Assessment of Water Quality of Tapi River at Surat City

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Abstract:

This study examines the water quality of the Tapi River in Surat City using secondary data collected over a twelve-month period from August 2023 to July 2024. As the river is a major source of water for domestic consumption, industrial activities, and agriculture, maintaining its quality is essential for environmental protection and the well-being of the local population. The analysis is based on water quality data published in the annual reports of the Gujarat Pollution Control Board (GPCB). Important indicators such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), fecal coliform, and total coliform were considered to assess the condition of the river.Descriptive statistical methods were used to summarize the data, while one-way ANOVA was applied to determine whether significant differences existed among the selected water quality parameters. The results show that the overall quality of river water generally complied with the prescribed standards of the Bureau of Indian Standards (BIS) and the Central Pollution Control Board (CPCB). However, higher COD and coliform concentrations were recorded at certain monitoring locations, especially near the ONGC Bridge and Varachha Bridge, indicating the influence of industrial effluents and urban wastewater discharge. The statistical analysis also revealed significant variation among the selected parameters, reflecting the impact of human activities on the river ecosystem. These findings emphasize the need for regular water quality monitoring and effective pollution control measures to support the sustainable management of the Tapi River in the face of increasing urbanization and industrial development in Surat.

Introduction:

Surat City, historically known as Suryapur from 1500 to 1520 A.D., was colonized by the King from Sauvira and later came under British control in 1759, remaining so until India's independence. Located on the banks of the Tapi River and along the Arabian Sea, Surat emerged as a major trade hub in the 16th to 18th centuries. Geographically, Surat is situated in South Gujarat, covering an area of 474.52 sq. km, and is organized into seven zones (City of Surat, 2024). The city of Surat is divided into nine administrative zones under SMC: North, Central, West, East A, East B, South, South-West, South-East, and another sub-division of South. The city serves as a crucial point on the Ahmedabad-Mumbai corridor, boasting national highways that connect it to Western India and has an international airport.

According to the Census of India (2011), Surat is the second-largest city in Gujarat and the eighth-largest city in the country in terms of population, with approximately 4.47 million residents. Owing to rapid urbanization and economic growth, the city's population is expected

to reach nearly 8.6 million by 2025 (City of Surat, 2024). Surat has a high literacy rate of 87.89%, including 91.22% among males and 83.44% among females, reflecting a relatively well-educated population. The city's demographic profile shows that about one-fourth of the population is below 25 years of age, while nearly 65% falls within the economically active age group of 26 to 65 years (City of Surat, 2024). Despite its economic progress, around 10.78% of the population continues to live in slum settlements (Vector Borne Diseases Control Department , 2018). Surat experiences a tropical climate with considerable seasonal variation. The recorded temperature ranges from a minimum of 9.9°C to a maximum of 44.5°C, and the city receives an average annual rainfall of about 60 inches (Vector Borne Diseases Control Department , 2018).The historical and geographical factors provide support to rapidly growing Surat. This region provides employment through strong textile and diamond industries. In the Swachh Survekshan 2023 (awarded in January 2024), Surat was jointly recognized as one of India's cleanest cities (alongside Indore) in the category of cities with a population over 1 lakh. However, with the rise of the Bombay port, Surat experienced economic decline, including a downturn in its shipbuilding industry. The growth of city in different sectors increased after independence.

Urbanization and Industrialization in Surat

Surat is located in south Gujarat near the Tapi river. It is one of the fastest growing city in case of urban and industrial sector (Economic Master Plan for Surat Economic Region, 2024) .The city's urbanization process accelerated significantly after the 1960s due to rapid economic expansion, migration, and infrastructural development (Shah, 1978).Surat's modern urban growth has been driven by its emergence as a global hub for diamond processing and textile manufacturing. The growth of industrial activities in Surat has attracted workers from different parts of India, resulting in continuous population growth. This rapid increase in population has contributed to the expansion of peri-urban settlements and the gradual transformation of agricultural land into residential neighborhoods and industrial estates. (Shah & Dave, 2020).

Urbanization has also been supported by improvements in civic services and governance under the Surat Municipal Corporation (SMC). Surat is widely recognized for its effective urban management practices, particularly in waste collection, road network development, and public health measures undertaken after the 1994 plague outbreak. These reforms contributed to transforming the city into one of the cleanest and most efficiently governed urban centers in India (World Bank, 2018). However, rapid industrialization and population expansion have also created challenges related to environmental degradation,

increased water demand, pressure on sanitation systems, and rising exposure to water and air pollution. Unplanned expansions along the urban fringe and industrial discharges into the Tapi River have emerged as key concerns for sustainable development recently.

Industrialization in Surat is largely defined by two major sectors: the diamond cutting and polishing industry and the synthetic textile industry (Mehta, 2019). Together, they contribute significantly to employment generation and export earnings (Mehta, 2019).The establishment of organized industrial estates such as Pandesara, Sachin GIDC, Kadodara, and Hazira industrial belt further strengthened the city's manufacturing base. The Hazira belt, in particular, hosts major petrochemical, LNG, and heavy engineering industries, including Reliance, ONGC, L&T, and Essar, which have played a pivotal role in boosting industrial infrastructure and ancillary services (GIDC, 2022). Hazira and the Surat Economic Zone are recognized as key growth areas. As an industrial hub, Surat specializes in sectors such as textile manufacturing, diamond cutting and polishing (responsible for 42% of the world's total), trade, Zari works, and petrochemicals. Major companies like Reliance, ESSAR, Shell, and ONGC operate in the region, employing over 1.5 million individuals in the diamond industry alone, predominantly located in Mota Varachha. Surat is India's second-largest textile hub, producing 90% of the nation's polyester and nylon yarn. With a daily output of around 40 million metric tons of synthetic fabric, it provides jobs for over a million people (City of Surat, 2024). The city's current GDP is estimated at US$40 billion, with economic sectors contributing 65% services, 25% manufacturing, and 10% agriculture (City of Surat, 2024).

Several ongoing and planned infrastructure projects are expected to strengthen Surat's economic development in the coming years. Major initiatives such as the Delhi–Mumbai Expressway and the proposed coastal corridor are likely to improve regional connectivity and support industrial and commercial growth. The city is also home to the Surat Diamond Bourse, spread over 36 acres, which is recognized as one of the world's largest office complexes for the diamond and jewellery trade. Another important development is the Gujarat Hira Bourse Park, covering approximately 247 acres and equipped with facilities such as a convention centre and supporting infrastructure. The Special Economic Zone (SEZ) at Sachin GIDC accommodates more than 250 industrial units from various sectors and provides a favourable environment for manufacturing through policy incentives. With its proximity to Hazira Port, access to an international airport, and well-developed transport and industrial infrastructure, Surat continues to attract domestic and international investment, further strengthening its position as

a leading centre for the diamond and textile industries. (Economic Master Plan for Surat Economic Region, 2024).

Tapi River-Geography and Importance

Tapi river originated from Betul district of Madhya Pradesh. The Tapi river end in Arabian sea after passing through Surat city. This river flow pass through three states that is Madhya Pradesh, Maharashtra and Gujarat. Total length is 724km in which first 282km river flows in Madhya Pradesh, 228km in Maharashtra and remaining 214km in Gujarat (TAP BASIN, 2014). Water of Tapi river is main source of water for people of surat city which supplemented by the Ukai Dam. Total capacity is 7,414 million cubic meters and people heavily dependent on it for domestic, industrial, and agricultural use (source: Surat Municipal Corporation - Tapi Revival Project). The significance of this river is considerable in City in case of economic and industrial point of view. The Tapi River, which provides 90% of Surat's water needs (SMC CDP 2041) and sustains an annual GDP growth of more than 11%, is the city's lifeline (Ministry of Housing and Urban Affairs (MoHUA), Government of India (2021). Ease of Living Index – Surat Profile). The city's diamond and textile industries relied largely on water for cooling and processing. SMC has begun reusing purified wastewater to meet water demands.

According to Surat Municipal Corporation, it provides more than 115 MLD of reclaimed water to companies, bringing in over Rs.140 crore a year. By using 11 sewage treatment plants (STPs) to recycle about 930 MLD of wastewater, the city lessens the demand on freshwater resources. Water delivery reached 1,564 MLD per day as of early 2025, indicating a rising demand that is expected to reach 2,332 MLD by 2041. SMC and the Asian Development Bank work together to run a public-private partnership that produces 40 MLD of superior industrial water from 57 MLD of sewage. Weir-cum-causeway, twelve intake wells, six treatment facilities, and Ukai Dam are all part of the integrated water resource infrastructure that guarantees a steady supply and guards against tidal saturation and saline intrusion. The Tapi River is a major source of water for farmers who utilize it for irrigation. Thus, it is significant from a social as well as an industrial and economic perspective.

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Literature Review

(Miteshkumar Dohjibhai Chaudhary, 2025)Water Quality of River Tapi, Surat Using WAWQI. The research aimed to assess the physicochemical characteristics of the Tapi River in Surat, evaluate its water quality using the Weighted Arithmetic Water Quality Index (WAWQI), determine its suitability for domestic, agricultural, and irrigation purposes, and analyze correlations among water quality parameters to identify pollution sources. The Tapi River is a vital water resource in Gujarat, supporting agriculture, industries, and urban water needs. Rapid industrial growth in areas like Hazira, Pandesara, Udhna, and Sachin has increased effluent discharge into the river. The study evaluated water quality condition using laboratory tests and statistical modeling, considering both domestic and industrial contributions to river pollution. Observations showed slightly alkaline pH values, lower than desirable DO levels, moderate organic and chemical pollution, and limited fertilizer runoff. Phosphate and potassium levels were higher, indicating inputs from detergents or agriculture. The WAWQI value was 37.049, classifying Tapi water as "good," suitable for domestic use with minor treatment. Strong negative correlations were observed between DO and COD and DO and nitrite, suggesting oxygen depletion due to organic and nitrogenous wastes. A moderate positive correlation between BOD and nitrate indicated agricultural runoff and sewage influence. Overall, the river showed acceptable quality but with signs of localized organic pollution.

(Dr. Pankaj J. Gandhi, 2022) Mapping the Socio–Economic and Environmental Impact of Weir Constructed on Tapti River and Industrial Zone Developed at Hazira of Surat: A Study Focused on Fisherman Community (Machhi Samaj) of the city. Research on the socio-economic and environmental impacts of a weir on the Tapti River and industrial growth in Hazira, Surat, assessed effects on the Machhi Samaj (fishermen community). The study, based on 150 structured interviews and water sampling conducted from August 2020 to May 2021, found reduced river flow after weir construction, leading to increased salinity and habitat degradation. Industrial pollution was severe, with turbidity exceeding WHO limits. Fishermen experienced a decline in fish catch (84.3%), with most earning between Rs. 8,000–15,000/month. Migration for jobs was common, with health issues like malaria rising as fish populations fell. The research concluded that while the weir served industrial needs, it disrupted ecology and the community's socio-economic stability. Recommendations included NGO awareness programs, effluent control, government support for fishermen, establishment of organized fish markets, and public health initiatives to restore environmental balance and enhance livelihoods.

(Hiralkumari B. Patel, 2013) Analysis of Pollutant Load Carrying Capacity of the River Tapi Using QUAL2Kw for Surat City. Research evaluated the Tapi River's pollutant assimilation in Surat, utilizing the QUAL2Kw model to estimate its capacity and identify critical low self-purification areas. A 22.39 km stretch was analyzed, categorizing into 21 reaches based on Irrigation Department data. Water samples from Sarthana, Katargam, and Jahangirpura were tested for various parameters showing high BOD and low DO, indicating organic pollution. The model, calibrated across three pollution scenarios, found upper sections had lower capacity while downstream reaches were more capable. Findings highlighted major effluent contributions from municipal and industrial sources, leading to significant contamination. Recommendations include enhanced sewage treatment, restorative projects, and ongoing assessments to improve river health and management.

Research Methodology

The research is covering geographical area of Surat covered by Surat Municipal Corporation. Surat second highest urbanized district in Gujarat (2011) with potential scope of industrialization. in this case, it is essential to have balance development of the region.

Research Gaps

The document outlines several significant research gaps in the study of water pollution in Surat District. Firstly, there is a lack of integrated socio-economic assessments, failing to

consider the effects of water pollution on health, income, and household water-use behavior. Secondly, there is no comprehensive community survey that collects primary data across different households in the district. Additionally, issues of public perception, awareness, and willingness to pay for water services are not addressed. The research does not include comparative analyses among various zones like urban and peri-urban areas, leaving certain distinctions unexplored. Furthermore, existing studies fail to integrate environmental data with socio-economic variables, lacking a statistical combined analysis. Lastly, there is no estimation of household-level economic burdens related to water quality, including costs associated with bottled water, medical expenses from water-borne diseases, and productivity losses.

Need of Research

The need for this research arises from the increasing pressure on the Tapi River due to rapid urbanization, industrial expansion, and population growth in Surat City. As the river supplies nearly ninety percent of the city's water requirements, deterioration in its quality poses serious risks to public health, aquatic ecosystems, and economic activities such as textiles and diamond processing. Industrial effluents, untreated or partially treated sewage, and urban runoff contribute unevenly across different river stretches, making localized assessment essential. Moreover, existing studies often focus on limited parameters or short timeframes, leaving gaps in understanding spatial and temporal variations. This research is therefore necessary to identify pollution-prone locations, assess compliance with environmental standards, and support evidence-based planning for pollution control and sustainable water resource management.

Objectives of the Study

- To identify the most polluted locations of Tapi River in Surat City based on descriptive statistics
- To compare the levels of key water quality parameters (pH, DO, BOD, COD, Fecal coliform, Total coliform) across different locations of the Tapi River in Surat City.

Hypothesis

- H0: The mean values of the water quality measures do not differ in a way that is statistically significant.
- H1: The mean values of the water quality metrics differ statistically significantly.

Sources of Data

Data collected from the secondary sources which included Research papers, Government Reports and Official websites.

Statistical Tools

Descriptive Statistics and Anova: Single Factor applied

Scope of the Study

The scope of the study is confined to the assessment of water quality of the Tapi River within the municipal limits of Surat City using secondary data for the period August 2023 to July 2024. The analysis focuses on selected physico-chemical and bacteriological parameters relevant to river health and suitability for outdoor bathing and general use. Spatial comparisons across major river locations such as Kathor, Varachha Bridge, ONGC Bridge, Rander, and Umara Temple allow identification of pollution patterns linked to industrial and urban activities. While the present study emphasizes descriptive and statistical evaluation, it also provides a foundation for future research involving long-term monitoring, source apportionment of pollutants, ecological impact assessment, and integration of socio-economic dimensions related to water use and health outcomes.

Material

Status of Water Quality of Tapi River from August 2023 to July 2024

Month	Location_Name	pH	DO	BOD	COD	Fecal_ coliform	Total_ coliform
August-2023	Kathor, N.H.	7.4	7.2	1.9	6	10	26
	Varachha Bridge	7.37	7.1	1.8	8	10	25
	ONGC Bridge	6.98	6.6	2.3	24	6	27
	Rander	7.56	7	1.8	6	6	21
	Swamivivekanand Bridge	7.5	7	1.8	12	6	22
	Sardar Bridge	7.5	7.1	2	14	6	17
	Umara Temple	7.48	6.8	2.2	-	4	26
	Kathor, N.H.	6.96	7.1	1.7	6	6	26

September-2023	Varachha Bridge	6.98	7	1.8	7	10	31
	ONGC Bridge	6.66	7	2.5	26	12	40
	Rander	7.12	7.2	1.9	9	14	39
	Swamivivekanand Bridge	6.84	7.1	2	22	6	32
	Sardar Bridge	6.77	7	1.9	24	10	34
	Umara Temple	6.74	6.9	2.4	-	10	39
October-2023	Kathor, N.H.	8.18	7.2	1.1	10	17	58
	Varachha Bridge	8.22	7.1	1.2	12	14	39
	ONGC Bridge	8.17	6.4	1.6	18	11	47
	Rander	7.77	7	1.4	10	17	58
	Swamivivekanand Bridge	7.16	6.4	1.4	22	11	39
	Sardar Bridge	7.68	6.4	1.8	26	10	34
	Umara Temple	8.05	6.2	1.8	-	12	40
November-2023	Kathor, N.H.	6.84	7.2	1.2	7	17	40
	Varachha Bridge	6.74	7.2	1.5	8	14	33
	ONGC Bridge	6.75	6.6	2.4	24	12	33
	Rander	7.82	7.1	1.6	8	14	34
	Swamivivekanand Bridge	7.1	6.5	2.3	13	15	41
	Sardar Bridge	7.07	6.7	2.3	14	15	40
	Umara Temple	7.1	6.8	2.2	-	14	39
December-2023	Kathor, N.H.	7.5	7.3	1.2	7	11	39
	Varachha Bridge	7.52	7	1.5	8	12	47
	ONGC Bridge	6.92	6	2.4	22	11	48

	Rander	7.48	6.9	2	10	17	58
	Swamivivekanand Bridge	7.48	6	2.1	20	10	58
	Sardar Bridge	7.29	6.1	2.3	1.8	10	39
	Umara Temple	7.24	6	2.7	-	12	47
January-2024	Kathor, N.H.	7.07	7.2	0.8	8	-	15
	Varachha Bridge	7.22	7.4	1	10	12	49
	ONGC Bridge	6.72	6.4	2.3	26	10	33
	Rander	7.26	7.4	1.4	14	10	39
	Swamivivekanand Bridge	7.61	6.3	1.9	18	12	46
	Sardar Bridge	7.32	6.2	2	22	12	43
	Umara Temple	7.17	6.3	2.4	-	17	48
February-2024	Kathor, N.H.	7.4	7.3	1	8	10	40
	Varachha Bridge	7.33	7.2	1.2	10	6	33
	ONGC Bridge	7.13	6.7	2.4	24	10	41
	Rander	7.81	7.1	1.1	10	13	48
	Swamivivekanand Bridge	7.16	6.8	1.8	20	12	38
	Sardar Bridge	7.19	6.9	2	21	13	39
	Umara Temple	7.28	6.6	2.2	-	17	48
March-2024	Kathor, N.H.	8.42	7.1	1.6	9	6	24
	Varachha Bridge	8.46	7	2	10	4	17
	ONGC Bridge	6.86	6.2	2.8	24	12	46
	Rander	8.48	6.9	1.9	10	14	63
	Swamivivekanand Bridge	8.22	6.5	2.8	22	14	48

	Sardar Bridge	7.97	6.6	2.6	24	10	32
	Umara Temple	6.94	6.7	2.4	-	10	34
April-2024	Kathor, N.H.	8.1	7	1.3	10	39	56
	Varachha Bridge	8.23	6.9	1.5	12	33	63
	ONGC Bridge	7.72	6.5	1.6	28	12	40
	Rander	8.18	6.9	1.4	12	17	40
	Swamivivekanand Bridge	7.63	6.5	1.8	22	15	48
	Sardar Bridge	7.66	6.4	1.7	22	14	32
	Umara Temple	7.69	6.7	1.5	-	14	47
May-2024	Kathor, N.H.	8.32	6.8	1.5	8	-	17
	Varachha Bridge	8.38	7.1	1.4	10	-	14
	ONGC Bridge	7.97	6.7	1.4	26	10	40
	Rander	8.16	7.1	1.6	10	11	27
	Swamivivekanand Bridge	8.46	6.6	1.9	20	10	33
	Sardar Bridge	7.88	6.2	1.9	22	10	29
	Umara Temple	7.93	6.8	1.8	-	10	46
June-2024	Kathor, N.H.	8.47	7	1.4	6	39	56
	Varachha Bridge	8.48	6.8	1.8	8	33	63
	ONGC Bridge	8.34	6.4	2.6	22	12	40
	Rander	8.45	6.7	1.9	10	17	40
	Swamivivekanand Bridge	8.46	6.8	1.7	22	14	41
	Sardar Bridge	8.47	7	1.3	23	15	48
	Umara Temple	8.36	6.8	1.5	-	14	47

	Kathor, N.H.	8.08	7.2	1	4	-	1
	Varachha Bridge	7.97	7.4	1.2	6	-	40
	ONGC Bridge	8.46	6.5	1.5	18	6	43
	Rander	8.16	7.1	1.4	6	-	47
	Swamivivekanand Bridge	7.82	6.6	1.6	14	14	58
	Sardar Bridge	7.92	6.7	1.5	12	13	38
July-2024	Umara Temple	7.22	6.7	1.4	-	13	33

Source: Annual reports of GPCB July 2024

Result And Discussion

Table: Descriptive Statistics of Tapi River Water Quality (August 2023-July 2024)

Parameter	Count	Mean	Min	Max	Std Dev	BIS / CPCB Permissible Limits (Class-B / Outdoor bathing)	Interpretation
pH	84	7.62	6.66	8.48	0.56	6.5 – 8.5	All values within permissible limit; Rander shows maximum pH, ONGC Bridgelowest.
DO (mg/L)	84	6.8	6	7.4	0.35	≥ 5 mg/L	DO is good at all locations; Rander and Varachha Bridge shows maximum DO, ONGC Bridge lowest

BOD (mg/L)	84	1.78	0.8	2.8	0.46	≤ 3 mg/L	All locations safe (<3 mg/L); organic pollution low.Swami Vivekanandand ONGC Bridge shows maximum, Kathor, N.H. lowest
COD (mg/L)	72	14.55	1.8	28	7.13	No fixed BIS limit (Usually < 10 mg/L desirable)	ONGC Bridge highest and Sardar Bridge lowest
Fecal Coliform (MPN)	78	12.83	4	39	6.35	≤ 500 MPN/100 ml	Higher at Kathor, N.H. and Lowest at Varachha Bridge and Umara Temple
Total Coliform (MPN)	84	38.89	1	63	11.98	≤ 500 MPN/100 ml	Very high at Rander and Varachha bridge and lowest at Kathor, N.H.

Anova: Single Factor						

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
pH	84	639.93	7.618214	0.309593		
DO	84	570.9	6.796429	0.12565		
BOD	84	149.7	1.782143	0.210641		
COD	72	1047.8	14.55278	50.80056		
Fecal_coliform	78	1001	12.83333	40.29654		
Total_coliform	84	3267	38.89286	143.5908		
ANOVA						
Source of Variation	*SS (Sum of Squares)*	*df (degrees of freedom)*	*MS (Mean Square)*	*F*	*P-value*	*F crit*
Between Groups	72464.74	5	14492.95	372.3836	1.2649E-162	2.232793
Within Groups	18681.32	480	38.91941			
Total	91146.06	485				

Interpretation

1)F-value = 372.384

- The F-value is very high. In ANOVA, a high F-value indicates that the variance within groups is far smaller than the variance between groups., suggesting significant differences among the group means.

2)P-value = 1.26 × 10^-162

- This is effectively 0, which is much lower than any common significance level (0.05, 0.01).
- This means we reject the null hypothesis.
- Interpretation: At least one water quality parameter mean is significantly different from the others.

3)F crit = 2.233

- Since F > F crit, it further confirms that the group differences are statistically significant.

Conclusion

The study concludes that the overall water quality of the Tapi River in Surat City remains within permissible limits for most key parameters; however, signs of localized pollution are evident, particularly in stretches influenced by industrial discharge and dense urban activity. Dissolved oxygen levels indicate generally healthy conditions, while low BOD values suggest limited organic pollution. In contrast, elevated COD and coliform concentrations at specific locations point toward chemical contamination and microbial pollution from sewage and industrial sources. The statistical analysis shows that water quality differs across various monitoring locations along the Tapi River, indicating that pollution levels are not uniform throughout the study area. These variations are mainly associated with local sources of contamination, including industrial discharges and urban wastewater. The findings suggest the need for location-specific pollution control measures, better treatment and management of wastewater, and regular monitoring of river water quality. Strengthening cooperation among government agencies, industries, and local authorities will play an important role in protecting the river and ensuring the sustainable use of its water resources for the growing population of Surat.

Recommendation

Based on the analysis of water quality parameters of the Tapi River in Surat City from August 2023 to July 2024, it is recommended that continuous and location-specific monitoring be strengthened, particularly at industrially influenced stretches such as ONGC Bridge, Rander, and Swami Vivekanand Bridge where higher COD and coliform levels were observed. Although most parameters remain within BIS/CPCB permissible limits, periodic spikes in

COD and microbial contamination indicate localized impacts from industrial discharge and urban sewage. The Surat Municipal Corporation and Gujarat Pollution Control Board should further enhance the efficiency of sewage treatment plants, ensure strict compliance with industrial effluent standards, and expand real-time water quality monitoring systems. Public awareness programs on sanitation and waste disposal, along with increased reuse of treated wastewater for industrial purposes, can reduce pressure on freshwater resources. Integrating water quality data with socio-economic and public health assessments will support evidence-based policymaking and promote sustainable management of the Tapi River ecosystem.

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