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Treated Water Reuse in Tata Steel Gamharia, Jharkhand: A Case Study

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Abstract: This study investigates the strategic reuse of treated water at Tata Steel Gamharia (TSG), Jharkhand, with a focus on reducing freshwater dependency and enhancing sustainability across various industrial operations. Through comprehensive water audits, departmental consumption analysis, and the implementation of six enabler projects, treated water from Effluent Treatment Plants (ETP) and Sewage Treatment Plants (STP) was successfully repurposed for non-critical applications such as gardening, dust suppression, coal quenching, and equipment cleaning. The study recorded substantial reductions in freshwater consumption across multiple departments, with daily savings exceeding 2070 KL. Enabler projects, including the use of ETP water in ash mound greenery (800 KL/day) and CPP operations (500 KL/day), played a critical role in achieving these targets. Effluent quality consistently met EPA 1986 (Schedule VI) standards, with pH (avg. 7.11), BOD (6.23 mg/l), and COD (36.4 mg/l) well within permissible limits, ensuring environmental safety and usability for secondary applications. These results confirm the technical and economic feasibility of treated water reuse and underscore its alignment with sustainable industrial water management practices. The study offers a replicable framework for similar industrial units seeking to reduce freshwater intake, improve environmental performance, and enhance resource efficiency through data-driven and infrastructure-supported water reuse initiatives.

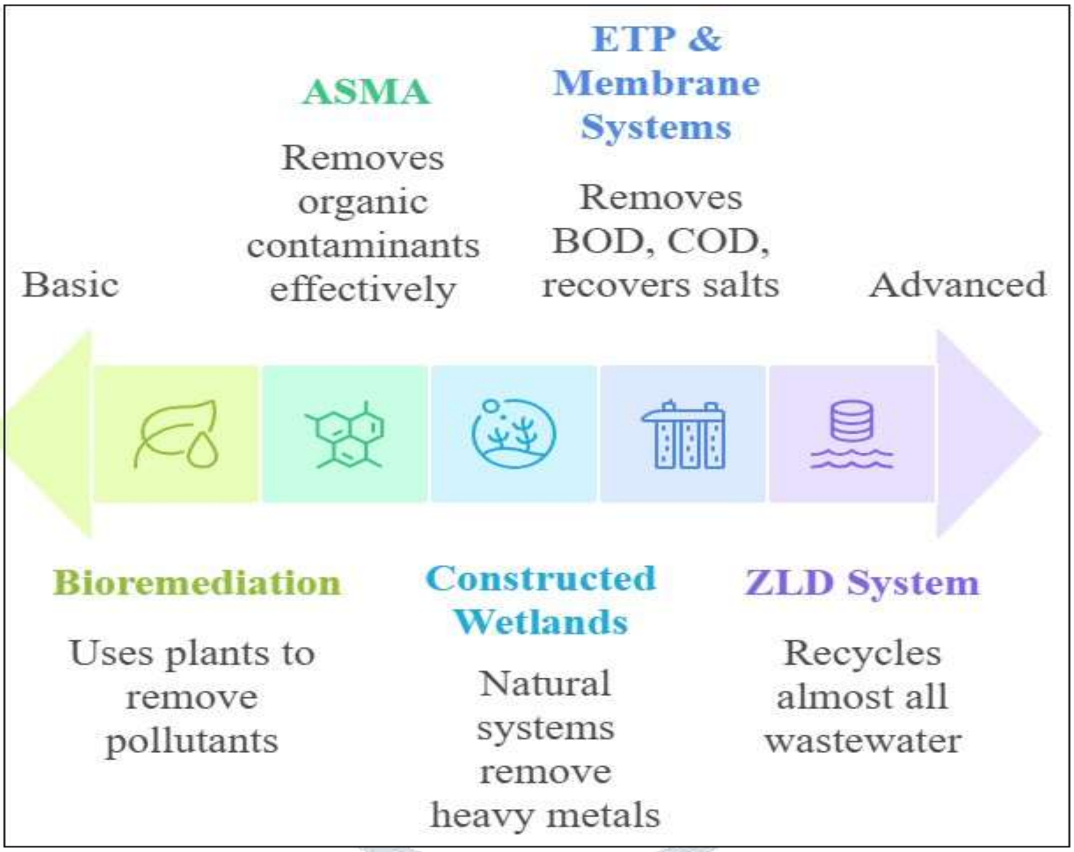
Keywords: Treated water reuse, Industrial water management, Effluent Treatment Plant (ETP), Sustainability in steel industry, Water conservation, Tata Steel Gamharia

1. Introduction

Water scarcity has become one of the most significant global concerns, particularly affecting industries that depend heavily on water resources (Verma et al., 2025; Verma et al., 2024a; Verma et al., 2024c; Verma et al., 2024; Ande et al., 2025a, 2025b). The steel sector is among the highest water-consuming industries, using water in nearly every stage of production. In response to growing environmental pressures and increasing freshwater limitations, industries are now turning to alternative strategies to reduce water dependency (Tandel et al., 2025; Patel et al., 2025). A notable solution gaining attention is the reuse of treated wastewater, which not only reduces reliance on freshwater but also helps manage effluent discharge responsibly. Tata Steel's Gamharia unit (TSG), situated in Jharkhand, India, is a key steel production facility known for producing Special Bar Quality (SBQ) steel. With a capacity of one million tonnes annually, the plant uses both traditional and modern steelmaking techniques, including Blast Furnace (BF), Electric Arc Furnace (EAF), Direct Reduced Iron (DRI), and Ladle Refining. As a large-scale facility, its water consumption is substantial, used for equipment cooling, slag quenching, furnace operations, cleaning, and dust suppression.

According to an internal audit, TSG draws approximately 21,000 kilolitres of freshwater daily from the Subarnarekha River (Tata Steel Gamharia, 2025). This heavy dependence on surface water contributes to local environmental stress and results in significant energy and treatment costs. To address this, the plant has initiated a water conservation approach by enhancing the use of treated water from its in-house Effluent Treatment Plant (ETP) and Sewage Treatment Plant (STP). The idea behind treated water reuse is to redirect effluent once properly treated for non-critical operations such as landscape irrigation (Verma et al., 2024b; Chadee et al., 2024; Verma et al., 2023a), cleaning, and road spraying. This shift towards internal water recycling supports the growing industry trend of embracing circular water management systems. Benefits include reduced freshwater extraction, lower discharge volumes, improved environmental compliance, and long-term cost savings (Vanitha et al., 2018). Technologies like membrane filtration and Zero Liquid Discharge (ZLD) systems are showing promise in industrial wastewater reuse. Although these systems require considerable investment, they offer strong returns in both environmental protection and cost-efficiency (Raja Sankar et al., 2017). At TSG, such systems have already helped recycle about 26% of the plant's total water demand, with plans to expand this to 43% (Tata Steel Gamharia, 2025) (**Figure 1**).

Treated water reuse also reduces the environmental burden of industrial pollutants such as heavy metals, hydrocarbons, and other toxic



substances commonly found in steel plant effluents. Proper reuse and treatment prevent harmful substances from reaching rivers and groundwater, thus safeguarding ecosystems and supporting corporate sustainability goals (Mwatujobe et al., 2020; Verma et al., 2023b; Verma et al., 2024d; Verma et al., 2023c). Nonetheless, implementing water reuse at scale poses several challenges. These include maintaining infrastructure, ensuring consistent treatment quality, training personnel, and adapting solutions to specific site conditions (Sinha et al., 2014). Overcoming these barriers is essential for the success of water reuse initiatives. The key objectives of this study are to reduce freshwater intake, assess departments where treated water can replace fresh supplies, analyze the cost benefits of reuse, and measure the overall impact on water conservation health (Kumar et al., 2023; Verma et al., 2022a; Verma et al., 2022b). This research aims to offer a scalable model at supports both industrial efficiency and environmental responsibility.

Figure 1. Literature from the basic to the advanced level for industrial wastewater treatment.

The concept of Zero Liquid Discharge (ZLD) is gaining traction, especially in water-intensive sectors. Raja Sankar et al. (2017) detailed a successful ZLD system in a dyeing industry. The approach involved a combination of reverse osmosis (RO), evaporation, and crystallization to recycle up to 85% of wastewater. RO was particularly effective in reducing Total Dissolved Solids (TDS), achieving 90% efficiency.

Raval et al. (2014) focused on the use of Anionic Surfactant Modified Alumina (ASMA) for removing phenol from industrial effluents. ASMA demonstrated consistent removal efficiency across varying concentrations and temperatures, with a removal rate of around 70%. This suggests its potential application in large-scale effluent treatment for organic contaminants. Mwatujobe et al. (2020) assessed industrial effluents in Dar es Salaam and found widespread non-compliance with regulatory discharge standards. Parameters such as BOD, COD, and TSS exceeded limits, and toxic heavy metals were prevalent. The study reported serious public health impacts due to effluent exposure, including potential cancer risks, especially in agricultural zones relying on polluted water.

In the context of steel manufacturing, Vanitha et al. (2018) reported successful recycling of 4,500 m^3/day of wastewater in a CRM plant using ETPs and membrane systems. The treatment showed nearly complete removal of BOD and COD, with excellent salt recovery rates from RO units. By maintaining specific pH and soda ash concentrations, fouling was reduced, enabling the reuse of 6,500 m^3/day of high-quality water. Bioremediation was also investigated by Rai et al. (1995), who studied several aquatic macrophytes for their capacity to remove heavy metals from effluents. Species such as Spirodela polyrrhiza and Hydrodictyon reticulatum effectively reduced levels of chromium, iron, manganese, cadmium, and lead, often to below permissible limits. The findings support phytoremediation as a viable low-cost treatment option for dilute wastewater streams. Whereas, Sharma et al. (1991) studied effluents from Bhilai Steel Plant and observed excessive concentrations of nitrate, ammonia, and sulfate, with ammonia surpassing regulatory limits. These pollutants pose serious environmental threats if discharged untreated. Dipu Sukumaran et al. (2013) evaluated constructed wetlands using aquatic plants like Typha latifolia and Eichhornia crassipes. These plants showed significant removal of lead, copper, cadmium, and arsenic from effluents. The results suggest that such natural systems can complement conventional treatment processes. Sahu et al. (2019) investigated stormwater management at Swami Vivekananda Airport, highlighting rainwater harvesting's role in groundwater recharge and water reuse. A well-designed filtration system and recharge wells could conserve over 126,000 m^3 of water annually. Finally, Pandey et al. (2018) found that industrial effluents from the Bhilai Steel Plant altered the physical and chemical properties of the surrounding soil and vegetation. Elevated concentrations of heavy metals were linked to abnormal plant growth and health concerns, indicating the need for improved treatment before reuse in irrigation.

2. Study Area

Tata Steel Gamharia is strategically located in Gamharia, a significant industrial township within the Seraikela- Kharsawan district of Jharkhand, India. Positioned near the city of Jamshedpur, this facility benefits from excellent regional connectivity, making it an ideal location for large-scale industrial operations. Jamshedpur, often referred to as the steel city of India, serves as a prominent manufacturing hub in eastern India, further strengthening Gamharia's logistical advantages. The area is well-connected through a network of roads and railways, including proximity to National Highway 33 and key railway stations, facilitating the efficient transport of raw materials and finished goods.

The exact geographical coordinates of the study area are 22.812895° North latitude and 86.084022° East longitude, based on the WGS 84 coordinate reference framework (**Figure 2**). The postal identification for this region is 832108. These coordinates offer precise spatial information for geospatial analysis, satellite mapping, and infrastructure planning. The site's selection was based on its industrial significance, accessibility to operational data, and its role in water-intensive steel manufacturing processes. It also lies within reach of various residential communities, providing a relevant context for evaluating environmental and social implications.

Salient features of the study area include:

1. Presence of major steel and ancillary manufacturing units, including Tata Steel's Special Bar Quality (SBQ) facility.
2. Access to the Subarnarekha River, a vital freshwater source for industrial use.
3. Availability of supporting infrastructure such as power supply, internal road networks, and process water treatment facilities.

4. Dense industrial land use integrated with planned residential and utility zones.
5. Location within a mineral-rich region that supports integrated steel production processes.
6. Favorable topography for wastewater treatment and stormwater drainage systems.

Figure 2. Location and Co-ordinates of Tata Steel Gamharia

3. Materials and Methods

a. Overview

This study was undertaken at Tata Steel Gamharia (TSG), an integrated steel manufacturing unit in Jharkhand, India. The facility consumes substantial quantities of water for its production operations. The study focuses on minimizing freshwater dependency through systematic reuse of treated water from the Effluent Treatment Plant (ETP) and Sewage Treatment Plant (STP) for non-critical industrial applications. A structured methodology involving water audits, departmental analysis, trend studies, and implementation of enabler projects was employed to optimize internal water resource utilization and evaluate its economic and environmental impacts.

b. Study Scope and Strategy

The study aimed to identify and map all potential points within the plant where treated wastewater could be substituted for freshwater. These include:

- Gardening and greenbelt development
- Road sprinkling and dust suppression
- Ash and coal quenching (especially during summer)
- Housekeeping and equipment cleaning
- Fire hydrant systems
- Water supply for Mist Beams and Fog Cannons

An exhaustive survey was carried out across departments to understand existing water consumption patterns, pinpoint opportunities for substitution, and implement dedicated treated water pipelines and storage systems.

4. Methodological Framework

The methodological approach includes:

4.1 Departmental Water Audit

Water consumption data for each department were collected and analyzed. The departments studied include:

- Captive Power Plant (CPP)
- Blast Furnace (BF)
- Direct Reduced Iron (DRI)
- Sinter Plant
- Pellet Plant
- Wire Rod Mill
- Bloom Mill
- Oxygen Plant

4.2 Comparative Analysis: FY Trends

Trends from FY 2023 to FY 2025 were assessed. The year-wise trend helped establish a baseline consumption, monitor implementation success, and highlight abnormal values resulting from shutdowns or equipment failures (**Table 1**).

Table 1. Specific Water Consumption Trend (FY'23–FY'25).

Department	Unit	FY'23	FY'24	FY'25
CPP	L/UNIT	4.65	4.53	4.53
BF	KL/THM	0.74	0.70	0.80
DRI	KL/MT	0.88	0.95	0.72
Sinter	KL/MT	0.1	0.1	0.1
Pellet	KL/MT	0.00	0.07	0.07

4.3 Enabler Projects Implementation

A total of six enabler projects were implemented to promote the use of treated water.

a. Enabler-1: CPP Secondary Water Use

- **Use**: Fire hydrant, gardening, fly ash and coal quenching, road sprinkling.
- **Infrastructure**: RCC tank, pump skid (50 m^3/hr), butterfly valve, pipeline header.
- **Impact**: 500 KL/day of freshwater saved.
- **Cost**: ₹26 Lakhs

b. Enabler-2: Sinter Plant PMD

- **Use**: Treated water for nodulization in Primary Mixing Drum (PMD).
- **Implementation**: Separate treated water pipeline with a flow meter.
- **Savings**: 100 KL/day
- **Cost**: ₹2.4 Lakhs

c. Enabler-3: Ash Mound Green Development

- **Project**: Kailash Top Biodiversity Park with 25,000 saplings.
- **Water Source**: ETP via HDPE pipeline.
- **Impact**: 800 KL/day saved.
- **Cost**: ₹2 Lakhs

d. Enabler-4: Mist Beam at RMHS Yard

- **Project**: Six Mist Beams installed in the Blast Furnace raw material yard.
- **Supply**: Treated ETP water piped from the Sinter Plant line.
- **Savings**: 100 KL/day
- **Cost**: ₹85 Lakhs

e. Enabler-5: STP Water for Batching Plant & Garden

- **Usage**: Batching plant operations and temple garden irrigation.
- **System**: Two separate pipeline lines.
- **Savings**: 70 KL/day

f. Enabler-6: DRI Treated Water Network

- **Previous**: Treated water used till FY’22, then shifted to fresh due to cooling issues.
- **Change**: Separate treated water system laid for secondary uses (gardening, roads).
- **Impact**: Specific water consumption reduced to 0.72 KL/MT in FY’25.
- **Savings**: 500 KL/day

4.4 Characterization of Wastewater

A comprehensive analysis of steel plant wastewater revealed various contaminants requiring advanced treatment (**Table 2**).

4.4.1 Physical Characteristics

Table 2. Physical Characteristics of wastewater.

Parameter	Observations
Color	Light brown to black, depending on decomposition level
Odor	Mild to foul due to anaerobic breakdown
Temperature	Ranged from 14°C to 25°C

Total Solids	45–70% as suspended solids; organic fractions include fats, proteins

4.4.2 Chemical Characteristics

- **Inorganics**: Chlorides, nitrates, sulfates, cyanide, ammonia, pH, alkalinity.
- **Organics**: BOD, COD, TOC, VOCs like benzene, styrene, PAHs.
- **Heavy Metals**: Chromium, lead, cadmium, mercury, all with toxicological risks.
- **Gaseous Emissions**: H_2S, CH_4, CO_2, monitored for system integrity.

4.5 Water Recycling Techniques

Water from ETP and STP is treated and redistributed for (**refer to Figure 3**):

- Green cover irrigation
- Equipment cleaning
- Cooling processes
- Fire protection systems

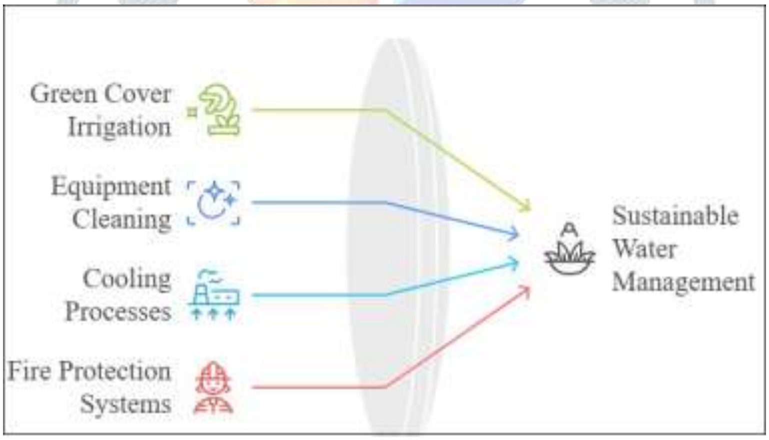


Figure 3. Different water recycling techniques.

5. Results and Discussion

5.1 Analysis of Water Consumption

The implementation of treated water reuse initiatives at Tata Steel Gamharia (TSG) has yielded significant results in terms of reducing freshwater consumption, enhancing sustainability, and achieving economic benefits. This section presents the findings of the water audit, department-wise consumption patterns, and the impact of individual projects. The data covers trends over the fiscal years FY'20 to FY'25, highlighting improvements in specific water consumption and treated water utilization.

Table 3. Department-wise Specific Fresh Water Consumption (FY'23 vs FY'24).

Department	FY'23 (KL/MT)	FY'24 (KL/MT)
CPP	4.65	4.53
BF	0.61	0.59

DRI	0.88	0.95
Sinter	0.10	0.10
Pellet	0.58	0.55
Oxygen Plant	0.15	0.13

As seen in **Table 3**, significant reductions in specific freshwater consumption were observed in most departments between FY'23 and FY'24. The Captive Power Plant (CPP) showed a marked improvement due to the installation of a dedicated ETP-treated water line, reducing usage from 4.65 to 4.53 KL/MT. Similar reductions were observed in the Pellet and Oxygen Plants. However, DRI consumption rose slightly due to a temporary shift back to freshwater use for critical cooling operations.

Table 4. Summary of Freshwater Savings from Key Projects

Project Enabler	Description	Water Savings (KL/Day)
E-1	ETP water for miscellaneous use at CPP	500
E-2	ETP water in Sinter Plant PMD	100
E-3	ETP water for greenery at Ash Mound	800
E-4	ETP water for Mist Beam system	100
E-5	STP water for Batching Plant and gardening	70
E-6	DRI Treated Water Network	500

Table 4 highlights the daily water savings achieved by implementing key treated water reuse projects. The largest saving was recorded at the Ash Mound green zone development project (800 KL/day), followed by the CPP, DRI and the Sinter Plant. These initiatives collectively contribute over 2070 KL/day of freshwater savings. Overall, the adoption of treated water reuse practices at TSG has resulted in measurable improvements in operational efficiency and environmental performance. Continued focus on expanding reuse, investing in advanced monitoring systems, and upgrading treatment infrastructure is expected to enhance these gains further.

5.2 Analysis of Effluent from Treatment Plant

The effluent quality monitoring data from March 2024 to October 2024 at Tata Steel Gamharia demonstrates consistent compliance with the Environmental Protection Act (EPA) 1986, Schedule VI standards. This indicates that the wastewater treatment processes in place are functioning efficiently and producing treated water suitable for secondary usage. The pH values across the monitored months ranged between 6.9 and 7.51, with an average of 7.11, remaining well within the acceptable range of 5.5 to 9.0 (**Table 5**).

Table 5. Summary of Effluent quality monitoring data.

S. No.	Test Parameters	Unit	Avg. Value	Range (Min-Max)	EPA Standard (Schedule VI)
1	pH at 25°C	-	7.11	6.9 – 7.51	5.5 – 9.0
2	Total Suspended Solids (TSS)	mg/l	28	25 – 32	100
3	Biochemical Oxygen Demand (BOD)	mg/l	6.23	5.5 – 7.4	30
4	Chemical Oxygen	mg/l	36.4	28 – 43.3	250

	Demand (COD)				
5	Ammoniacal Nitrogen (as N)	mg/l	22.8	19 – 27	50

6	Cyanide (as CN)	mg/l	<0.02	<0.02 (all months)	0.2

These neutral pH levels ensure that the treated water is neither acidic nor alkaline, making it safe for non-potable reuse applications such as gardening, road sprinkling, and mist beam operations. Total Suspended Solids (TSS) recorded an average of 28 mg/l, far below the permissible limit of 100 mg/l. This suggests excellent performance in solid particle removal, which is crucial for preventing system clogging in irrigation and other reuse applications. Similarly, the Biochemical Oxygen Demand (BOD) averaged 6.23 mg/l, and Chemical Oxygen Demand (COD) averaged 36.4 mg/l, both substantially lower than their respective standards of 30 mg/l and 250 mg/l. These values confirm effective organic pollutant degradation, ensuring that the treated effluent does not pose any environmental risk when reused.

Ammoniacal nitrogen concentrations remained below the threshold of 50 mg/l throughout the study period, with an average of 22.8 mg/l, indicating stable nitrification performance in biological treatment units. This is especially important for reuse in green cover development and coal quenching, where elevated ammonia could be harmful. Notably, cyanide concentrations were consistently recorded as less than 0.02 mg/l in all months, which is significantly below the limit of 0.2 mg/l. This demonstrates the non-toxic nature of the treated water, confirming its suitability for safe and widespread reuse.

These findings align strongly with the study's objectives, which aimed to reduce freshwater dependency by utilizing treated water from the Effluent Treatment Plant (ETP) and Sewage Treatment Plant (STP). The high quality of treated water validates the project's aim to identify points of secondary usage across departments, thereby facilitating cost savings and promoting sustainable water resource management. The consistent compliance with environmental standards also enhances the reliability of treated water reuse in diverse operational processes, supporting the plant's broader goals of environmental stewardship and resource efficiency.

6 Conclusions

The successful implementation of treated water reuse initiatives at Tata Steel Gamharia (TSG) represents a transformative step toward sustainable industrial water management. In an era where freshwater scarcity poses significant challenges to manufacturing operations, this study highlights how strategic planning, technological nvestment, and data-driven decision-making can drastically reduce freshwater dependency without compromising operational efficiency. Through detailed departmental audits, year-over-year consumption tracking, and the deployment of six dedicated enabler projects, TSG achieved a remarkable freshwater savings of over 2070 kilolitres per day. Key projects, such as the use of treated effluent in greenbelt development at the ash mound and for miscellaneous applications in the Captive Power Plant, not only optimized water use but also contributed to the site's broader environmental stewardship objectives. Crucially, the treated effluent consistently met EPA (1986) Schedule VI discharge standards for parameters such as pH, BOD, COD, and cyanide, validating the effectiveness of both Effluent Treatment Plant (ETP) and Sewage Treatment Plant (STP) systems. This underscores the feasibility of scaling reuse for non-potable applications like gardening, road sprinkling, coal quenching, and equipment cleaning.

The study not only achieved its primary objectives, reducing freshwater intake and identifying viable reuse points, but also created a replicable framework for other integrated steel plants. It illustrates how sustainability and profitability can coexist when water resources are managed holistically. Moving forward, expanding treated water infrastructure, integrating real-time monitoring technologies, and fostering cross-departmental collaboration will be key to maximizing reuse potential. The Tata Steel Gamharia model offers a blueprint for industries aiming to align with India's national water mission and global sustainable development goals, making it a benchmark for responsible and efficient water stewardship in the steel sector.

6.1 Future scope and limitations

Despite the notable progress in implementing treated water reuse at Tata Steel Gamharia, several limitations persist. The reuse of treated water remains confined mainly to non-critical applications, leaving high-quality process water requirements dependent on freshwater. Moreover, infrastructure constraints, periodic breakdowns, and line leakages sometimes disrupt the continuous supply of treated water. The absence of real-time water quality monitoring also poses a challenge in ensuring consistent treatment standards. Additionally, seasonal variations in wastewater generation and operational shutdowns affect the overall efficiency of the reuse system.

Looking ahead, the potential for expanding treated water reuse is substantial. The future scope includes integrating smart water management systems with digital flow meters and quality sensors for real-time tracking. There is also scope to implement advanced membrane technologies and tertiary treatment methods to make treated water suitable for semi-critical applications. Further research can explore cost-effective options to scale up Zero Liquid Discharge (ZLD) initiatives. Collaboration with academic institutions and government agencies could pave the way for innovations and funding support. Expanding green cover using recycled water and creating water-neutral zones within the plant are additional future opportunities. With focused investment and strategic planning, Tata Steel

Gamharia can serve as a benchmark for industrial water sustainability across India.

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