fluctuations significantly affect hydro-chemical characteristics. During pre-monsoon periods (March–June), parameters like hardness, alkalinity, TDS, and salinity increase due to high evaporation rates, particularly in areas like Hatia and the Jharia coalfield. Monsoon seasons (July–September) typically reduce concentrations of acidity, alkalinity, hardness, chlorides, and pH due to dilution from rainfall, but increase EC, TDS, and biochemical oxygen demand (BOD) due to runoff carrying pollutants. Post-monsoon periods (October–December) show elevated chloride and hardness levels, reflecting reduced dilution and increased anthropogenic inputs. Dissolved oxygen (DO) tends to decrease during pre-monsoon due to higher temperatures and organic decomposition, while BOD increases, indicating organic pollution. These variations highlight the dynamic interplay between climatic factors and pollution sources, with monsoons exacerbating pollution through runoff in urban and mining areas.

3. *Heavy Metal Concentrations:*

Heavy metal contamination is a critical concern in Jharkhand's surface waters, particularly in mining-intensive regions like East Singhbhum and near industrial sites. Metals such as iron (Fe), manganese (Mn), zinc (Zn), lead (Pb), copper (Cu), nickel (Ni), and arsenic (As) are prevalent, with Fe and Mn often exceeding drinking water standards (e.g., Fe: 0.08–1.21 mg/L, Mn: 0.02–0.32served as an early sentinel for increasing pollution, necessitating stringent monitoring and management strategies to safeguard water resources and protect human and ecological health.

- **Contaminant Sources in Surface Water Bodies of Jharkhand**

1. *Mining Activities:*

Mining, particularly coal, uranium, and copper extraction, is a primary source of surface water contamination in Jharkhand. Regions like Jharia, West Bokaro, and East Singhbhum experience significant pollution from mine tailings, which release heavy metals such as iron, manganese, and lead into rivers and ponds. Acid mine drainage contributes to elevated sulphate and TDS levels, as seen in the Jharia coalfield, where 61% of samples were rated poor quality. Runoff from mining sites carries sediments laden with metals, increasing turbidity and metal concentrations in surface waters like the Subarnarekha and Damodar rivers. These activities also alter water chemistry *through sulphide oxidation, further degrading water quality and rendering it unsuitable for direct consumption.*

2. ***Industrial Effluents:***

Industrial activities, especially steel and copper plants near Jamshedpur and Ghatshila, significantly contribute to surface water pollution. Untreated wastewater discharges from these facilities introduce heavy metals (e.g., Cr, Cu, Zn, Cd, Pb) into rivers like the Subarnarekha and Kharkai. These effluents elevate TDS, EC, and chloride levels, as observed in the Damodar River, where physicochemical parameters consistently exceed regulatory standards. Industrial discharges also increase coliform bacteria, with levels in the Damodar reaching 2,600–20,000 CFU/100 ml, posing health risks. The cumulative effect of these discharges is evident in sediment geochemistry, highlighting the need for improved wastewater treatment.

3. ***Agricultural Runoff:***

Agricultural runoff is a significant non-point source of pollution in Jharkhand, particularly in the Subarnarekha watershed. Runoff carries fertilizers and pesticides, increasing nitrate, sulphate, and organic matter in surface waters, which elevates BOD and reduces DO. This is particularly pronounced during monsoons, when runoff intensifies, as seen in the Ranchi stretch, where EC and BOD increased during the rainy season. Such inputs contribute to nutrient enrichment, leading to eutrophication and algal blooms, further degrading water quality for domestic and irrigation purposes.

4. ***Urbanization and Domestic Waste:***

Rapid urbanization in Jharkhand, particularly around dams like Hatia and Kanke, contributes to surface water contamination through untreated domestic sewage. This introduces high levels of coliform bacteria, as observed in Basagarh pond, where total and faecal coliform counts indicated severe contamination. Urban runoff also increases TSS, TDS, and organic pollutants, exacerbating water quality issues. Land use changes, with a noted decline in forest cover and wetlands, amplify these effects by reducing natural filtration, as evidenced by NDWI and NDVI analyses showing increased drought areas and vegetation loss.

- **Environmental and Socio-Economic Impacts of Surface Water Contamination in Jharkhand**

1. ***Ecological Impacts:***

Surface water contamination in Jharkhand severely impacts aquatic ecosystems. Elevated heavy metal concentrations (e.g., Fe, Mn, As) in rivers like the Subarnarekha and Kharkai disrupt aquatic life, with bioavailable metals in sediments affecting fish and other organisms. High BOD and low DO levels, as seen in Basagarh pond, indicate organic pollution, leading to hypoxic conditions that threaten aquatic biodiversity. Eutrophication from agricultural runoff promotes algal blooms, further depleting oxygen and altering food webs. Increased turbidity and TSS from mining and *urban runoff reduce light penetration, affecting photosynthesis and aquatic plant growth. The decline in water quality, as indicated by poor WQI ratings across multiple sites, compromises the ecological integrity of rivers and dams, reducing their capacity to support diverse ecosystems.*

2. *Water Availability and Quality:*

Contamination significantly reduces the availability of safe water for domestic, agricultural, and industrial uses. Studies across Jharkhand show that 21–71.5% of surface water samples are of poor or very poor quality, often requiring treatment before use. High fluoride levels in areas like Hatia, exceeding IS 10500:2012 standards, and bacterial contamination in the Damodar River increase health risks, limiting potable water access. For irrigation, high salinity, residual sodium carbonate, and magnesium hazards in regions like Raniganj restrict agricultural productivity, affecting crop yields and soil health. This scarcity of clean water exacerbates water stress in a region heavily dependent on surface water bodies like dams and rivers.

3. *Public Health Risks:*

Contaminated surface water poses significant health risks to communities relying on these sources for drinking, cooking, and bathing. High coliform bacteria levels, as found in the Damodar and Basagarh pond, increase the risk of waterborne diseases such as cholera, hepatitis A, and salmonellosis. Elevated fluoride and heavy metal concentrations, particularly in mining areas, can lead to chronic health issues like fluorosis and heavy metal toxicity. The lack of regular water quality monitoring and treatment exacerbates these risks, particularly in rural areas where access to purification methods is limited, increasing the burden of water-related illnesses on vulnerable populations.

4. *Socio-Economic Consequences:*

The degradation of surface water quality has profound socio-economic impacts. Poor water quality reduces agricultural productivity, affecting farmers' livelihoods in a region where agriculture is a primary income source. The need for water treatment increases costs for households and municipalities, straining limited resources. Industrial reliance on contaminated water sources raises production costs due to the need for pre-treatment, impacting economic output in mining and manufacturing sectors. Furthermore, the loss of forest cover and wetlands, as shown by NDVI and NDWI analyses, reduces ecosystem services like water purification, increasing long-term socio-economic costs. These combined effects hinder sustainable development, necessitating urgent investments in pollution control and water management to support Jharkhand's socio-economic growth.

- **Suggestions for Mitigating Surface Water Contamination in Jharkhand**

Strengthening Pollution Control Measures:

To address the severe contamination of surface water bodies in Jharkhand, implementing stringent pollution control measures is critical. Regulatory authorities should enforce stricter guidelines for industries, particularly coal, uranium, and steel plants, to treat effluents before discharge. Establishing advanced wastewater treatment facilities near high-risk areas like Jharia and Jamshedpur can reduce heavy metal and organic pollutant loads in rivers such as the Damodar and Subarnarekha. Regular inspections and hefty penalties for non-compliance can deter untreated discharges. Additionally, mining operations must adopt sustainable practices, such as proper management of tailings and acid mine drainage, to minimize sulphate and metal contamination. Encouraging industries to adopt cleaner technologies will further reduce the environmental footprint of mining and industrial activities.

1. Enhancing Water Quality Monitoring

A robust monitoring system is essential to track water quality trends and identify contamination sources promptly. Establishing a network of real-time monitoring stations across major rivers and dams, such as Hatia, Kanke, and Chandil, can provide continuous data on parameters like pH, TDS, DO, BOD, and heavy metals. These stations should be equipped with automated sensors for early detection of pollution spikes, especially during monsoons when runoff increases. Collaboration with research institutions and environmental laboratories, like those in Ranchi, can enhance data accuracy. Community-based monitoring programs can also engage local stakeholders, ensuring grassroots-level vigilance and timely reporting of contamination incidents.

2. Promoting Sustainable Land Use Practices

Rapid urbanization and deforestation, as indicated by declining NDVI and NDWI values, exacerbate water quality issues. Promoting afforestation and wetland conservation around water bodies can enhance natural filtration and reduce runoff of sediments and pollutants. Urban planning should prioritize green belts and buffer zones along rivers to minimize domestic and industrial waste infiltration. Agricultural practices need regulation to reduce pesticide and fertilizer runoff, particularly in the Subarnarekha watershed. Incentivizing organic farming and precision irrigation can lower nitrate and sulphate inputs, preserving water quality for irrigation and domestic use.

3. Community Awareness and Water Treatment

Raising public awareness about water contamination risks is vital, especially in rural areas reliant on untreated surface water. Educational campaigns can inform communities about the dangers of waterborne diseases and the importance of purification methods like boiling or chlorination. Providing affordable water treatment solutions, such as community-level filtration units, can ensure safe drinking water in areas with high fluoride and coliform levels. Government and NGO partnerships can distribute purification kits and train locals in their use, reducing health risks from contaminated water sources like Basagarh pond.

- **Conclusion:**

Surface water bodies in Jharkhand, including the Damodar, Subarnarekha, and Kharkai rivers, and various dams and ponds, face significant contamination from mining, industrial effluents, agricultural runoff, and urbanization. High levels of TDS, heavy metals, and coliform bacteria, coupled with seasonal fluctuations in parameters like hardness and BOD, render much of the water unsuitable for drinking without treatment. These issues, driven by activities in regions like Jharia, East Singhbhum, and Raniganj, threaten aquatic ecosystems, public health, and socio-economic development. The decline in forest cover and wetlands further exacerbates water quality deterioration, reducing natural purification capacity. Urgent action is needed to implement pollution control, enhance monitoring, promote sustainable land use, and raise community awareness. By addressing these challenges through coordinated efforts, Jharkhand can safeguard its water resources, ensuring their sustainability for future generations and supporting ecological and economic resilience.

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