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Spatial variability of physicochemical characteristics and ecological health status of the Subarnarekha River, eastern India

Pratiksha Delphin Toppo[1], Pipas Kumar*[2], Bharti Singh Raipat[2], Kanchita Toppo[2], Md Tauqir Zaya[1], Anushka Kumari[1], Asma Kerketta[1], and Srishti Grace Toppo[1]

[1]Department of Zoology, St. Xavier's College, Ranchi, Jharkhand, India
[2]Faculty of Environmental Sciences, Department of Zoology, St. Xavier's College, Ranchi, Jharkhand, India

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Corresponding Author: **Pipas Kumar** | E-Mail: **(pipasx2@gmail.com)**

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ABSTRACT

The Subarnarekha River is a critical hydro-ecological corridor of eastern India, supporting diverse ecological functions while supplying water for domestic, agricultural, and industrial use. Rapid urbanization, industrial expansion, and rising anthropogenic pressure have raised concerns over its deteriorating water quality, particularly within Ranchi district. This study evaluated the spatial variation in physicochemical characteristics of the river at eight strategically selected locations, representing upstream agricultural reaches, urban settlements, industrial zones, reservoir and waterfall segments, and downstream recovery reaches, during the pre-monsoon season (April–May 2026). Fourteen physicochemical parameters were monitored as indicators of river health. pH, temperature, total dissolved solids, salt percentage, salinity, and electrical conductivity were measured in situ, while dissolved oxygen, biochemical oxygen demand, free carbon dioxide, total alkalinity, total hardness, calcium and magnesium hardness, and chloride were determined in the laboratory, following standard APHA and IS 3025 protocols. Spatial variability was assessed using descriptive statistics, and measured values were compared against Bureau of Indian Standards (IS 10500:2012) and Central Pollution Control Board criteria to determine ecological condition and pollution status. Results revealed wide spatial variation across stations and marked water quality deterioration in reaches influenced by industrial, urban, and suburban growth. Upstream stations at Nagri and Dhurwa showed comparatively good water quality, with low dissolved solids, higher dissolved oxygen, and lower biochemical oxygen demand. Stations within urban and industrial stretches, particularly Chutia, Namkum, and Tatisilwai, recorded elevated electrical conductivity, dissolved solids, alkalinity, hardness, free carbon dioxide, and biochemical oxygen demand alongside reduced dissolved oxygen, indicating substantial anthropogenic influence. Downstream stations at Getalsud, Hundru, and Muri showed partial recovery, suggesting natural self-purification. Ecological threat assessment classified Nagri and Dhurwa as low-risk, Getalsud, Hundru, and Muri as moderately threatened, Namkum and Tatisilwai as high-risk, and Chutia as the principal pollution hotspot exhibiting critical degradation. By characterizing the physicochemical profile of each site individually, the study identifies the principal stressors driving water quality decline in specific reaches and pinpoints where remedial action is needed. The findings underscore the value of site-specific monitoring and support targeted, localized intervention and effluent treatment strategies for the conservation and management of the Subarnarekha River basin.

Keywords: *environmental monitoring; Jharkhand; ionic enrichment; organic pollution; Ranchi; river water; spatial variation*

Introduction

Water is unevenly distributed across the world, and approximately 71% of the surface of the Earth is covered by water, which is why the planet is often described as the "Blue Planet". Despite this apparent abundance, about 97% of this water is saline and only about 2.5% is fresh water, a small proportion of which is available for domestic use [1]. In India, rivers are the principal source of fresh water and have been used extensively; this heavy use has, however, become a limiting factor for several reasons, one of which is water pollution. India receives an average of about 4,000 billion cubic metres of rainfall each year [2], of which approximately 49% enters Indian rivers, and barely 17% of this rainwater is used for economic and domestic purposes. Rainfall in India is at its peak between June and September, a period known as the monsoon. Unlike the rivers that discharge into the Arabian Sea, about 70% of the rivers of India discharge into the Bay of Bengal [2], and one of these is the Subarnarekha River of Jharkhand. Rivers, although the principal source of fresh water, are becoming severely polluted through the discharge of sewage and industrial effluents, and all the major rivers of India are now highly polluted [3]. The present status of Indian rivers is a matter of considerable concern. An article published by Earth5R in February 2026 reported that almost all the major rivers in India are currently under heavy pressure from untreated sewage, industrial effluents and agricultural runoff [4].

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Although Indian rivers supply a large proportion of the water used for drinking, irrigation and agriculture, over the past three decades the discharge of waste effluents has systematically degraded their assimilative capacity. Increasing anthropogenic activity has intensified the water pollution crisis to such an extent that contamination has not only degraded water quality but has also disrupted ecosystem functioning, rendering the water unsafe for aquatic life, for drinking, and for agricultural use, and thereby posing a threat to both human and aquatic ecosystems. Among the major causes of water pollution are the inappropriate release of industrial effluents and sewage into river water, the dumping of plastic waste, and agricultural runoff rich in nitrate- and phosphorus-containing fertilizers, pesticides, and insecticides, which is a major cause of algal blooms and the subsequent depletion of oxygen. This increasing input of contaminants and nutrients has affected both the physical and the chemical characteristics of the water. Reports of the Central Pollution Control Board (CPCB) for 2005 indicated that organic pollution is predominant in Indian aquatic resources [5]. The CPCB has monitored Indian rivers continuously since the mid-1990s; by 2018 it had identified 351 polluted stretches on 323 rivers, by 2022 some 311 stretches on 279 rivers, and in its most recent assessment in 2025 some 296 severely polluted stretches on 271 rivers [4, 6]. India is already water-stressed on the criterion applied by the Central Water Commission, the average annual per capita availability having fallen to 1,486 m^3 in 2021, against a water-stress threshold of 1,700 m^3 and a water-scarcity threshold of 1,000 m^3, and it is projected to decline further to 1,367 m^3 by 2031 [7].

Methods

Description of the study area: the Subarnarekha River basin

The Subarnarekha takes its name from the Sanskrit *subarna* ("gold") and *rekha* ("line"), reflecting a long-held belief that the river once carried gold in its sand; residents along the middle reaches still pan grains of the metal from its bed [8]. Rising near Nagri, close to Ranchi, the river runs 395 km eastward through Jharkhand (Fig. 1), West Bengal and Odisha, serving as the hydro-ecological corridor of the Chota Nagpur Plateau before discharging into the Bay of Bengal. Its catchment within Jharkhand covers approximately 18,951 km^2, about 60–65% of the basin, spanning agricultural, urban, suburban and industrial zones and passing through Ranchi, Jamshedpur and Chaibasa; major right-bank tributaries include the Raru, Kanchi, Karkai, Garu, Dulang and Kharkai [8]. The basin receives an average annual rainfall of about 1,800 mm, concentrated in the monsoon period from June to October [9].

Land use and land cover across the basin changed considerably between 2000 and 2023 [10], and the river is now under high ecological stress from population growth and industrialization. The Jharkhand State Pollution Control Board (JSPCB) reports that only about 25% of the sewage generated within the basin is treated before discharge, a factor implicated in an approximately 40% decline in native aquatic species [11]; a 2023 JSPCB survey near Jamshedpur recorded lead concentrations of 0.61–2.85 mg/L against a prescribed limit of 0.05 mg/L [12]. Management measures including biomonitoring, source control, and environmental flow management have been introduced, and the National Green Tribunal directed the establishment of sewage treatment plants by 2024 [13], yet pollution has continued to rise, and industries still discharge wastewater directly into the river.

A 2025 roadmap for curbing pollution in the Subarnarekha and the Kharkai has since been proposed [14]. Without effective treatment, the river faces severe ecological degradation, loss of fish species, public health risks, and a shortage of drinking water for dependent communities.

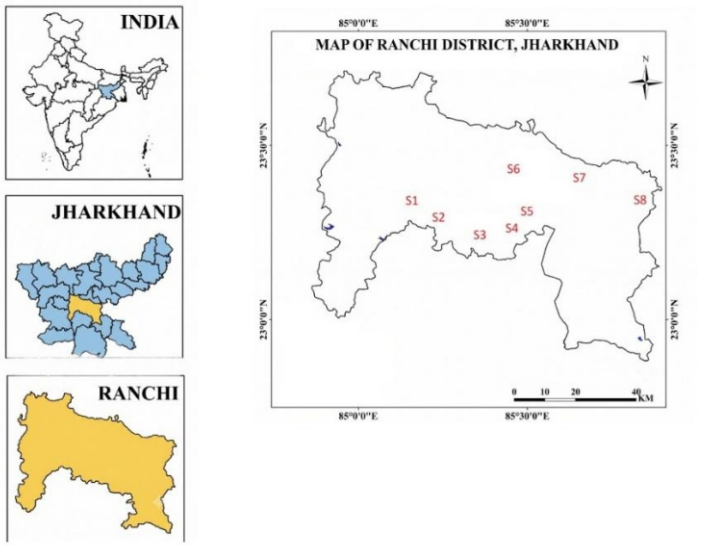


Fig. 1. Map of the Subarnarekha River and selected sampling sites (S1-S8).

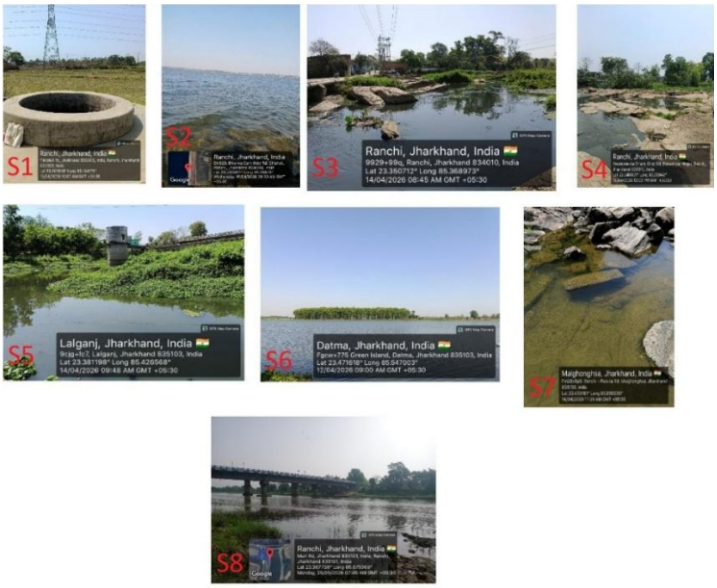


Fig. 2. All eight sampling sites (S1-S8).

Sampling stations

Eight sampling stations were established along the Subarnarekha within Ranchi district, selected to cover the full sequence of zones through which the river passes, from agricultural land through urban and industrialized areas to an artificial reservoir, a waterfall and the downstream recovery reach (Table 1, Fig. 2). Samples were collected during the pre-monsoon season in April and May 2026, to capture conditions at low flow, when water levels are reduced, and pollutant concentrations are correspondingly high.

Site 1, Nagri (S1). The origin of the river; an agricultural zone with upstream flow regulation.

Site 2, Dhurwa (S2). A predominantly urban zone with some industrial presence, selected to capture the influence of the urban area and of the dam.

Site 3, Namkum (S3). An urban neighbourhood with designated industrial areas, selected to capture small-scale industrial discharge and urban runoff [15].
Site 4, Chutia (S4). A suburban area in transition from rural to urban land use, with intensive agricultural practice.
Site 5, Tatisilwai (S5). A suburban census area with small-scale industries, selected to monitor industrial effluents [15, 16].
Sites 6 and 7, Getalsud (S6) and Hundru (S7). A self-purification zone and an aeration point, respectively.
Site 8, Muri (S8). The downstream recovery zone, the last station before the river leaves the district.

Table 1: Locality table with GPS coordinates of each sampling station

Sampling stations (site)	locations (all within Ranchi district)	latitude	longitude
Site-(S1)	Nagri	23.301848°N	85.184178°E
Site-(S2)	Dhurwa	23.293983°N	85.25876°E
Site-(S3)	Namkum	23.350708°N	85.368986°E
Site-(S4)	Chutia	23.340601°N	85.35948° E
Site-(S5)	Tatisilwai	23.381136°N	85.426618°E
Site-(S6)	Getalsud	23.471832°N	85.545272° E
Site-(S7)	Hundru	23.450161°N	85.666536°E
Site-(S8)	Muri	23.367738°N	85.875368°E

Sampling and analytical methods

Water samples were collected by manual grab sampling, one of the simplest and most widely used approaches to water collection [17, 18], and recognized under Section 1060 of the 21st edition (2005) of APHA Standard Methods as the accepted procedure for almost all the physicochemical parameters determined here [19]. Temperature, pH, electrical conductivity, total dissolved solids, salinity and salt percentage were determined on site using a Hofun pool salt tester and a five-in-one digital pH pen (Shanghai GL Environmental Technology Co., Ltd.) [20, 21]. Salt percentage was calculated as the mass of dissolved salt divided by the total mass of the solution, expressed as a mass fraction (w/w %).
The remaining parameters were determined in the laboratory following IS 3025, the Indian Standard protocol for the sampling and testing of water. In each of the titrimetric determinations below, V_1 denotes the volume of the water sample and V_2 the volume of titrant.
Free carbon dioxide was determined by titration against sodium hydroxide following IS 3025 (Part 61) [25]:
Free CO_2 (mg/L) = (V_2 × 0.05 N × 44 × 1000) / V_1
Total hardness was determined by EDTA titration following IS 3025 (Part 21) [26]:
TH (mg/L as $CaCO_3$) = (V_2 × 0.01 M × 100 × 1000) / V_1
Calcium hardness was determined by EDTA titration following IS 3025 (Part 40) [27]:
Ca hardness (mg/L as $CaCO_3$) = (V_2 × 0.01 M × 40.08 × 1000) / V_1
Magnesium hardness was obtained by difference from the total and calcium hardness of each sample:
Mg hardness (mg/L as $CaCO_3$) = total hardness – calcium hardness
Chloride was determined argentometrically following IS 3025 (Part 32) [28]:
Chloride (mg/L) = (V_2 × 0.02 N × 35.45 × 1000) / V_1
Total alkalinity was determined by titration against standard sulfuric acid following IS 3025 (Part 23) [29]:
TA (mg/L as $CaCO_3$) = (V_2 × 0.02 N × 50 × 1000) / V_1
Dissolved oxygen was determined by the Winkler method following IS 3025 (Part 38) [30]:
DO (mg/L) = (V_2 × 0.025 N × 8 × 1000) / V_1
Biochemical oxygen demand was determined over five days at 20 °C [22] as the difference between the initial dissolved oxygen (DO_1) and that remaining after incubation (DO_2):
BOD_5 (mg/L) = DO_1 – Do_2

Data analysis

The data were analysed by descriptive statistics, comprising measures of central tendency (mean, median and mode), measures of dispersion (range, variance, standard deviation and coefficient of variation) and positional statistics (percentiles).

Ecosystem health assessment

The health of an aquatic ecosystem depends on the balance among its abiotic components, including temperature, pH, alkalinity, hardness, dissolved oxygen and free carbon dioxide. Measured values were therefore assessed against the limits specified in IS 10500:2012 (Table 2) of the Bureau of Indian Standards for drinking water [23,24] and in the CPCB classification of surface waters (Table 3) [31], and the resulting categories were used to assign an ecosystem threat level to each station as per the protocol proposed by the Central Pollution Control Board (Table 4)

Table 2: Drinking water quality standards prescribed by the Bureau of Indian Standards (IS 10500:2012).

Parameters	Acceptable limits (Safe Range)	Permissible range (Temporary tolerance)
pH	6.5-8.5	No Relaxation
TDS(mg/L or ppm)	500	2000
Ca hardness(mg/L)	75	200
Mg hardness(mg/L)	30	100
Cl^- chloride (mg/L)	250	1000

Table 3: Surface water classification and quality criteria prescribed by the Central Pollution Control Board

Classes	Designated use	Criteria for water quality standards
Class A	Drinking water without any conventional treatment	pH6.5-8.5, TDS<500, DO >6.0mg/L, BOD< 2.0mg/L, Cl^-< 250mg/L, Total Hardness< 200, Ca hardness < 75mg/L, Mg hardness < 30 mg/L
Class B	Water used for bathing	TDS<1500,DO>4.0,BOD<3.0,TH< 300mg/L, Cl^-< 600mg/L,pH6.5-8.5, Ca hardness < 75mg/L, Mg hardness < 30 mg/L
Class C	Drinking water after treatment and followed by disinfection	pH6.5-8.5,TDS<1500mg/L,DO>4.0mg/L,BOD< 3.0mg/L, TH< 300mg/L, Cl^-< 600mg/L, Ca hardness < 75mg/L, Mg hardness < 30 mg/L
Class D	Water used for fisheries and wildlife	pH6.5-8.5,TDS<1500mg/L,DO>4.0mg/L,BOD< 3.0mg/L, TH< 300mg/L, Cl^-< 600mg/L, Ca hardness < 75mg/L, Mg hardness < 30 mg/L
Class E	Water for irrigation and industrial usage	pH6.5-8.5,TDS<300mg/L,DO-Not specific, BOD< 3.0mg/L, TH< 300mg/L, Cl^- Not specific, Ca hardness < 75mg/L, Mg hardness < 30 mg/L

The ranges proposed by BIS and CPCB provide the basis for categorizing water and the corresponding threat levels as low, moderate, high or critical.

Table 4: Classification of ecosystem threat levels proposed by the Central Pollution Control Board.

Threat levels	Quality	Criteria
Low threat	Good quality	Must fulfill all the parameters belonging to the class A and B
Moderate threat	Degraded quality (Moderate level of pollution) Moderate quality	DO=4-5mg/L BOD=2-6mg/L
High threat	Severely degraded (high pollution) Poor quality.	DO= <2mg/L BOD=>6-12mg/L
Critical threat	Very poor quality (Extremely high pollution	DO=0mg/L BOD =>20mg/L

Results

Temperature

The overall temperature pattern across the eight stations showed that the water at Chutia (S4) was under appreciable thermal stress relative to the remaining stations, the recorded value there being 30.2 °C (Fig. 3). The elevation at S4 is consistent with the physical setting of that reach: shallow, slow-moving water at a reduced pre-monsoon discharge, limited riparian shading and the receipt of urban and small-scale industrial return flows all raise the equilibrium temperature of the water. The consequence is twofold. First, as temperature rises, the water can hold less oxygen. Second, the rates of microbial respiration and organic matter decomposition increase with temperature, so that oxygen demand rises at the same time as oxygen-holding capacity falls. The thermal signal at S4 therefore reinforces, rather than merely accompanies, the oxygen depletion recorded at that station.

The descriptive statistical analysis confirmed this pattern: temperatures across most of the study area lay within a common thermal regime, with the mean and median almost identical, indicating a nearly symmetrical distribution and low variability among the majority of stations. Chutia (S4) was the clear exception, standing out from this narrow band as the only station under comparable thermal stress.

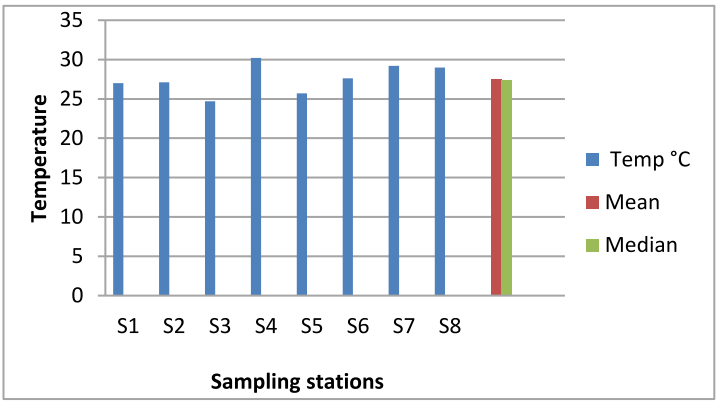


Fig. 3. Temperature at the eight sampling stations, with measures of central tendency.

pH

The pH recorded across the sampling stations showed the water at Nagri (S1), Namkum (S3), Chutia (S4) and Tatisilwai (S5) to be slightly acidic to near-neutral, with values of 5.87, 6.72, 6.85 and 6.58 respectively (Fig. 4). The low values arise from two different causes. At S1, the depressed pH reflects a headwater setting on the granite-gneiss and lateritic terrain of the Chota Nagpur Plateau, where carbonate minerals are scarce; the correspondingly low alkalinity recorded there (60 mg/L as $CaCO_3$) leaves the water with little buffering capacity, so that soil-derived organic acids and dissolved carbon dioxide are sufficient to depress the pH. At S3, S4 and S5, by contrast, the mildly depressed pH occurs alongside high alkalinity and high free carbon dioxide, and is therefore attributable to carbonic acid generated by heterotrophic decomposition of an elevated organic load rather than to an absence of buffering.

The descriptive statistics gave a narrow range of values and a low coefficient of variation, indicating minimal spatial variation in pH. Water at most stations was near-neutral to mildly alkaline and lay within the limits of IS 10500:2012 [23] and the CPCB classification [31]; S1 alone fell below the acceptable range of 6.5–8.5 and was therefore acidic.

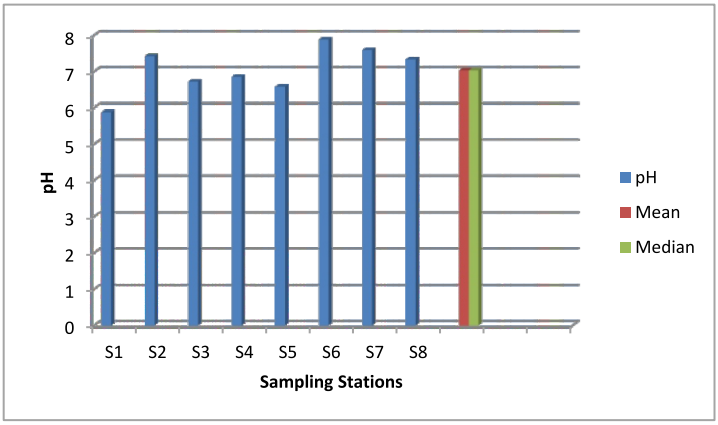


Fig. 4. pH at the eight sampling stations, with measures of central tendency.

Electrical conductivity

Electrical conductivity is directly related to TDS, since both are governed by the concentration and mobility of dissolved ions. Against the CPCB and BIS criteria, and the reference values reported by Atlas Scientific [32], the EC of a clean freshwater stream is of the order of 10–200 µS/cm, with TDS below the acceptable limit of 500 mg/L set by IS 10500:2012 for drinking water and below 300 mg/L where the water is used for irrigation [23]. On this basis, S1 and S2 exhibited a very low ionic content, whereas S3, S4, and S5 showed markedly elevated TDS and conductivity. Chutia (S4) recorded the highest values, with a TDS of 497 mg/L and an EC of 999 µS/cm. The ratio of EC to TDS at S4 is approximately 2:1, corresponding to a conversion factor of about 0.5 that is characteristic of natural waters dominated by mixed inorganic salts; this confirms that the measured solids are predominantly ionic rather than organic in nature.

The statistical analysis identified two distinct clusters. S1, S2, S6, S7 and S8 had a very low EC and TDS characteristic of unimpacted fresh water, whereas S3, S4 and S5 recorded a substantially elevated ionic content indicative of urban and industrial influence, arising principally from dissolved salts and chloride in particular. BIS prescribes no numerical limit for electrical conductivity, so the mean EC of 458 µS/cm is best interpreted against the 10–200 µS/cm expected of an unimpacted headwater stream, relative to which it is appreciably elevated.

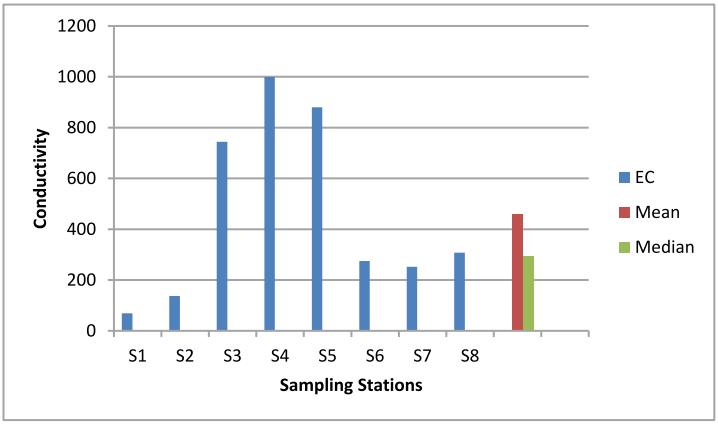


Fig. 5. Electrical conductivity (µS/cm) at the eight sampling stations, with measures of central tendency.

Total dissolved solids

The mean TDS of 228.4 mg/L lies within the acceptable range of the CPCB and BIS (IS 10500) drinking water quality standards [23], but is strongly influenced by the three most affected stations and conceals the bimodal distribution evident in Figs. 5, 6; the site-specific values should therefore be used in preference to it.

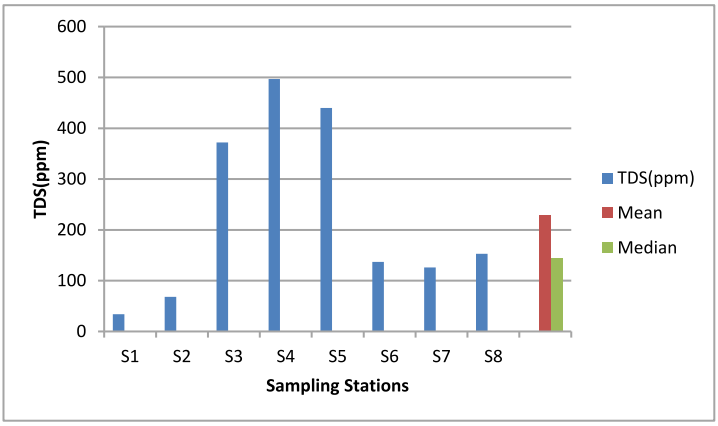


Fig. 6. Total dissolved solids (ppm) at the eight sampling stations, with measures of central tendency.

Salinity and salt percentage

Salinity and salt percentage express the concentration of dissolved salts in the water, an increased salt content being reflected in a higher TDS and a greater ionic strength. Both varied markedly from S1 to S8, with the highest values occurring at Chutia (S4), where salinity reached 502 ppm and the salt content 0.05% (w/w). In absolute terms, 502 ppm corresponds to 0.5 g/L, so the water at S4 remains fresh by the conventional limnological definition, which places the freshwater–brackish boundary at approximately 1 g/L. The significance of this value lies not in absolute salinity but in enrichment, the concentration at S4 being roughly an order of magnitude above the headwater background at S1; sustained enrichment of this magnitude imposes an additional osmoregulatory cost on stenohaline freshwater fauna and shifts the ionic composition away from that to which the resident community is adapted.

The statistical analysis indicates three zones: very low salinity characteristic of fresh water at S1 and S2, moderate salinity at S6, S7 and S8, and elevated salinity at S3, S4 and S5, corresponding to a high TDS and electrical conductivity.

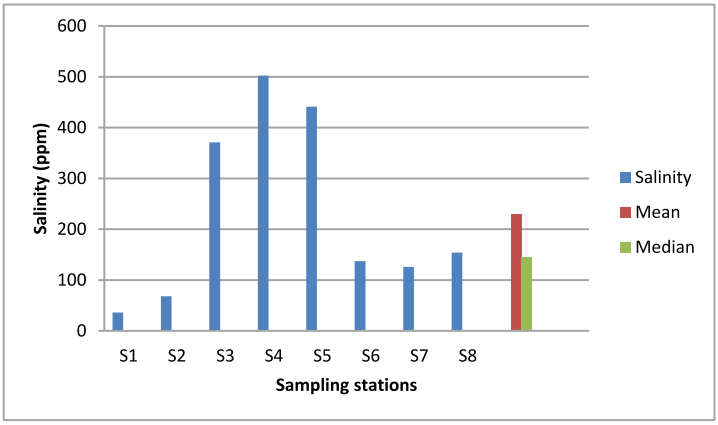


Fig. 7. Salinity (ppm) at the eight sampling stations, with measures of central tendency.

Free carbon dioxide

According to the CPCB and BIS criteria, surface water typically contains less than 10 mg/L of free carbon dioxide, whereas groundwater may exceed this value. Laboratory analysis gave a range from 4.4 mg/L at S1 to 52.8 mg/L at S4, with elevated concentrations at S3, S4 and S5. The concentration of free CO_2 in a river reach is the net outcome of production by respiration and microbial decomposition against removal by photosynthesis and atmospheric exchange. Concentrations five to twelve times the background value recorded at S1 therefore indicate that heterotrophic respiration substantially exceeds primary production and atmospheric loss at these three stations, the expected signature of a reach receiving a heavy organic load. The accumulated CO_2 hydrates to carbonic acid and depresses the pH, while a high partial pressure of CO_2 reduces the efficiency of gas exchange across fish gills, so that the respiratory stress imposed on the aquatic biota is greater than the dissolved oxygen concentration alone would suggest. That the pH nevertheless remains close to neutral at these stations is explained by their high alkalinity: free CO_2 and pH are inversely coupled, but the strength of that coupling is set by the alkalinity of the water.

The descriptive analysis gave a high coefficient of variation, with a modal value of 4.4 mg/L at S1, S6, S7 and S8 representing the background condition of well-oxygenated surface water.

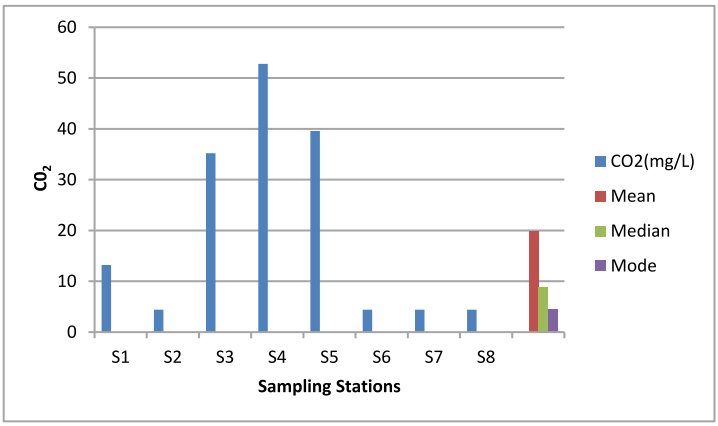


Fig. 8. Free carbon dioxide at the eight sampling stations, with measures of central tendency.

Total hardness (calcium and magnesium)

Total hardness ranged from 50 mg/L as $CaCO_3$ at Nagri (S1) to 305 mg/L at Chutia (S4). Samples from S1, S2, S6, S7 and S8 fell within the 200 mg/L limit laid down by CPCB and by IS 10500:2012 for drinking water [23], whereas the urbanized and industrialized stations S3, S4 and S5 were considerably higher, indicating water too hard for domestic use.

When calcium and magnesium are considered separately, the hardness of the water is seen to be governed principally by magnesium. Against acceptable limits of 75 mg/L for calcium hardness and 30 mg/L for magnesium hardness, all stations complied for calcium, whereas magnesium exceeded the limit at almost every station, with a marked elevation at S3, S4 and S5. A magnesium-dominated signature is unusual in waters whose hardness derives from limestone dissolution, which yields calcium-dominated water; it is instead consistent with the geology of the Chota Nagpur Plateau, in which the weathering of magnesium-bearing silicate minerals in amphibolite, chlorite schist and associated mafic rocks releases Mg^{2+} preferentially. The further elevation at S3, S4 and S5 above the geologically comparable stations S6, S7 and S8 indicates that this geogenic baseline is being augmented by an anthropogenic ionic input in the urban and industrial reaches.

The statistical data reflect a wide range of hardness and hence high variability, classifying the water as soft at S1, moderately hard at S2, S6, S7 and S8, and very hard at S3, S4 and S5.

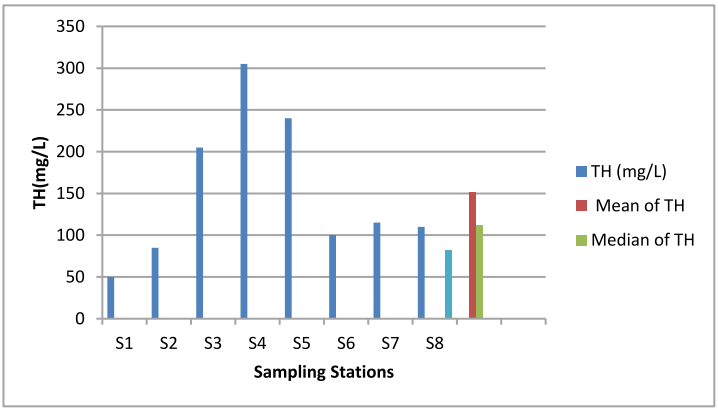


Fig. 9. Total hardness at the eight sampling stations, with measures of central tendency.

Chloride distribution

Chloride occurs naturally in water but also enters through anthropogenic pathways such as agricultural runoff and industrial discharge. Concentrations ranged from 21.27 mg/L at S1 to 166.85 mg/L at S4, with the higher values occurring in reaches flowing through urban, suburban and industrial areas, and all remained below the acceptable limit of 250 mg/L recommended by CPCB and IS 10500 for drinking water [23, 31]. The diagnostic value of chloride, however, lies in its behaviour rather than its absolute concentration. Under normal river conditions, chloride is not appreciably adsorbed, precipitated, oxidised, reduced or taken up by biota, so once introduced it is removed only by dilution. The approximately eightfold enrichment between S1 and S4 therefore cannot be attributed to in-stream processes and must reflect external inputs, principally domestic sewage, in which chloride is a well-established tracer, together with industrial effluent and agricultural return flow carrying potassium chloride fertiliser.

Chloride is also a major constituent of TDS and a principal contributor to salinity, which is why the chloride, TDS, electrical conductivity and salinity profiles rise and fall together across the eight stations.

The statistical analysis gave a relatively high coefficient of variation, with low to moderate values at S1, S2, S6, S7 and S8 and markedly higher values at S3, S4 and S5.

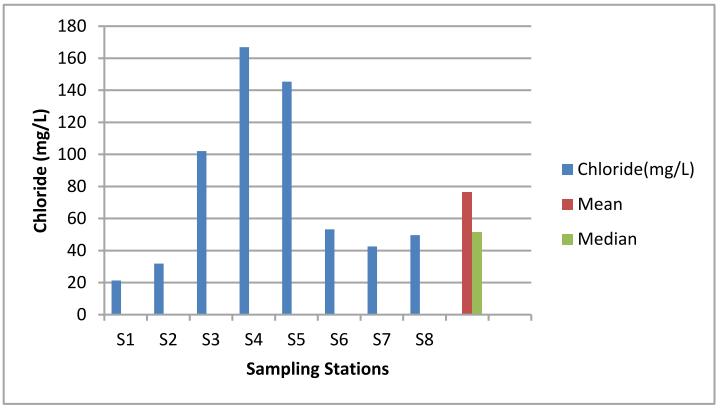


Fig. 10. Chloride at the eight sampling stations, with measures of central tendency.

Total alkalinity

Alkalinity is the quantitative capacity of an aqueous solution to neutralize an acid [33], and is important for aquatic life because it buffers the water against rapid changes in pH. Total alkalinity ranged from 60 mg/L as $CaCO_3$ at S1 to 485 mg/L at S4, and was comparatively high at Namkum (S3), Chutia (S4) and Tatisilwai (S5). The CPCB and BIS criteria indicate that the total alkalinity of river water should generally lie between 20 and 200 mg/L as $CaCO_3$ [23, 34]. Stations S1, S2, S6, S7 and S8 fell within this range and therefore retained a buffering capacity adequate without being excessive, sufficient to stabilize the pH and protect the resident aquatic community, with most freshwater organisms functioning best within a pH range of approximately 6.5–8.5.

The statistical analysis demonstrated a wide spread and high variation across the sampling stations, S3, S4, and S5 exhibiting extremely high alkalinity. The relationship between alkalinity and total hardness determines the type of hardness present. Where total hardness exceeds total alkalinity, the alkalinity accounts for carbonate, or temporary, hardness and the excess (TH – TA) represents non-carbonate, or permanent, hardness associated with the sulfates and chlorides of calcium and magnesium; where total hardness is equal to or less than total alkalinity, all the hardness present is carbonate hardness and the surplus (TA – TH) is balanced by monovalent cations, principally sodium and potassium, present as bicarbonate. In the present data the mean total alkalinity (206.9 mg/L as $CaCO_3$) exceeded the mean total hardness (151.3 mg/L as $CaCO_3$). The hardness of the Subarnarekha is therefore essentially carbonate in character, with a surplus indicating a sodium- and potassium-bicarbonate component — consistent with the chloride and salinity results, since domestic sewage is enriched in sodium, and with the silicate weathering that characterizes the Chota Nagpur Plateau, both of which supply monovalent cations without a corresponding increase in hardness.

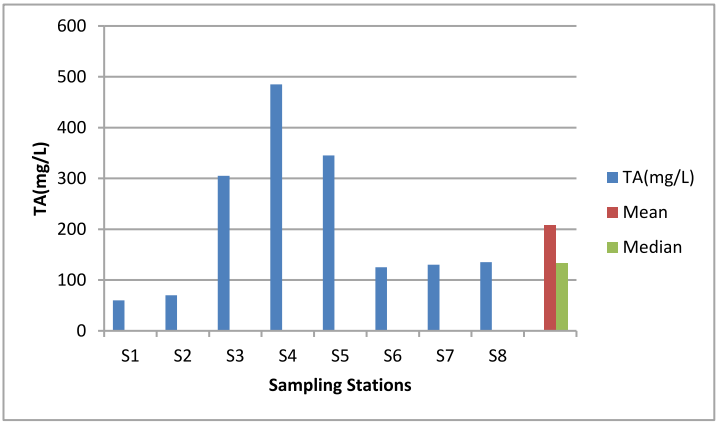


Fig. 11. Total alkalinity at the eight sampling stations, with measures of central tendency.

Dissolved oxygen

Dissolved oxygen ranged from 8 mg/L to 3 mg/L across the eight stations. The pattern obtained agrees with the classical relationship between dissolved oxygen, free carbon dioxide and pH described [33, 35] and summarized in Table 5.

The DO_1 analysis identified S3, S4 and S5 as the most heavily impacted stations, oxygen concentrations there falling below 6 mg/L. According to IS 10500 and the CPCB classification of surface waters, the range required to support a healthy aquatic ecosystem and to meet human health requirements lies between 6 and 8 mg/L [23, 31], below which organic pollution is indicated. A healthy flowing river maintains this range more readily than stagnant water, because turbulent re-aeration continually replenishes the oxygen consumed by respiration and decomposition. The minimum recorded here, 3 mg/L, falls below the 4 mg/L threshold specified by CPCB for Class C and Class D waters, that is, below the concentration required both for drinking water after conventional treatment and for the propagation of fisheries and wildlife.

Table 5: Relationship between dissolved oxygen, free carbon dioxide and pH

Dissolved oxygen	Free EFG	pH
Increases	Decreases	Increases
Decreases	Increases	Decreases

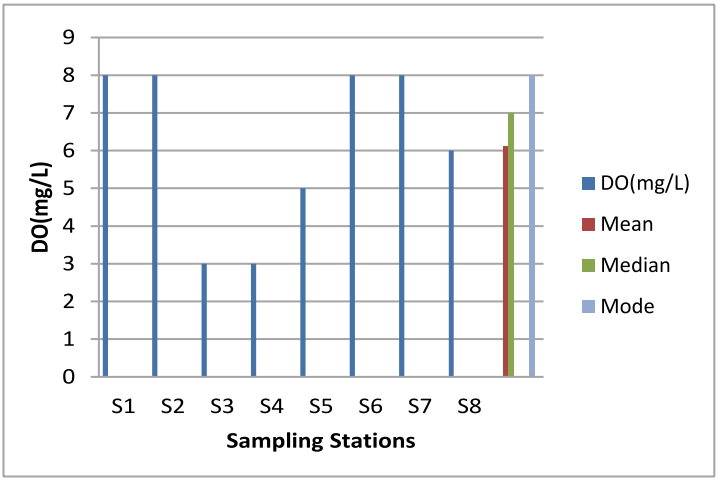


Fig. 12. Dissolved oxygen at the eight sampling stations, with measures of central tendency.

Biochemical oxygen demand

The DO_2 analysis provided the basis for calculating the biochemical oxygen demand. The range recommended under IS 10500:2012 for drinking water and under the CPCB standards is 0–2 mg/L [23, 31]; values above this range show that microorganisms are consuming a large proportion of the available dissolved oxygen in decomposing waste material, leaving little for other aquatic organisms and producing the condition known as hypoxia. The DO_2 values obtained after five days of incubation varied from 0 to 8 mg/L, with the urban, suburban and industrial stations S3, S4 and S5 showing the greatest decline; oxygen was exhausted in the incubated samples from these stations, whose initial dissolved oxygen was already below 6 mg/L. Because these samples became anoxic before the end of the five-day period, the BOD values reported for S3, S4 and S5 should be regarded as minimum estimates of the true oxygen demand. Since BOD is a direct measure of the oxygen consumed in the biodegradation of organic matter, the coincidence at these three stations of a high BOD, a high free carbon dioxide concentration and a depressed dissolved oxygen concentration is internally consistent and points to a single dominant driver, namely the input of untreated or only partially treated organic waste.

The high relative variability of BOD indicates very high spatial variation, with a clear division between well-oxygenated and oxygen-depleted stations: S1, S2, S6, S7 and S8 lay within the permissible range, half the samples having a BOD of 2 mg/L or less, whereas S3, S4 and S5 exceeded it.

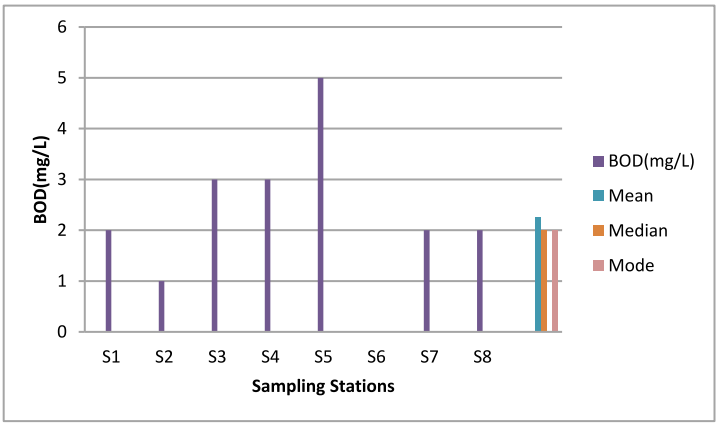


Fig. 13. Biochemical oxygen demand at the eight sampling stations, with measures of central tendency.

Comparison with previous studies

The spatial pattern reported here can be set against the two published assessments of the Subarnarekha that are most closely comparable. A study on the same river within Ranchi district, also across eight stations, applied the weighted arithmetic water quality index to samples collected between January and May 2024 and obtained index values of 6.76–26.4, placing the water between the excellent and acceptable categories [36].

Those dissolved oxygen, BOD, hardness, alkalinity and chloride values are broadly consistent with those recorded here at S1, S2 and the downstream recovery stations, but the present study additionally resolves a sharply degraded mid-reach at Namkum, Chutia and Tatisilwai. The difference is most plausibly one of station placement rather than a change in the river between 2024 and 2026, since the present sampling design deliberately targeted the urban and industrial corridor. Further downstream, index values of 25.16–49.47 and a pH of 7.3–7.8 have been reported for the Balasore reach of Odisha [37], indicating that the enrichment recorded here in the Ranchi corridor is attenuated well before the river reaches its lower course. Taken together, these comparisons support the interpretation that degradation of the Subarnarekha is localized around discrete urban and industrial inputs rather than uniform along its length.

The threat category assigned to each station in Table 6 was determined from the aggregate performance of all 14 parameters rather than from dissolved oxygen and biochemical oxygen demand alone, since simultaneous exceedance across several independent parameter groups is a more reliable indicator of ecological stress than the failure of any single criterion. S3 and S5 are accordingly classified as posing a high threat, the majority of their parameters approaching or exceeding the desirable range, and S4 as posing a critical threat, every parameter group being affected simultaneously.

Classification of ecosystem threat levels by site

Table 6: Ecosystem threat assessment of the eight sampling stations

Ecosystem threats	Water quality	Criteria
Minimal threat	Good quality **(S1, S2)**	Fulfilling almost all the standards Proposed by CPCB (Class A to -E).
Moderate threat	Fair/Moderate quality **(S6, S7,S8)**	EC and Mg (Elevated) whose further increase can possibly degrade the water.
High threat	Poor quality **(S3, S5)**	Most of the parameters exceeding above the desirable range while few closer to the threshold suggesting water to be experiencing some kind of ecological stress.
Critical threat	Very poor quality **(S4)**	Failing almost all of the desirable threshold as proposed by CPCB (Class A to E) .

Discussion

Physicochemical analysis of eight sampling stations along the Subarnarekha River revealed wide spatial variation among the parameters measured. On the basis of the CPCB classification for ecological threat assessment, the water was graded into four categories: good, moderate, poor and very poor.

The water quality at Nagri (S1) and Dhurwa (S2) was graded as good, placing these stations within the minimal threat zone. Both recorded a low BOD, a healthy dissolved oxygen concentration, minimal salinity, TDS and electrical conductivity, with hardness and alkalinity within the acceptable range, indicating minimal anthropogenic influence; the sole exception was the slightly acidic pH at Nagri (S1).

Getalsud (S6), Hundru (S7) and Muri (S8) fell within the moderate category. Although most parameters lay within the acceptable range of the CPCB standards and IS 10500, a slight elevation in magnesium and electrical conductivity indicates the onset of an input of dissolved solids, nutrients and ions through agricultural runoff, which could pose a risk in the future.

Namkum (S3) and Tatisilwai (S5) were graded as poor, with most of their parameters approaching or exceeding the permissible threshold. These stations recorded elevated BOD, ionic concentration, total hardness and alkalinity, together with low dissolved oxygen, indicating water strongly influenced by the discharge of industrial effluent and sewage.

Chutia (S4) was graded as very poor, with almost every parameter exceeding the safe limit. The high BOD indicates a heavy organic pollution load and the low dissolved oxygen indicates a severe oxygen deficiency, and the simultaneous failure of several parameters creates conditions stressful for the survival of aquatic biota.

Taken together, these results indicate that degradation along the reach studied is concentrated within a discrete urban and industrial corridor. Water quality is good at the source and in the upper reach, deteriorates sharply between Namkum (S3) and Tatisilwai (S5), and improves again at Getalsud (S6), Hundru (S7) and Muri (S8).

Getalsud reservoir (S6) increases the hydraulic residence time, allowing suspended and settleable solids and their associated ionic and organic load to be deposited, while the turbulent descent at Hundru Falls (S7) provides intense re-aeration that restores dissolved oxygen and strips accumulated free carbon dioxide to the atmosphere. The river therefore retains an appreciable capacity for self-purification, and the degradation observed here reflects the exceedance of that capacity within a limited reach rather than its permanent loss.

The internal consistency of the data supports this interpretation. At Namkum (S3), Chutia (S4) and Tatisilwai (S5), the elevated TDS, electrical conductivity, salinity, chloride, magnesium hardness and alkalinity co-vary, the expected signature of a common ionic source rather than of independent analytical variation, while the simultaneous occurrence of high free carbon dioxide, high BOD and depressed dissolved oxygen identifies the decomposition of an organic load as the dominant oxygen-consuming process. Chutia (S4) is the only station at which every parameter group is affected at once, and is therefore identified here as a pollution hotspot and a priority for intervention.

These interpretations should be read in the light of the design of the study. Sampling was confined to a single pre-monsoon season and one grab sample was taken at each station, so the data characterize the low-flow condition, in which dilution is at a minimum and pollutant concentrations are at their seasonal maximum; they do not permit an assessment of temporal variability or of within-site analytical variance. The absence of replicate samples also precludes inferential statistical testing, and the analysis presented here is accordingly descriptive. Nutrients, heavy metals, and microbiological indicators were not determined, although the industrial character of the impacted reach makes metal contamination plausible, and discharge was not measured, so pollutant loads could not be calculated from the concentration data.

Conclusions

The physicochemical characterization of the Subarnarekha River across eight sampling stations in Ranchi district resolved three distinct water quality zones during the pre-monsoon season.

The upper reach at Nagri (S1) and Dhurwa (S2) retained a low ionic content, an adequate dissolved oxygen concentration and a low biochemical oxygen demand, and conformed to the CPCB and BIS (IS 10500:2012) criteria at almost every parameter, the sole exception being the mildly acidic pH at Nagri (S1), which reflects the low carbonate content and correspondingly weak buffering capacity of the headwater terrain. The urban and industrial corridor at Namkum (S3), Chutia (S4) and Tatisilwai (S5) showed the opposite condition, with elevated electrical conductivity, total dissolved solids, salinity, chloride, magnesium hardness, total alkalinity and free carbon dioxide occurring together with depressed dissolved oxygen and an elevated biochemical oxygen demand. Chutia(S4) recorded the highest value for almost every parameter measured and the lowest dissolved oxygen, and is identified here as a pollution hotspot: it is the only station at which every parameter group is affected simultaneously. The downstream reaches at Getalsud (S6), Hundru (S7) and Muri (S8) occupied an intermediate condition, most parameters returning to within acceptable limits but with magnesium and electrical conductivity remaining slightly elevated.

The principal importance of these findings is that degradation of the Subarnarekha within the reach studied is not a monotonic decline from source to mouth but is concentrated within a discrete urban and industrial corridor, beyond which the river demonstrably recovers through sedimentation in Getalsud reservoir (S6) and re-aeration at Hundru Falls (S7). The river therefore retains an appreciable capacity for self-purification, and the degradation recorded here represents the exceedance of that capacity within a limited reach rather than its permanent loss. This distinction is consequential for management, because it indicates that remedial effort directed at a small number of identifiable local sources can be expected to yield a disproportionate improvement in the condition of the river as a whole.

Three priorities emerge from this assessment. First, Namkum (S3), Chutia (S4) and Tatisilwai (S5) require site-specific effluent treatment and the interception of untreated sewage before discharge, since the ionic and organic signatures recorded there originate from identifiable local sources. Second, Getalsud (S6), Hundru (S7) and Muri (S8), where magnesium and electrical conductivity are already elevated, warrant preventive monitoring so that the onset of degradation can be detected before the assimilative capacity of these reaches is exceeded. Third, the pre-monsoon baseline established here should be extended to the monsoon and post-monsoon seasons, with replicate sampling and with the inclusion of nutrients, heavy metals and microbiological indicators, in order to convert this site-specific characterization into a basis for the continuous management of the Subarnarekha.

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Declarations

Author contributions.

Conceptualization- Pipas Kumar
Data curation- Pipas Kumar, Kanchita Toppo
Formal analysis- Pratiksha Delphin Toppo, Md Tauqir Zaya, Anushka Kumari, Asma Kerketta, Srishti Grace Toppo
Funding acquisition-NA
Investigation- Pipas Kumar, Pratiksha Delphin Toppo
Methodology- Pipas Kumar, Pratiksha Delphin Toppo
Project administration- Bharti Singh Raipat
Resources- Bharti Singh Raipat
Software- Pratiksha Delphin Toppo
Supervision- Pipas Kumar
Validation- Pipas Kumar, Md Tauqir Zaya, Anushka Kumari, Asma Kerketta, Srishti Grace Toppo
Visualization- Pipas Kumar
Writing – original draft- Pratiksha Delphin Toppo
Writing – review and editing- Pipas Kumar

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Data availability. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics statement. This study involved neither human participants nor animal subjects, and no ethical approval was therefore required.

Use of AI and AI-assisted technologies. During the preparation of this manuscript, the author(s) used **ChatGPT** solely to improve readability, correct basic grammar and spelling, and verify reference formatting. After using this tool/service, the author(s) reviewed and edited the content.

References

1. Saluja DS (2023) Assessment of water quality and pollution status of Machna River during monsoon season in District-Betul: a physico-chemical analysis. International Journal of Science and Research 12(8):2136–2138. https://doi.org/10.21275/SR23824195133
2. Bharati VK (2018) E-resources searching behaviour of research scholars of Mahatma Gandhi Kashi Vidyapith, Varanasi: a case study. Asian Journal of Information Science and Technology 8(2):9–13. https://doi.org/10.51983/ajist-2018.8.2.188
3. Singh G (2026) The role of artificial intelligence (AI) in personalized learning. International Journal of Scientific Research in Engineering and Management 10(2):1–9. https://doi.org/10.55041/IJSREM56942
4. Katiyar R (2026) The policy vacuum – fragmented governance in India's pharma sector. In: Pills, Profits, and Problems: An Anatomy of India's Pharmaceutical Crisis. https://doi.org/10.70034/ppp/bk/2026pp.25
5. Bhardwaj R, Singh RK (2022) Water quality modeling of the River Ganga in the northern region of India using the artificial neural network technique. Journal of Water Management Modeling 30:C486. https://doi.org/10.14796/JWMM.C486
6. Mallick M (2025) Assessment of physico-chemical water quality parameters of the Brahmani River. NG Civil Engineering 1(1):15–23. https://doi.org/10.66132/ngce20250103
7. Kumar CP, Chandramalla CB (2022) Impact of COVID-19 on food grain stock and per capita availability in Andhra Pradesh, India: a critical analysis. Asian Journal of Research in Social Sciences and Humanities 12(5):312–317. https://doi.org/10.5958/2249-7315.2022.00320.3
8. Kumar P, Joshi V (2019) Modelling surface run-off response using hydrological model SWAT in the upper watershed of River Subarnarekha, India. Earth Sciences Malaysia 3(2):9–15. https://doi.org/10.26480/esmy.02.2019.09.15
9. Kumar P, Joshi V (2019) A geospatial-statistical approach to alienate priority area of upper watershed of River Subarnarekha using morphometric assessment framework. Malaysian Journal of Geosciences 3(1):21–31. https://doi.org/10.26480/mjg.01.2019.21.31

10. Das M, Saha P, Ghosh M (2026) A spatiotemporal assessment of land use and land cover dynamics in Haldia, West Bengal (1995–2025) using geospatial techniques. International Journal of Research and Analytical Reviews 13(1):]. https://doi.org/10.56975/ijrar.v13i1.326520
11. Chakraborty B, Chatterjee ND (2026) Assessment of long term hydrological variability and flow regime alterations in the Subarnarekha River basin using non parametric trend analysis and wavelet approaches. Discover Geoscience 4:224. https://doi.org/10.1007/s44288-026-00601-7
12. Tabassum F, Krishna AP (2023) Temporal change dynamics of the hydrometeorological conditions of upper Subarnarekha River Basin (SRB) using geospatial techniques. Proceedings of the 5th International Electronic Conference on Remote Sensing:article 16364. https://doi.org/10.3390/ECRS2023-16364
13. [13]. Roy IRW, Raj AS, Viaroli S (2025) Microplastic removal, identification and characterization in Chennai sewage treatment plants. Journal of Environmental Management [vol: pp–pp]. https://doi.org/10.1016/j.jenvman.2025.125120
14. Verma A, Kumar S, Parhi PK (2025) Rainfall runoff and flood plain inundation modeling of the Kharkai River, India using HEC-HMS and HEC-RAS. Journal of Water Management Modeling 33:C546. https://doi.org/10.14796/JWMM.C546
15. Golla SK, Barot H, Pachava V, Yadav P (2026) Enterprise profile and structural associations among micro, small and medium enterprises: an empirical study from Gujarat, India. International Journal for Multidisciplinary Research 8(4).. https://doi.org/10.36948/ijfmr.2026.v08i04.84380
16. Roy BC, Sarkar S, Sinha RC, Srivastava I (2019) Identification of a new industrial area based on a macro-level analysis: a case of Bokaro District, Jharkhand, India. International Journal of Engineering and Advanced Technology 9(2):1626–1632. https://doi.org/10.35940/IJEAT.A1168.129219
17. Grab sampling (2021) The Fairchild Books Dictionary of Textiles. https://doi.org/10.5040/9781501365072.7096
18. Bryce RW, Evans JC, Olsen KB (1991) Ground-water sample collection and analysis plan for the ground-water surveillance project. https://doi.org/10.2172/5699547
19. Joint Statement of American Water Works Association and American Public Health Association on Procedure for Issuing "Standard Methods for the Examination of Water and Sewage" (1932). Journal of the American Water Works Association 24(10):1609–1612. https://doi.org/10.1002/j.1551-8833.1932.tb18153.x
20. Riswanto R, Marwoto P, Nugroho SE (2026) Prototype of TDS, EC, temperature monitoring system with NodeMCU ESP8266 in water quality prediction against variations in catfish density BUDIKDAMBER. Compton: Jurnal Ilmiah Pendidikan Fisika 12(2):35–54. https://doi.org/10.30738/cjipf.v12i2.21377
21. Rusdi BM, Supardi ZAI (2023) Design a pH, temperature and solute monitoring device in IoT-based goldfish aquarium water with NodeMCU ESP32. Inovasi Fisika Indonesia 12(3):77–86. https://doi.org/10.26740/ifi.v12n3.p77-86
22. Manjunath Swamy HM, Nagaraja B, Kiran BR (2022) Water chemistry with reference to physico-chemical parameters of eutrophic tank in Bhadravathi town, Karnataka. International Journal of Biology, Pharmacy and Allied Sciences 11(1):1–11. https://doi.org/10.31032/IJBPAS/2022/11.1.5763
23. Bureau of Indian Standards (2012) IS 10500:2012. Drinking water—specification (second revision). Bureau of Indian Standards, New Delhi.
24. Bureau of Indian Standards (1986) IS 11624:1986. Guidelines for the quality of irrigation water. Bureau of Indian Standards, New Delhi.
25. Bureau of Indian Standards (2008) IS 3025 (Part 61):2008. Methods of sampling and test (physical and chemical) for water and wastewater, Part 61: Total and free carbon dioxide. Bureau of Indian Standards, New Delhi.
26. Bureau of Indian Standards (2009) IS 3025 (Part 21):2009. Methods of sampling and test (physical and chemical) for water and wastewater, Part 21: Total hardness. Bureau of Indian Standards, New Delhi.
27. Bureau of Indian Standards (1991) IS 3025 (Part 40):1991. Methods of sampling and test (physical and chemical) for water and wastewater, Part 40: Calcium. Bureau of Indian Standards, New Delhi.
28. Bureau of Indian Standards (1988) IS 3025 (Part 32):1988. Methods of sampling and test (physical and chemical) for water and wastewater, Part 32: Chloride. Bureau of Indian Standards, New Delhi.
29. Bureau of Indian Standards (2023) IS 3025 (Part 23):2023. Methods of sampling and test (physical and chemical) for water and wastewater, Part 23: Alkalinity. Bureau of Indian Standards, New Delhi.
30. Bureau of Indian Standards (1989) IS 3025 (Part 38):1989. Methods of sampling and test (physical and chemical) for water and wastewater, Part 38: Dissolved oxygen (first revision). Bureau of Indian Standards, New Delhi.
31. Kumar MD, Ramdas A, Vedantam N, Campling P, Ermen SV, Mandal S (2024) Market instruments and institutions for reducing pollution in the Ganga River Basin. Water Policy 26(7):741–772. https://doi.org/10.2166/wp.2024.126
32. Liu Y, Zhou Q, Chen M (2025) Applying full-text citation content mining to analyze the triangular citation structure in scientific literature. The Electronic Library 43(6):841–866. https://doi.org/10.1108/EL-09-2024-0283
33. Chatterjee A, Das P, Sinha SK (2025) Assessment of physico-chemical parameters and trace of micro bacteriological parameter for water bodies of western region of Ranchi district. International Journal of Environment and Waste Management 38(2):207–224. https://doi.org/10.1504/IJEWM.2025.148775
34. Ministry of Health and Family Welfare, Government of India (1986) Statement on National Health Policy: Ministry of Health and Family Welfare, Government of India, New Delhi, 1982. Journal of Public Health Policy.
35. Orr JC, Epitalon JM, Dickson AG, Gattuso JP (2018) Routine uncertainty propagation for the marine carbon dioxide system. Marine Chemistry 207:84–94. https://doi.org/10.1016/j.marchem.2018.10.006
36. Dahanga P, Nath S (2024) Monitoring and assessment of Subarnarekha River water quality using water quality index. International Journal of Environment and Climate Change 14(10):81–91. https://doi.org/10.9734/ijecc/2024/v14i104469
37. Karim AA, Panda RB (2014) Assessment of water quality of Subarnarekha River in Balasore Region, Odisha, India. Current World Environment 9(2):437–446. https://doi.org/10.12944/CWE.9.2.27