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REGULATORY EFFECTIVENESS IN WASTEWATER MANAGEMENT UNDER MINISTERIAL REGULATION NO. 5 OF 2014 AT PTPN 1 REGIONAL 7 PEMATANG KIWAH

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Abstract

PTPN 1 Regional 7 Pematang Kiwah is a crumb rubber processing unit in Natar District, South Lampung Regency, that generates wastewater with a high organic load. This study identifies wastewater sources and management processes, assesses compliance with effluent standards under Ministerial Regulation No. 5 of 2014, and evaluates factors affecting regulatory implementation. A mixed-methods approach combined in-depth interviews, treatment plant observations, document review, community questionnaires, and laboratory monitoring data for July-December 2025. Wastewater originated from raw-material handling, wet processing, and drying and was treated through an integrated anaerobic, facultative, and aerobic pond system. The overall compliance rate was 97.62%, classified as very good. BOD, COD, TSS, ammonia nitrogen, total nitrogen, and specific wastewater discharge met the stated limits in all six months. The only exceedance was pH in December 2025, at 9.1 against an upper limit of 9.0. Key performance indicators across technical, operational, administrative, environmental, and social dimensions were rated good to very good. Regulatory implementation was classified as effective within the study framework. Further improvements are needed in pH control, treatment performance, maintenance, environmental audit documentation, and real-time monitoring.

Keywords: Effluent Compliance; Regulatory Effectiveness; Rubber Industry; Wastewater Management; Wastewater Treatment Plant.

INTRODUCTION

The plantation industry contributes to the national economy while generating waste at several stages of production. Wastewater requires particular attention because it can disperse into receiving waters and adversely affect surface-water quality, ecosystems, and surrounding communities if inadequately treated. PTPN 1 Regional 7 Pematang Kiwah, a business unit of PT Perkebunan Nusantara I (Persero), operates in Natar District, South Lampung Regency, Lampung Province. The facility processes approximately 15-20 tonnes of dry crumb rubber per day. Production involves receiving latex or raw rubber, coagulation, size reduction, washing, drying, and packaging. Wastewater arises from latex dilution, equipment cleaning, washing of floors and production channels, and utility activities such as boiler operation and sanitation.

The wastewater contains organic matter, suspended solids, and nitrogen compounds that require treatment before discharge. According to the facility's 2024 operating records, average wastewater generation was 35-50 m^3/day, with untreated BOD of 800-1,200 mg/L, COD of 1,500-2,500 mg/L, and TSS of 600-900 mg/L. Wastewater is treated in a wastewater treatment plant (WWTP) that combines anaerobic and aerobic processes. Ministerial Regulation No. 5 of 2014 provides the effluent quality benchmarks used in this study. However, implementation can be constrained by treatment capacity, equipment condition, operating practices, staff availability, supervision, maintenance delays, and production fluctuations.

This study examines how wastewater is managed at PTPN 1 Regional 7 Pematang Kiwah, whether treated effluent meets the stated regulatory limits, and which factors support or constrain implementation. Specifically, it identifies wastewater sources and management procedures, measures compliance with effluent standards, examines implementation factors, and evaluates regulatory effectiveness. The findings provide a basis for improving the facility's wastewater management and environmental compliance.

LITERATURE REVIEW

Wastewater management in crumb rubber processing combines physical separation with biological treatment. Rubber traps remove recoverable rubber particles and suspended matter before wastewater enters biological ponds. Anaerobic treatment reduces organic loads through fermentation and methanogenesis, while facultative and aerobic stages provide further treatment and support effluent stabilization. These treatment principles provide the conceptual basis for examining the integrated pond system at the study site.

Regulatory compliance and implementation effectiveness are assessed through complementary measures. Compliance indicates whether measured effluent values satisfy the specified limits, whereas the performance framework used in this study also considers operations, administrative procedures, environmental conditions, and community perceptions. Combining these measures allows an assessment of both effluent outcomes and the organizational processes supporting them. The study addresses the site-specific need for an integrated evaluation of monitoring results and implementation conditions. Bibliographic sources and incomplete citations in the original manuscript require completion by the authors.

METHOD

Study Location and Period

The study was conducted at PTPN 1 Regional 7 Pematang Kiwah, Jalan Raya Natar No. 71A, Natar District, South Lampung Regency, Lampung Province, at approximately 105.20090° E and 5.31920° S. Monitoring records were collected and reviewed from December 2025 to January 2026. The wastewater quality dataset covered July-December 2025, corresponding to one six-month environmental management and monitoring reporting period (RKL-RPL).

Research Approach and Design

The study adopted an applied, descriptive, and analytical mixed-methods design. Qualitative analysis examined implementation processes, constraints, perceptions, and institutional practices through interviews, observations, and document review. Quantitative analysis used descriptive statistics to assess effluent quality, compliance rates, and performance indicators.

Population Sampling and Data Collection

The study population comprised the wastewater management system, including wastewater sources, treatment units, monitoring points, and reporting procedures, together with residents living within 2 km of the WWTP outlet. The system assessment used secondary inlet and outlet laboratory data for July-December 2025, supplemented by in-depth interviews with the environmental or HSE manager, WWTP supervisors or operators, and environmental monitoring staff. Thirty community respondents were selected through purposive and convenience sampling. The original manuscript justified this sample size by reference to Roscoe's sampling guidance, but did not provide the bibliographic reference. Primary data were collected through interviews, direct observations using a 30-item checklist, and a 27-item community perception questionnaire. Secondary sources included regulatory documents, company RKL-RPL reports, laboratory results, environmental quality records from the environmental agency, and literature.

Data Analysis

First, descriptive analysis characterized wastewater sources and quality and the technical, operational, and administrative aspects of management. Second, each measured parameter was compared with its stated regulatory limit. The compliance rate was calculated as the number of compliant observations divided by the total number of observations, multiplied by 100%. Rates were classified as very good (90-100%), good (75-89%), fair (60-74%), or poor (<60%), following the categories reported in the original manuscript.

Third, key performance indicators (KPIs) assessed five dimensions: technical treatment performance, operations, administration, environmental impact, and social outcomes. Scores ranged from 1 to 5 based on achievement relative to the relevant targets. Fourth, gap analysis identified differences between actual results and the standards. Fifth, interview and observation findings were used to identify supporting and inhibiting factors across resource, managerial, technical, and external aspects. Findings were triangulated across interviews, observations, community questionnaires, and secondary data. The KPI values and classifications below reproduce those reported in the source manuscript.

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RESULTS AND DISCUSSION

Site Profile and Wastewater Management System

PTPN 1 Regional 7 Pematang Kiwah processes raw rubber into technically specified rubber (TSR/SIR). Production comprises three broad stages: raw-material receipt and weighing, wet processing, and dry processing. Figure 1 presents the production sequence. Wastewater management follows a regular monitoring schedule: discharge and pH are monitored daily, while physicochemical parameters, including pH, TSS, BOD, COD, ammonia, and total nitrogen, are tested monthly in cooperation with the Lampung Provincial Environmental Agency. Standard operating procedures (SOPs) and a defined environmental management structure support routine WWTP operation.

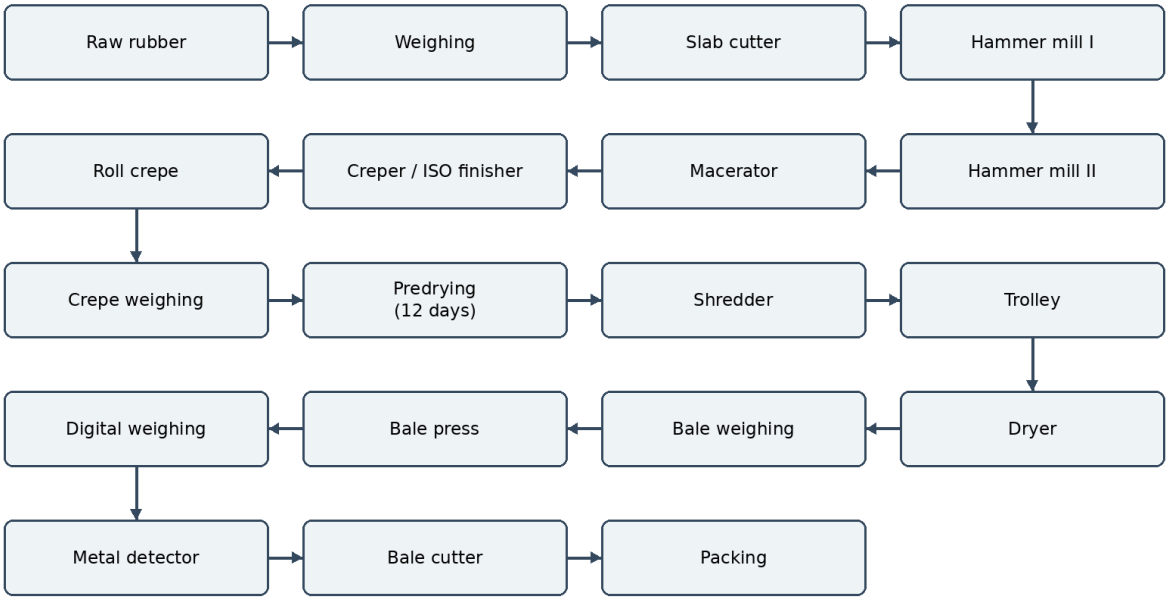


Figure 1. Rubber production process at the Pematang Kiwah unit
Source: Adapted and translated from PTPN 1 Regional 7 Pematang Kiwah documentation (2026).

Wastewater Sources and Characteristics

Total process-water demand is approximately 30 m^3 per tonne of product, all of which may contribute to wastewater generation. Raw-material receipt and weighing use approximately 3 m^3/tonne, generating wastewater from raw-rubber drainage and dry-rubber-content testing, with residual rubber and moderate suspended-solids concentrations. Wet processing is the largest contributor, using approximately 20 m^3/tonne in blending tanks, hammer mills, macerators, and crepers. These streams generally carry high BOD, COD, and TSS loads. Dry processing accounts for approximately 7 m^3/tonne, including static-screen operations, dryer steam condensate, and equipment and floor cleaning, with lower organic concentrations. All three streams are conveyed to the WWTP before discharge to receiving waters.

Wastewater Treatment Plant Performance

The WWTP applies progressive biological treatment. Pretreatment units, comprising a pre-rubber trap and Rubber Traps I and II, physically separate rubber particles and suspended solids. Treatment then proceeds through Anaerobic Ponds I-III, with a combined effective volume of 18,300 m^3 and a hydraulic retention time of 23.67 days; Facultative Ponds I-II, with 7,245 m^3 and 9.37 days; and Aerobic Ponds I-III, with 9,143 m^3 and 11.83 days. Figure 2 summarizes the treatment sequence. The anaerobic ponds reduce dissolved organic loads through fermentation and methanogenesis, with BOD removal estimated in the source manuscript at more than 80% of the inlet load. Facultative ponds support pH stabilization and further ammonia removal. Aerobic ponds provide final polishing, including further nitrogen removal and effluent stabilization.

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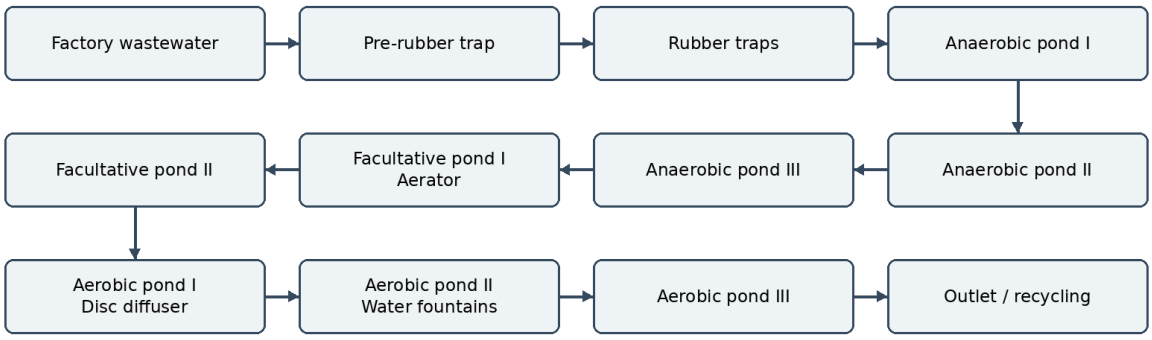


Figure 2. WWTP treatment sequence at PTPN 1 Regional 7 Pematang Kiwah
Source: Schematic adapted from the facility layout (2026). Recycling lines are simplified.

Table 1 compares inlet and monthly outlet wastewater quality for July-December 2025 with the effluent limits used in the study.

Table 1. WWTP inlet and outlet parameters compared with effluent limits

Parameter	Limit	Jul	Aug	Sep	Oct	Nov	Dec	WWTP inlet
pH	6.0-9.0	8.1	8.0	8.3	7.8	7.4	9.1	5.2
BOD (mg/L)	60	8	10	18	9	10	20	417
COD (mg/L)	200	27	32	60	30	34	68	1391
TSS (mg/L)	100	6	16	14	16	1	38	36
NH3-N (mg/L)	5	0.2	0.2	0.6	0.05	0.2	2	20
Total N (mg/L)	10	0.03	1	1	1	1	4	26
Discharge (m³/t)	40	12.45	12.41	12.72	13.02	10.2	10.47	-

Source: Research data analysis (2026).

BOD ranged from 8 to 20 mg/L against a limit of 60 mg/L; COD from 27 to 68 mg/L against 200 mg/L; TSS from 1 to 38 mg/L against 100 mg/L; NH3-N from 0.05 to 2 mg/L against 5 mg/L; total nitrogen from 0.03 to 4 mg/L against 10 mg/L; and specific discharge from 10.20 to 13.02 m³/tonne against a maximum of 40 m³/tonne. These parameters complied throughout the monitoring period. The only exceedance was pH in December 2025, at 9.1 against an upper limit of 9.0. The source manuscript attributes this provisionally to peak-harvest production fluctuations and reduced hydraulic retention time; the available results do not establish that mechanism directly.

Compliance with Effluent Standards

Compliance was determined by comparing the number of observations meeting the limits with the total observations for each parameter during the six-month monitoring period (Table 2).

Table 2. Compliance rates by parameter from July to December 2025

Parameter	Limit	Compliant tests	Total tests	Compliance Rate	Rating
pH	6.0-9.0	5	6	83.3%	Good
BOD (mg/L)	60	6	6	100%	Very good
COD (mg/L)	200	6	6	100%	Very good
TSS (mg/L)	100	6	6	100%	Very good
NH3-N (mg/L)	5	6	6	100%	Very good
Total N (mg/L)	10	6	6	100%	Very good
Discharge (m³/t)	40	6	6	100%	Very good
Mean	-	5.9	6	97.62%	Very good

Source: Research data analysis (2026).

Six parameters, namely BOD, COD, TSS, NH3-N, total nitrogen, and discharge, achieved 100% compliance and were classified as very good. The pH compliance rate was 83.3%, classified as good, because one monthly observation exceeded the limit. Overall, 41 of 42 parameter-month observations complied, giving an

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aggregate rate of 97.62%. Within the study's classification framework, this is very good and indicates consistently high compliance over the observed period.

Effectiveness Evaluation Using Key Performance Indicators

The KPI evaluation integrated technical, operational, administrative, environmental, and social dimensions. Table 3 reproduces the dimension-level achievements and ratings reported in the source manuscript.

Table 3. Reported wastewater management KPI achievements

KPI dimension	Main indicators	Mean achievement	Score / rating
Technical (WWTP treatment performance)	pH, BOD, COD, TSS, NH3-N, total N	88.62%	4 - Good
Operational	Monitoring frequency, operating time, WWTP downtime	100%	5 - Very good
Administrative	Timely reporting, documentation completeness	95.56%	4 - Good
Environmental impact	Receiving-water quality status	100%	5 - Very good
Social	Community satisfaction, number of complaints	97%	4 - Good

Source: Research data analysis (2026).

In the technical dimension, reported BOD removal (95.20%), COD removal (95.26%), and NH3-N removal (90.00%) received a score of 4, classified as good. The reported pH indicator (83.33%), TSS removal (83.33%), and total nitrogen removal (84.62%) received a score of 3, classified as fair. The reported technical mean was 88.62%, rated good. Operational indicators, including monitoring frequency, operating time, and zero days of downtime, received a score of 5, rated very good.

For administration, reporting timeliness reached 100% and received a score of 5. Documentation completeness was 77.78%, with a score of 3, because the current-year environmental audit results were unavailable. The reported administrative achievement was 95.56%, rated good. Receiving-water quality was reported to meet the relevant standards, producing an environmental-impact score of 5. In the social dimension, community satisfaction was 86.67%, with a score of 4. No community complaints were recorded against a maximum target of three cases annually, producing a score of 5 for that indicator. The reported social achievement was 97%, rated good. These dimension-level values follow the original study's scoring framework; their aggregation cannot be reconstructed fully from the summary data supplied.

Supporting and Inhibiting Factors

Interview and observation findings identified supporting and inhibiting factors across four aspects, as summarized in Table 4.

Table 4. Factors affecting regulatory implementation

Aspect	Supporting factors	Inhibiting factors
Resources	Trained WWTP operators; funding available in the company work plan and budget (RKAP); WWTP integrated with production.	Limited specialist technical competence; insufficient maintenance funding; aging treatment technology.
Managerial	Management commitment to compliance; wastewater SOPs; regular reporting to environmental authorities.	Production targets can reduce environmental priority; inconsistent SOP implementation under peak loads; internal monitoring is not real-time.
Technical	Adequate treatment capacity under normal production; operating and maintained equipment.	Peak-harvest wastewater volumes may exceed design capacity; some equipment has exceeded its economic service life.
External	Routine guidance and oversight by the Lampung Provincial Environmental Agency and the ministry; community oversight.	Limited government inspection frequency; no structured complaint mechanism or two-way community communication.

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Trained operators and RKAP funding support treatment continuity, although specialist knowledge of the regulation and maintenance allocations require improvement. Management commitment and SOPs encourage compliance, while peak-harvest production pressure may affect environmental priorities. The WWTP reportedly has adequate capacity under normal production conditions, but aging equipment and peak loading remain concerns. Guidance from environmental authorities and community oversight support implementation, although more frequent inspections and structured community communication could strengthen accountability.

Overall Effectiveness and Data Triangulation

The combined compliance and KPI evaluation classified regulatory implementation at the facility as effective. The reported findings indicate routine treatment, consistent monitoring, timely reporting, and generally favorable environmental and community outcomes. Improvements remain necessary in pH control, TSS and total nitrogen treatment, and internal environmental audit documentation. Laboratory compliance results were triangulated with physical WWTP observations, operator interviews, and community perceptions. The source manuscript reports that 87.33% of questionnaire responses expressed agreement with favorable statements about wastewater management. It also reports few formal complaints and clear, odorless outlet conditions during field observation. These observations support the site-specific assessment but do not establish long-term environmental outcomes beyond the monitoring period.

CONCLUSION

Wastewater at PTPN 1 Regional 7 Pematang Kiwah originates from raw-material cleaning and handling, wet processing, and drying related activities. Treatment uses an integrated anaerobic, facultative, and aerobic pond system supported by SOPs and routine monitoring. Overall compliance with the stated effluent limits was 97.62% during July-December 2025. BOD, COD, TSS, NH3-N, total nitrogen, and specific discharge complied in every month; only pH exceeded the upper limit slightly in December 2025.

Regulatory implementation was classified as effective within the study framework. Supporting factors included trained operators, budget allocations, management commitment, SOPs, and environmental oversight. Constraints included limited specialist competence, maintenance funding, aging equipment, monitoring without real-time capability, and limited inspection frequency. Operational and environmental-impact indicators were rated very good, while technical treatment performance and environmental audit documentation require further improvement.

The company should review WWTP capacity for peak-harvest loads, strengthen pH control in the aerobic ponds, introduce real time outlet monitoring, and systematically budget for maintenance and equipment renewal. Structured community communication and complaint procedures and periodic internal environmental audits are also recommended. Environmental authorities should increase field supervision during peak-harvest periods, when wastewater management faces the greatest operational pressure.

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