Jurnal Informasi dan Teknologi

https://jidt.org/jidt

2025 Vol. 7 No. 2 Hal: 67-75 e-ISSN: 2714-9730

Analysis of Hardness Level in Enim River for Demineralization Water Process in Thermal Power Plant Tanjung Enim

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Abstract

Demineralization water is removal of dissolved ionic mineral impurities present in water and other liquids. Mineral content in water can cause crusts in power plant equipment such as boilers and turbine, lowering yield and selectivity values in the reaction process. The aim of the research is to diagnose the conditions of water process Tanjung Enim thermal power plant with standard value of ASME CRTD Vol. 34 and Power Plant water treatment standard. Demineralization Water treatment process starts from Multimedia Filter (MMF), Carbon Filter (CF), Reverse Osmosis (RO), Electrodeionization. Demineralization water sampling taken in January, february, march and April. The water sampling used in RAW Water, Feed RO, Electrodeionization process, feed water and boiler drum to measure the parameters of pH, conductivity, turbidity, Fe, Cl2 and Si02, P04 and ions of Na+, Fe+, Cu+ some of parameters result the fluctuative value but still in both of water treatment standard.

Keywords: *Demineralization, Mineral, Parameters, Standard, Water Treatment.*

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1. Introduction

Water quality management is one of the most important challenges in thermal power plants. It directly affects both plant efficiency and equipment life [1]. In power plants, water has multiple functions. These include steam generation, cooling, and various support processes. Proper water treatment is essential for optimal plant performance [2].

Poor water quality creates serious operational problems. Scale formation, corrosion, and equipment fouling are common issues. These problems reduce heat transfer efficiency and can cause unplanned shutdowns [3]. The economic impact is significant. Plants may lose millions of dollars due to poor water quality.

Thermal power plants need complex water treatment systems. These systems must remove both dissolved and suspended contaminants. Multi-stage purification is required to meet strict boiler feedwater standards [4]. Each stage has a specific purpose in the overall treatment process.

The challenges of water treatment in tropical regions, particularly in developing countries like Indonesia, are compounded by several factors including seasonal variability in raw water quality, limited infrastructure for water monitoring, and diverse pollution sources affecting natural water bodies [5]. Indonesian rivers frequently experience elevated levels of suspended solids, organic matter, and mineral content due to tropical weathering patterns, agricultural runoff, and industrial discharge [6]. Recent studies have highlighted that thermal power plants in Southeast Asia experience water quality-related operational issues, with Indonesian facilities particularly affected by high turbidity and mineral content in source water [7]. These challenges are further intensified by the country's rapid industrial growth and increasing environmental pressures on water resources [8].

The Enim River in South Sumatra, Indonesia, exemplifies these regional water quality challenges. Located in a coal-rich region with significant mining activities, the river serves as the primary water source for the Tanjung Enim Thermal Power Plant, a 3×10 MW facility utilizing Circulating Fluidized Bed (CFB) boiler technology. Preliminary assessments indicate that Enim River water exhibits characteristics typical of tropical river systems, including elevated turbidity levels (5-11 NTU), moderate conductivity, and variable mineral content that fluctuates seasonally. The power plant's water treatment system employs a multi-stage approach including Multi Media Filter (MMF), Carbon Filter (CF), Reverse Osmosis (RO), and Electrodeionization (EDI) to achieve the water quality standards required for CFB boiler operation. However, operational challenges have been reported, particularly in maintaining consistent electrodeionization performance and managing silica levels in the treatment process.

Despite extensive research on power plant water treatment technologies, there remains a significant knowledge gap regarding the long-term performance evaluation of integrated treatment systems handling tropical river water with high variability in source quality. Most existing studies focus on single-stage treatment processes or operate under controlled conditions with stable influent water quality [9]. Furthermore, limited research has been conducted on the specific challenges faced by CFB boilers in tropical climates, where higher ambient temperatures and humidity can affect both raw water characteristics and treatment system performance [10]. The interaction between multiple treatment stages and their collective efficiency in handling fluctuating raw water quality parameters requires systematic investigation to optimize operational strategies and prevent equipment degradation [11].

This study aims to conduct a comprehensive analysis of water treatment performance at the Tanjung Enim Thermal Power Plant, with specific objectives to: (1) evaluate the effectiveness of the multi-stage treatment system in meeting ASME CRTD Vol.34 and plant design standards across varying seasonal conditions [12]; (2) identify critical control parameters and their interdependencies throughout the treatment process; (3) quantify the impact of raw water quality fluctuations on final treated water ications; and (4) assess system reliability and propose optimization strategies for enhanced performance. The research employs a four-month monitoring program covering both wet and dry season conditions to capture the full spectrum of water quality variations typical of tropical river systems.

The significance of this research extends beyond the specific case study, as findings will contribute to the broader understanding of water treatment optimization in tropical power generation facilities. The study provides practical insights for similar installations across Southeast Asia and other tropical regions facing comparable water quality challenges. Additionally, the systematic evaluation methodology developed can serve as a framework for ongoing performance assessment and predictive maintenance strategies in power plant water treatment systems. The expected outcomes include specific recommendations for operational parameter adjustments, equipment modification strategies, and enhanced monitoring protocols to ensure consistent water quality delivery under variable source conditions.

2. Research Methods

2.1. Study Design and Location

The study was conducted at Tanjung Enim Thermal Power Plant, South Sumatra, Indonesia. This research used a descriptive analytical approach. The study focused on evaluating water quality parameters throughout the demineralization process. Water samples were collected from Enim River, which serves as the primary water source for the power plant.

2.2. Water Treatment Process Overview

The demineralization system at Tanjung Enim Power Plant follows a multi-stage process. Figure 1 shows the complete treatment sequence. Raw water from Enim River undergoes several treatment stages before becoming suitable for boiler feed water. The treatment process includes the following stages Pre-treatment with chemical injection, Multimedia Filter (MMF), Carbon Filter (CF), Reverse Osmosis (RO), Electrodeionization (EDI) [13].

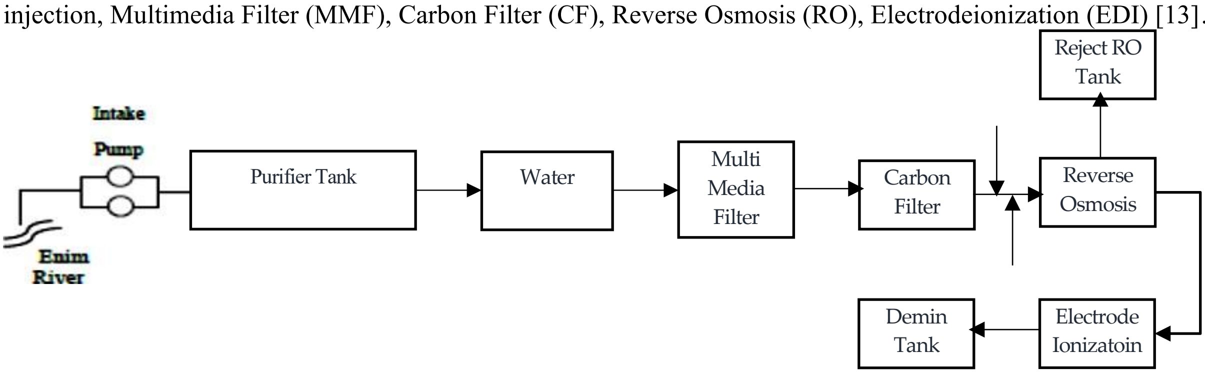

Figure 1. The Demineralized Water Process at the Tanjung Enim Power Plant

2.3. Chemical Pre-treatment

Before entering the filtration system, raw water undergoes chemical treatment involving the injection of three specific chemicals. Poly Aluminum Chloride (PAC) is added to aid in the formation of flocculants, which are small clumps of particles suspended in the water. To further enhance this process, Poly Acrylamide Anionic (PAM) is introduced to bind the flocculants together, forming larger and heavier deposits that can be more easily removed. Additionally, Sodium Hypochlorite (NaOCl) is used as a disinfectant to eliminate germs and bacteria, ensuring the water is safer for the next stages of treatment [14].

2.4. Filtration Stages

The water treatment process begins with the Multimedia Filter (MMF), which acts as the initial filtration stage to remove undissolved impurities. This filter is filled with quartz sand and anthracite, materials that are effective in trapping Total Suspended Solids (TSS). When the filter becomes clogged, it is cleaned through a backwashing process to maintain its performance.

Next, the Carbon Filter (CF) is used to further purify the water. It contains activated carbon, which helps remove dissolved solids. In addition, the CF effectively eliminates unwanted odors and colors, improving the overall clarity and quality of the water.

Following this stage, the water undergoes Reverse Osmosis (RO), a process that filters out ions using membrane technology. Before reaching the membrane, the water passes through a cartridge filter, which removes particles as small as 5 microns using fine filter media. The final stage is Electrodeionization (EDI), which uses a direct current (DC) electric field to exchange anions and cations in the water. This process results in high-purity product water, which is then transferred to demineralized water storage tanks for further use.

2.5. Sampling Strategy

Water samples were collected from five different points in the treatment process. These points include raw water before any treatment, feed water to the Reverse Osmosis (RO) system after passing through the Multimedia Filter (MMF) and Carbon Filter (CF), the outlet of the Electrodeionization (EDI) process, feed water before entering the boiler, and finally the water inside the boiler drum.

2.6. Water Quality Parameters

The study measured multiple water quality parameters. These parameters were selected based on power plant requirements and international standards. The measured parameters include Physical parameters (pH, conductivity, turbidity), Chemical parameters (Cl_2, Fe, SiO_2, PO_4), and Ionic parameters (Na^+, Fe^+, Cu^+).

2.7. Laboratory Analysis

The study measured multiple water quality parameters. These parameters were selected based on power plant requirements and international standards. The measured parameters include Physical parameters (pH, conductivity, turbidity), Chemical parameters (Cl_2, Fe, SiO_2, PO_4), and Ionic parameters (Na^+, Fe^+, Cu^+).

Table 1. Method Used for the Analysis of the Different Water Quality Parameters

Parameters	Method Number
pH	4500-H+B
Conductivity (μS/cm)	2510B
R-Cl_2	1253
SiO_2 (mg/L)	859
Turbidity (NTU)	2130B
T-Fe (mg/L)	MHi 98/117
PO_4 (mg/L)	4110B

2.8. Quality Standards

The results were compared against two quality standards: the Tanjung Enim Power Plant design standards (see Table 2) and the ASME CRTD Vol. 34 standards. These standards set acceptable limits for each parameter to ensure the safe and efficient operation of power plant equipment.

Table 2. Standard of water treatment of ASME CRTD Vol 34

	Drum operating pressure[b] MPa (psig)				
Feedwater[c]	0.0-2.07 (0-300)	2.08-3.10 (301-450)	3.11-4.14 (451-450)	4.15-5.17 (601-750)	5.18-6.21 (751-900)

Dissolved oxygen (mg/1 O_2) Measured before O_2 Scavenger addition[d]	< 0.04	< 0.04	< 0.007	< 0.007	< 0.007
Total iron (mg/1 Fe)	$\leq$ 0.100	$\leq$ 0.050	$\leq$ 0.030	$\leq$ 0.025	$\leq$ 0.020
Total copper (mg/1 Cu)	$\leq$ 0.050	$\leq$ 0.025	$\leq$ 0.020	$\leq$ 0.020	$\leq$ 0.015
Total hardness (mg/1 $CaCO_3$	$\leq$ 0.300	$\leq$ 0.300	$\leq$ 0.200	$\leq$ 0.200	$\leq$ 0.100
pH range @ 25°C	7.5-10.0	7.5-10.0	7.5-10.0	7.5-10.0	7.5-10.0
Chemicals for preboiler system proctection. Nonvolatile TOC mg/ 1 C[e]	< 1	< 1	< 0.5	< 0.5	< 0.5
Oily matter (mg/1)	< 1	< 1	< 0.5	< 0.5	< 0.5
Boiler water (in drum)					
Total solids (ppm)	3500	3000	2500	2000	1500
Silica (mg/1 SiO_2)	$\leq$ 150	$\leq$ 90	$\leq$ 40	$\leq$ 30	$\leq$ 20
Total alkalinity (mg/1 $CaCO_3$)	< 0.350[f]	< 300[f]	< 250[f]	< 200[f]	150[f]
Free hydroxide alkalinity (mg/ 1 $CaCO_3$)[g]					
Spesific conductance (μmho/cm) @ 25°C without neutralization	< 0.3500[h]	< 3000[h]	< 2000[h]	< 2000[h]	< 1500[h]

2.9. Data Analysis

Data was compiled and analyzed using descriptive statistics. Trends were identified across the four-month sampling period. Parameters exceeding standard limits were flagged for detailed analysis. Graphical presentations were prepared to show parameter variations over time.

3. Results and Discussion

3.1. Results

3.1.1. Water Quality Parameters Analysis

The physicochemical analysis of water samples collected from November 2024 to February 2025 at various treatment stages in Tanjung Enim Power Plant is presented in Table 5. The analysis covered five critical treatment points: raw water from Enim River, feed water before reverse osmosis (Feed RO), electrodeionization outlet (EDI), feed water to boiler, and boiler drum water.

Table 3. Physicochemical Analyses of Water Samples

Parameters	Novembe r 2024	December 2024	January 2025	February 2025	Status
RAW Water					
pH	7.19	6.37	6.60	6.80	✓
Conductivity	87.21	78.60	77.81	76.58	✓
Turbidity	5.59	11.06	6.49	6.60	✗
Cl2	0.23	0.26	0.28	0.21	✓
Feed RO					
pH	7.11	6.42	6.69	6.66	✓

Conductivity	86.01	82.15	80.09	72.38	✓
Turbidity	0.27	2.04	0.26	0.52	⚠
Fe	0.00	0.00	0.00	0.01	✓
Electrodeionization (EDI)					
pH	6.63	6.28	6.74	7.01	✓
Conductivity	0.91	1.15	0.97	1.32	⚠
SiO_2	32.89	21.12	3.84	3.41	✗
Feed Water					
pH	9.33	9.35	9.42	9.53	✓
Conductivity	9.52	13.62	22.37	13.89	✓
Na+	0.00041	0.00026	0.018	0.00047	⚠
Fe+	0.000	0.000	0.000	0.0002	✓
Cu+	0.00203	0.000	0.000	0.00687	✓
Boiler Drum					
pH	8.96	8.92	8.62	8.91	⚠
Conductivity	6.71	13.70	24.81	8.90	✓
PO4	0.13	0.36	5.63	5.24	⚠
$Si0_2$	0.00	0.00	0.00	0.00	✓

3.1.2. Parameter Performance Assessment

The physicochemical analysis of water samples collected from November 2024 to February 2025 at various treatment stages in Tanjung Enim Power Plant is presented in Table 5. The analysis covered five critical treatment points: raw water from Enim River, feed water before reverse osmosis (Feed RO), electrodeionization outlet (EDI), feed water to boiler, and boiler drum water.

3.1.2.1. pH Performance

pH values across all treatment stages remained within acceptable ranges (6-11) according to both power plant design standards and ASME CRTD Vol.34. Raw water pH ranged from 6.37 to 7.19, while boiler drum pH maintained alkaline conditions (8.62-8.96).

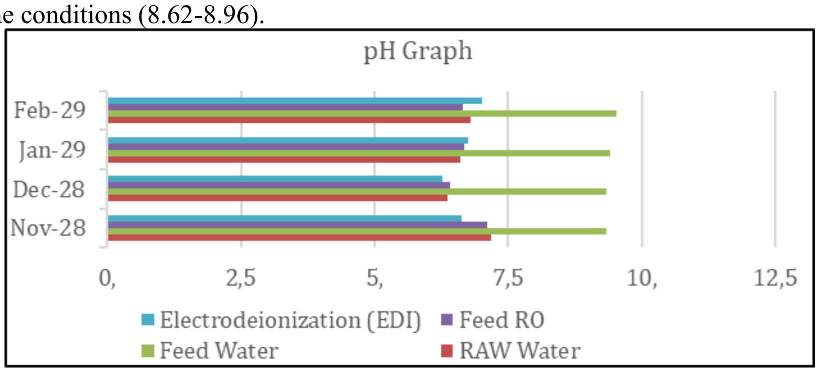

Figure 2. pH Of Enim River in Every Water Treatment

3.1.2.2. Conductivity Performance

Conductivity showed significant reduction efficiency through the treatment process. Raw water conductivity (76.58-87.21 µS/cm) was effectively reduced to below 1.32 µS/cm after EDI treatment. However, EDI conductivity exceeded the design limit (<1 µS/cm) in December 2024 and February 2025.

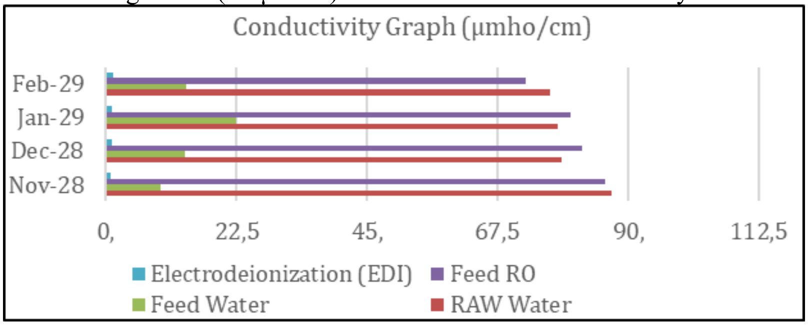

Figure 3. Conductivity Of Enim River in Every Water Treatment

3.1.2.3. Turbidity Performance

Raw water turbidity consistently exceeded the design standard (<5 NTU), with values ranging from 5.59 to 11.06 NTU. The Multi Media Filter effectively reduced turbidity to acceptable levels (0.26-2.04 NTU) for RO feed water.

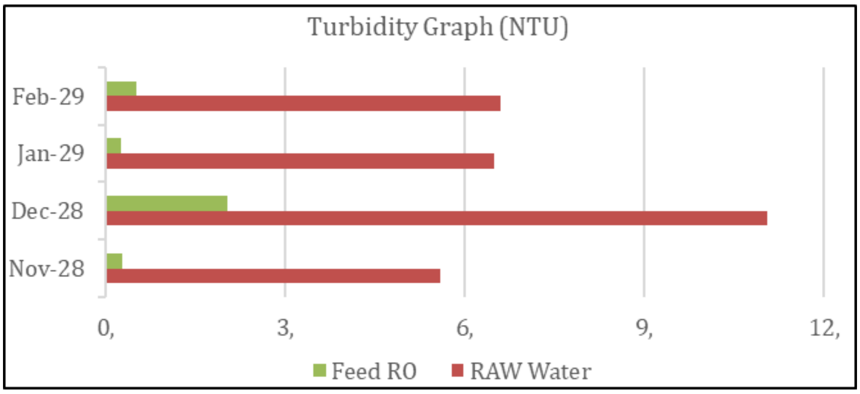

Figure 4. Turbidity Of Enim River in Every Water Treatment

3.1.2.3. Chemical Parameters Performance

In the monitoring of chemical parameters, the EDI outlet recorded elevated silica (SiO_2) levels ranging from 21.12 to 32.89 mg/L in November and December 2024, significantly exceeding the 100 mg/L limit. Phosphate (PO_4) levels in the boiler drum were below the specified range of 5–15 mg/L during the same months but improved to acceptable levels in January and February 2025. Meanwhile, metal ions such as sodium (Na^+), iron (Fe^+), and copper (Cu^+) consistently remained within acceptable limits throughout the monitoring period.

3.2. Discussion

3.2.1. Treatment Efficiency Analysis

The water treatment system at Tanjung Enim Power Plant demonstrates overall effectiveness in meeting most water quality standards, consistent with findings from similar thermal power plant studies [13][15]. The multi-stage treatment approach successfully reduces major contaminants from Enim River water, achieving demineralization levels suitable for boiler feed water applications.

3.2.1.1. pH Control and Corrosion Prevention

The maintained pH levels across all treatment stages indicate effective chemical conditioning. pH control is critical in power plant water systems as it directly affects equipment longevity and operational efficiency [16]. The alkaline conditions in feed water and slightly lower pH in boiler drum provide optimal conditions for corrosion inhibition while preventing excessive alkalinity that could lead to caustic embrittlement [17].

Studies by Skolubovich et al. [16] emphasize that controlled pH prevents both acidic corrosion of boiler tubes and alkaline scaling, which aligns with the observed pH management in this system. The pH buffering capacity appears adequate, though closer monitoring during seasonal variations would be beneficial.

3.2.1.2. Conductivity Control Challenges

The conductivity exceedances in the EDI system represent a significant operational concern. Larin et al. [13] noted that single-stage reverse osmosis systems often struggle with consistent ion removal efficiency, particularly when feed water quality fluctuates. The observed conductivity spikes (1.15-1.32 μS/cm) suggest that the current RO system may require upgrading to a two-stage configuration.

Two-stage RO systems provide operational redundancy and improved ion removal efficiency [18][19]. When the first stage experiences membrane fouling or reduced efficiency, the second stage maintains water quality standards. This redundancy is particularly important for thermal power plants where water quality directly impacts equipment reliability and maintenance costs.

3.2.1.3. Turbidity and Suspended Solids Management

The elevated raw water turbidity reflects typical challenges associated with river water sources, particularly during monsoon seasons or periods of increased upstream activity [14]. The consistent turbidity reduction achieved by the MMF system demonstrates effective mechanical filtration performance.

However, the periodic spikes in raw water turbidity suggest that upstream watershed management or enhanced pretreatment may be necessary. Mohiyaden et al. [14] reported similar challenges in river water treatment systems, recommending enhanced coagulation-flocculation processes during high turbidity periods.

3.2.2. Critical Parameter Analysis

The water treatment system at Tanjung Enim Power Plant demonstrates overall effectiveness in meeting most water quality standards, consistent with findings from similar thermal power plant studies [13][15]. The multi-stage treatment approach successfully reduces major contaminants from Enim River water, achieving demineralization levels suitable for boiler feed water applications.

3.2.2.1. Silica Management Issues

The elevated silica levels in EDI effluent during November and December 2024 present a significant operational risk. Silica scaling in boiler systems can cause severe damage to heat transfer surfaces and turbine components [20]. The reduction observed in January and February 2025 suggests successful corrective measures, though the root cause analysis is essential.

Silica removal efficiency in EDI systems is highly dependent on membrane condition, current density, and flow rates. The observed improvement may result from membrane cleaning, current optimization, or reduced inlet silica loading. Continuous monitoring and preventive maintenance protocols should be established to prevent recurrence.

3.2.2.2. Phosphate Dosing System Performance

The phosphate deficiency in boiler drum water during November and December 2024 indicates chemical dosing system malfunctions. Phosphate serves multiple critical functions in boiler water chemistry: pH control, hardness precipitation, and metal ion complexation [15].

The successful restoration of phosphate levels in January and February 2025 following dosing pump repairs confirms the mechanical nature of this issue. However, this incident highlights the need for redundant dosing systems and enhanced monitoring protocols for critical chemical feed systems.

3.2.3. System Optimization Recommendations

The phosphate deficiency in boiler drum water during November and December 2024 indicates chemical dosing system malfunctions. Phosphate serves multiple critical functions in boiler water chemistry: pH control, hardness precipitation, and metal ion complexation [15].

The successful restoration of phosphate levels in January and February 2025 following dosing pump repairs confirms the mechanical nature of this issue. However, this incident highlights the need for redundant dosing systems and enhanced monitoring protocols for critical chemical feed systems.

3.2.3.1. Reverse Osmosis System Enhancement

The challenges in controlling conductivity strongly indicate the need for an upgrade to a two-stage Reverse Osmosis (RO) configuration. This modification would offer several advantages, including improved ion removal efficiency, enhanced operational reliability, reduced loading on the Electrodeionization (EDI) unit, and extended membrane lifespan [5]. Additionally, a two-stage system provides better resilience to variations in feed water quality [6]. A cost-benefit analysis is recommended to weigh the reduced maintenance costs and improved system performance against the capital investment required for the upgrade [3].

3.2.3.2. Pretreatment System Improvements
Raw water turbidity management could be significantly improved through several strategic measures. Upgrading the coagulation-flocculation system with automated dosing control would ensure more consistent and effective treatment [7]. Enhancing the design of settling tanks, particularly by improving sludge removal mechanisms, would further support turbidity reduction. During periods of high turbidity, the installation of pre-filtration systems could provide an additional layer of protection. In the long term, implementing watershed management initiatives to reduce upstream erosion would help address the root causes of turbidity at the source [6].

3.2.3.3. Monitoring and Control System Upgrades
The implementation of continuous monitoring systems for critical parameters offers several significant advantages. It enables real-time process optimization, allowing for immediate adjustments that improve efficiency and water quality [10]. Such systems also facilitate early detection of system malfunctions, minimizing downtime and preventing potential damage. Furthermore, automated chemical dosing adjustments can be made based on live data, ensuring optimal treatment levels are consistently maintained [11]. Lastly, continuous monitoring supports predictive maintenance scheduling, helping to anticipate and address equipment issues before they lead to failures, thereby enhancing overall operational reliability [5].

3.2.4. Economic and Enviromental Implications
The identified water quality issues have direct economic impacts through increased maintenance costs, reduced equipment life, and potential forced outages [3]. Proactive system improvements, while requiring capital investment, would likely provide positive returns through reduced operational costs and improved plant availability.

3.2.5. Comparative Analysis with Industry Standards
The overall performance of the Tanjung Enim water treatment system compares favorably with similar facilities reported in literature [13][14][15]. However, the identified improvement opportunities, particularly regarding RO system configuration and monitoring capabilities, would bring the system to best-practice standards for modern thermal power plants.

Future research should focus on long-term performance trends, seasonal variations, and the effectiveness of implemented improvements [12]. Additionally, investigation into alternative treatment technologies, such as advanced oxidation processes for specific contaminants, may provide further optimization opportunities [9].

4. Conclusion

The comprehensive analysis of water hardness levels in the Enim River was conducted for the demineralization process at the Tanjung Enim Thermal Power Plant. The results show that the multi-stage treatment system is effective. It meets most water quality standards needed for boiler feed water applications.

The treatment process can reduce major contaminants from raw river water. The pH levels remain within acceptable ranges across all treatment stages. This shows that chemical conditioning is effective in preventing corrosion.

However, several critical operational challenges were found. These include conductivity exceedances in the Electrodeionization (EDI) system. Elevated raw water turbidity was also observed, which is typical of tropical river sources. Additionally, significant silica levels were detected in the EDI effluent during certain monitoring periods.

To address these issues, several improvements are recommended. Upgrading to a two-stage reverse osmosis configuration would improve ion removal efficiency. Enhancing pretreatment systems with automated dosing control would help manage turbidity more effectively. Implementing continuous monitoring systems would support real-time process optimization.

These findings offer valuable insights for other thermal power plant installations in tropical regions. Facilities facing similar water quality challenges can receive help from the recommended improvements. Moreover, the systematic evaluation method used in this study can serve as a framework. It is useful for ongoing performance assessments and predictive maintenance in power plant water treatment systems.

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