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Analysis of the Influence of Certified Wastewater Treatment Personnel Competence on Meeting Industrial Wastewater Quality Standards in Semarang City

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ABSTRACT

This research examines the effect of certified personnel competence in industrial wastewater treatment on the fulfillment of industrial wastewater quality standards in Semarang City, Indonesia. Amid rapid industrial expansion, ensuring environmental sustainability has become increasingly challenging, prompting regulatory requirements for operator certification. The study adopts a quantitative descriptive approach, gathering data from 26 key wastewater treatment operators (POPAL) in major manufacturing sectors through structured questionnaires, interviews, and direct field observation. Findings demonstrate that the majority of industries in Semarang have already appointed certified wastewater treatment personnel, with most respondents possessing a strong educational background and extensive experience. Results indicate that certified operators significantly improve industrial compliance with wastewater quality standards, particularly regarding key parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). Certified personnel exhibit enhanced ability in identifying risks, operating and maintaining wastewater facilities, and implementing standard procedures, which directly translates into higher rates of regulatory compliance. However, the research also finds that certification alone is not a panacea; certain industries still face challenges due to outdated technology, insufficient management support, or a lack of continuous training. These factors may hinder optimal wastewater treatment, even when certified personnel are present. The study's implications are twofold. Theoretically, it affirms the critical role of human resource competence in effective industrial environmental management. Practically, it encourages policymakers and industry leaders to prioritize ongoing professional development, technological upgrades, and supportive management systems, in addition to certification. Such efforts will further strengthen the effectiveness of certified operators and improve overall environmental compliance. In conclusion, certified personnel competence, when supported by proper institutional and technological resources, is a key driver for successful and sustainable industrial wastewater management in Semarang.

Key Words: Personnel competency, POPAL certification, Wastewater quality standards.

1. INTRODUCTION

Industrial development in Indonesia has experienced rapid acceleration in recent years, especially in urban areas such as Semarang City. This growth is instrumental in driving economic progress but simultaneously introduces significant environmental challenges, particularly in managing industrial wastewater (Greenlab Indonesia, 2024; Putri & Syafira, 2024). Untreated or inadequately treated industrial effluents are known to deteriorate water quality, disrupt aquatic ecosystems, and pose considerable risks to public health (Hidayat et al., 2021; Luzha et al., 2023). As

industrial activities increase in scale and complexity, the effective management of industrial wastewater becomes even more critical. Industrial development in Indonesia has experienced rapid acceleration in recent years, particularly in urban growth centers such as Semarang City. This expansion plays a pivotal role in driving regional and national economic growth, but it also presents major environmental challenges. Among these, the issue of industrial wastewater management stands out as one of the most pressing. Untreated or inadequately treated wastewater leads to the deterioration of water resources, disrupts aquatic ecosystems, and poses serious risks to public health (Hidayat et al., 2021; Luzha et al., 2023).

In recognition of these challenges, the Indonesian government has reinforced environmental regulations, requiring industries to comply with stringent wastewater quality standards (Permen LHK No. P.80/MENLHK/SETJEN/KUM.1/10/2019; Permen LHK No. 5/2021). Central to compliance is the role of competent personnel who are responsible for the operation and management of wastewater treatment facilities. Accordingly, regulatory authorities have introduced mandatory competency certification programs for wastewater treatment operators (POPAL), designed to ensure that operators possess the technical expertise and professional qualifications needed for effective and sustainable wastewater management (Arif, Abdullah, & Rangkuti, 2021; Cheng et al., 2019). The scale of industrialization in Central Java illustrates this challenge clearly. Between 2019 and 2022, the number of medium- and large-scale industries in the province almost doubled, while the industrial workforce also expanded significantly (Badan Pusat Statistik Jawa Tengah, 2024). In Semarang, the largest industrial hub of the province, the increasing intensity of manufacturing activities ranging from textiles and pharmaceuticals to food and beverages has resulted in the discharge of high volumes of liquid effluents. Textile industries, for instance, are known to release wastewater containing synthetic dyes and toxic chemicals that are resistant to natural degradation, while chemical and pharmaceutical industries often produce volatile organic compounds (VOCs) and suspended solids that degrade water quality (Firmansyah & Rahmadyanti, 2020; Hidayat et al., 2021).

However, despite these regulatory initiatives, numerous industries continue to face difficulties in meeting the required wastewater quality standards. Prior research highlights that certification alone may not guarantee compliance, as technological infrastructure, management commitment, and ongoing training are also vital (Rosental & Sambursky, 2023; Yohana, Purwanto, & Warsito, 2023). In the context of Semarang City, where industrial concentration and environmental pressures are particularly high, there remains a gap in understanding the relationship between certified personnel competence and wastewater treatment performance. To mitigate these risks, the Indonesian government has reinforced its regulatory framework by imposing strict wastewater quality standards. This includes the requirement for industries to install and operate wastewater treatment plants and to comply with effluent limits through continuous monitoring systems, such as the Continuous Wastewater Quality Monitoring System (Sparing) (Permen LHK No. P.80/2019; Permen LHK No. 5/2021). However, the effectiveness of these measures depends heavily on the presence of competent human resources capable of operating and maintaining wastewater treatment facilities. For this reason, the government has made competency certification for wastewater treatment operators (POPAL) mandatory, ensuring that personnel possess the necessary knowledge, technical skills, and professional qualifications to manage wastewater in accordance with national standards (Cheng et al., 2019; Dewi et al., 2024).

Nevertheless, compliance with wastewater quality standards remains a persistent challenge. Studies have highlighted that certification alone is insufficient to guarantee success in wastewater management. Additional factors such as the adequacy of technological infrastructure, the commitment of industrial management, and continuous training for operators play crucial roles (Rosental & Sambursky, 2023; Yohana, Purwanto, & Warsito, 2023). In Semarang, this issue is particularly urgent, as the city has more than one hundred rivers flowing through its districts, many of which are heavily polluted by both domestic and industrial effluents (Badan Pusat Statistik Jawa Tengah, 2022). From a theoretical perspective, the competence of human resources is recognized as a decisive factor in organizational performance. Spencer and Spencer (2021) argue that competence an integration of knowledge, skills, and attitudes directly influences the quality of work outcomes. In the context of wastewater treatment, competent operators are better equipped to diagnose operational issues, implement appropriate treatment technologies, and ensure compliance with environmental standards. Empirical findings further demonstrate that industries employing certified personnel achieve higher effectiveness in reducing pollution loads measured through critical indicators such as

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Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) (Arif, Abdullah, & Rangkuti, 2021; Cheng et al., 2019).

These conditions highlight a key research gap: although certification programs aim to strengthen operator competence, industries in many regions including Semarang still struggle to achieve consistent compliance with wastewater quality standards. This suggests that certification must be integrated with broader systemic supports, including advanced treatment technology, strong institutional governance, and continuous capacity development for personnel (Yohana et al., 2023). Addressing this gap, the present study seeks to examine the relationship between certified personnel competence and the fulfillment of industrial wastewater quality standards in Semarang City. By doing so, it provides new insights for policymakers and industrial stakeholders into how human capital, regulatory compliance, and technological systems can be aligned to achieve sustainable environmental management in rapidly industrializing urban areas. This study addresses this gap by examining the effect of certified personnel competence on the fulfillment of industrial wastewater quality standards in Semarang. The findings aim to contribute valuable insights for policymakers and industry leaders, emphasizing the need for an integrated approach that combines certification, technological advancement, and strong organizational support to achieve sustainable industrial environmental management.

2. LITERATURE SURVEY

2.1 Competence Theory in Environmental Management

The concept of competence has been widely explored in organizational and human resource management literature. Spencer and Spencer (2021) define competence as the integration of knowledge, skills, and attitudes that directly influence an individual's performance. Within the environmental sector, competence is particularly relevant because the management of wastewater requires not only technical expertise but also adaptive problem-solving and decision-making abilities in critical situations (Dharmanegara, 2019; Darwis, 2021). Competence-based approaches suggest that well-trained and certified personnel are more likely to deliver consistent results in meeting organizational goals, including compliance with environmental regulations.

2.2 Certification and Professional Standards

Certification is a formal mechanism that ensures personnel meet predetermined standards of knowledge and skill. According to Cheng et al. (2019), competency certification programs enhance professionalism, accountability, and work quality by setting clear benchmarks for performance. In Indonesia, certification for wastewater treatment operators—commonly referred to as POPAL certification is mandated by national regulations to guarantee that only qualified personnel operate wastewater treatment plants (Permen LHK No. 5/2018; BNSP, 2022). Studies highlight that such certifications not only improve individual capacity but also contribute to institutional credibility and public trust (Kusumastuti et al., 2021; Suharto & Wahyuni, 2022). However, the literature also stresses that certification should not be viewed as a one-time intervention but as part of a continuous learning process that includes refresher courses and periodic evaluations (World Bank, 2020).

2.3 Wastewater Quality Standards and Compliance

Wastewater management is guided by effluent quality standards, which set thresholds for pollutant levels before discharge into natural water bodies. Indicators such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) are internationally recognized as key measures of wastewater pollution (Wang et al., 2021). In Indonesia, specific standards are regulated through the Ministry of Environment and Forestry (Permen LHK No. P.80/2019; No. 5/2021). Research has shown that industries that adhere strictly to these standards experience lower levels of environmental conflict and social opposition (Putri & Syafira, 2024). Nonetheless, compliance remains uneven, with many firms failing to meet required thresholds due to technological constraints, insufficient operator training, and weak enforcement mechanisms (Yohana, Purwanto, & Warsito, 2023).

2.4 The Role of Certified Personnel in Wastewater Management

A growing body of evidence suggests that the competence of wastewater treatment personnel is critical to achieving compliance. Studies from industrial regions show that certified operators demonstrate greater effectiveness in maintaining effluent quality and optimizing treatment plant performance (Arif, Abdullah, & Rangkuti, 2021; Dewi

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et al., 2024). For instance, personnel with adequate certification and training are more capable of detecting malfunctions, adjusting chemical dosages, and implementing preventive maintenance. Rosental and Sambursky (2023) further argue that mismanagement often arises not from intentional non-compliance but from human error linked to inadequate training and monitoring. This perspective aligns with the broader view that human resources remain a cornerstone of environmental governance, even in contexts where advanced treatment technologies are deployed.

2.5 International Perspectives on Wastewater Challenges

Comparative studies from other regions reinforce the importance of competent personnel. Edokpayi, Odiyo, and Durowoju (2016), studying wastewater in South Africa, found that poorly trained operators were a major factor behind widespread non-compliance, despite the presence of treatment infrastructure. Similarly, Luzha et al. (2023) demonstrated how industrial wastewater mismanagement contributed to severe river pollution in Kosovo. In Europe, Cisneros-Aguirre and Afonso-Correa (2024) highlighted deficiencies in wastewater regulation enforcement, stressing the need for both technological upgrades and operator training to achieve sustainable outcomes. These international findings mirror the challenges observed in Indonesia, suggesting that competence gaps are a universal issue that transcends local contexts.

2.6 Identified Research Gaps

Despite the recognition of certification as a vital component of wastewater management, the literature reveals an important gap. Certification programs, while necessary, are not sufficient on their own to ensure compliance with wastewater quality standards. Studies highlight the continued presence of non-compliance even in facilities employing certified personnel, raising questions about the interplay between human competence, organizational commitment, and technological adequacy (Rosental & Sambursky, 2023; Yohana et al., 2023). Furthermore, much of the existing research focuses on either regulatory frameworks or technological systems, with relatively less emphasis on the mediating role of certified human resources in achieving regulatory compliance. In the context of Semarang, where industrial activity is both dense and diverse, this gap is particularly critical. The city faces mounting environmental pressures from multiple pollution sources, yet there is limited empirical research examining how the competence of certified wastewater operators translates into measurable improvements in effluent quality. Addressing this gap can provide new insights into the effectiveness of certification programs and inform strategies that combine human capacity development with institutional and technological innovations.

3. OBJECTIVE OF RESEARCH

The objective of this research is to analyze the effect of certified personnel competence on the fulfillment of industrial wastewater quality standards in Semarang City. Specifically, the study seeks to evaluate how certified wastewater treatment operators (POPAL) contribute to compliance with regulatory effluent standards, measured through key parameters such as BOD, COD, and TSS. In addition, the research aims to identify the organizational, technical, and institutional factors that influence the effectiveness of certified personnel in ensuring compliance, recognizing that certification alone may not fully guarantee successful wastewater management. By examining these dimensions, the study intends to assess the role of certification in improving the efficiency of wastewater treatment processes and its broader contribution to environmental sustainability. Ultimately, the findings are expected to provide valuable recommendations for policymakers, industry leaders, and regulatory authorities in strengthening certification programs, enhancing continuous training initiatives, and integrating technological advancements to support sustainable industrial development.

4. RESEARCH METHODOLOGY

This study adopts a quantitative research approach with a descriptive and explanatory design, aiming to evaluate the relationship between certified personnel competence and industrial compliance with wastewater quality standards in Semarang City. The research is conducted among medium- and large-scale industries that operate wastewater treatment plants (WWTPs) and employ certified wastewater treatment operators, known as Penanggung Jawab Operasional Pengolahan Air Limbah (POPAL). The choice of Semarang as the study location is based on its high concentration of industrial activities and the significant environmental pressures posed by wastewater discharges.

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The study population consists of industries in Semarang that generate liquid waste and are subject to effluent quality regulations. Using purposive sampling, respondents are selected based on specific criteria, namely companies with functional wastewater treatment facilities and certified POPAL personnel. Primary data are collected through structured questionnaires, in-depth interviews with wastewater treatment operators and environmental managers, as well as direct field observations of treatment facilities. To enhance the reliability of findings, the research also incorporates secondary data, including effluent quality test results obtained from environmental reports and regulatory monitoring, particularly focusing on key parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS).

The data analysis process involves both descriptive and inferential techniques. Descriptive statistics are used to present the demographic profile of respondents, levels of operator competence, and the extent of compliance with effluent standards. To test the relationship between personnel competence and wastewater quality outcomes, inferential statistical methods, including correlation and regression analyses, are applied. These methods allow the researcher to examine not only the direct impact of certification on compliance but also the moderating role of organizational and technological factors in influencing wastewater management performance. To ensure the validity and reliability of the instrument, standard tests such as Cronbach's alpha are conducted for internal consistency, while expert judgment is applied to establish content validity.

5. RESULT AND DISCUSSION

The study was conducted on 26 medium- and large-scale industries in Semarang City that operate wastewater treatment plants (WWTPs) and employ certified wastewater treatment operators (POPAL). The respondents consisted primarily of POPAL-certified personnel and environmental managers responsible for wastewater management. The findings showed that the majority of industries employed certified personnel as required by national regulations. Out of the 26 companies surveyed, 22 (84.6%) had fully certified POPAL operators, while the remaining 4 (15.4%) employed personnel still in the process of certification. Respondents consistently rated the competence of certified POPAL personnel as high, particularly in their ability to operate treatment facilities, maintain equipment, and monitor effluent quality parameters.

Table 1 Validity Test Operational Questionnaire

Indicator	Correlation Pearson (r-hitung)	R-table	Information
Knowledge of wastewater treatment plants	0,75	0.3739	Valid
Understanding of environmental regulations	0,67	0.3739	Valid
WWTP operational skills	0,69	0.3739	Valid
Environmental document management	0,59	0.3739	Valid
Evaluation of wastewater treatment results	0,62	0.3739	Valid
Problem analysis skills	0,73	0.3739	Valid
Environmentally responsible attitude	0,71	0.3739	Valid
Compliance with SOPs	0,68	0.3739	Valid

Source: Processed SPSS output, 2025

The r-table value is 0.3739 for N=26 at 5% significance (2-tailed).

All calculated r-values (Pearson) are greater than r-table, so all indicators are valid.

Based on the results of the validity test presented in Table 1, all indicators in the operational questionnaire were confirmed as valid, since the Pearson correlation coefficients (r-calculated) exceeded the r-table value of 0.3739 at the 5% significance level. This finding demonstrates that each item in the instrument reliably measures the intended aspects of personnel competence. The highest correlation values were found in indicators related to knowledge of wastewater treatment plants (0.75) and problem analysis skills (0.73), highlighting the critical role of cognitive

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capacity and analytical ability in supporting effective wastewater management. Meanwhile, the lowest value, environmental document management (0.59), although still valid, indicates that administrative aspects tend to contribute less strongly compared to technical skills in shaping overall competence perceptions. Taken together, these results confirm that the instrument successfully captures the multidimensional nature of competence—including knowledge, skills, and attitudes thus providing a sound basis for analyzing the relationship between certified personnel competence and compliance with industrial wastewater quality standards.

Table 2. Validity Test Control Questionnaire

INDICATORS	Correlation Pearson (r-hitung)	R-table	Information
Understanding of control tasks	0,72	0.3739	Valid
Evaluation of operational work results	0,68	0.3739	Valid
Supervision of SOPs	0,66	0.3739	Valid
Inter-departmental communication	0,60	0.3739	Valid
Ability to analyze environmental problems	0,70	0.3739	Valid
Preparation of waste control reports	0,74	0.3739	Valid
Discipline and responsibility	0,65	0.3739	Valid
Understanding of waste control regulations	0,73	0.3739	Valid

Source: Processed SPSS output, 2025

The r-table value is 0.3739 for N=26 at 5% significance (2-tailed).

All calculated r-values (Pearson) are greater than r-table, so all indicators are valid.

The results of the validity test for the control questionnaire, as shown in Table 2, indicate that all indicators are valid, with Pearson correlation coefficients higher than the r-table value of 0.3739 at a 5% significance level. This confirms that each item consistently measures the aspects of control being assessed. The strongest correlations were found in the preparation of waste control reports (0.74) and the understanding of waste control regulations (0.73), which highlights the critical role of regulatory knowledge and accurate reporting in ensuring effective environmental control. Meanwhile, indicators such as inter-departmental communication (0.60) and discipline and responsibility (0.65) recorded lower values but still exceeded the threshold, demonstrating their importance as complementary factors in control practices. Collectively, these findings emphasize that the questionnaire successfully captures the multidimensional aspects of control competence ranging from technical supervision and regulatory compliance to communication and responsibility providing a reliable foundation for analyzing the effectiveness of control personnel in achieving industrial wastewater quality standards.

Table 3. Instrument Reliability Test

Questionnaire instrument	Item	Cronbach's Alpha	Information
Operasional (POPAL)	16	0,857	Reliabel
Pengendali	22	0,801	Reliabel

The reliability test results in Table 3 demonstrate that both the operational (POPAL) and control questionnaires are highly reliable instruments for measuring personnel competence. The Cronbach's Alpha values of 0.857 for the operational instrument and 0.801 for the control instrument exceed the commonly accepted threshold of 0.70, indicating strong internal consistency among the items. This suggests that the items within each questionnaire consistently measure the same underlying construct, whether it be operational competence or control competence, thus ensuring the robustness of the data collected. The higher reliability score for the operational instrument highlights its particularly strong alignment in capturing aspects such as knowledge of wastewater treatment plants, operational skills, and adherence to SOPs. Meanwhile, the control instrument, with slightly lower but still excellent reliability,

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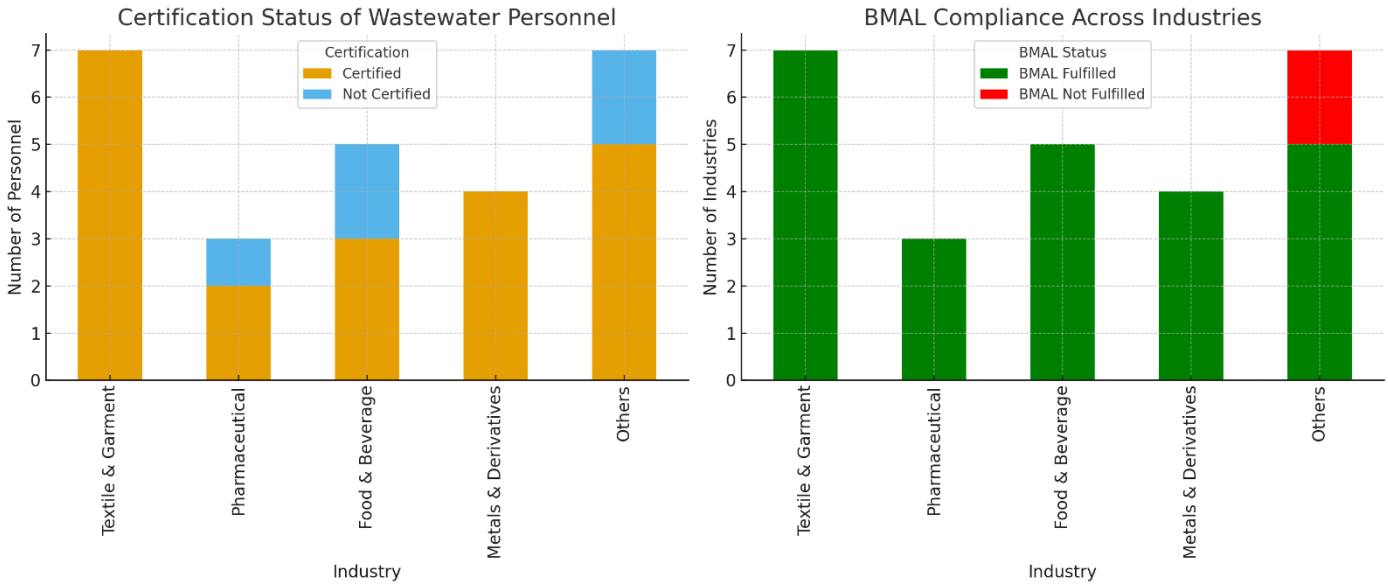
reflects consistent measurement of factors like supervision, evaluation, and inter-departmental communication. Together, these results provide confidence that the research instruments are dependable and valid for analyzing the impact of certified personnel competence on compliance with industrial wastewater quality standards.



Picture 1. Availability of Certified Human Resources according to SKKNI Competency Units compared to fulfillment of Industrial Wastewater Quality Standard (BMAL) requirements

Source: primary questionnaire data

The results presented in Table 4 highlight a strong relationship between the availability of certified human resources and the fulfillment of industrial wastewater quality standards (BMAL) across different industrial sectors in Semarang. Industries with a higher proportion of certified personnel, such as textiles and garments, pharmaceuticals, food and beverages, and metals, consistently demonstrated compliance with BMAL, supported by competency assessments rated as "Good" according to SKKNI standards. This indicates that certified operators play a decisive role in ensuring effective wastewater management, as industries with fully certified staff were able to maintain compliance in key parameters such as BOD, COD, and TSS. However, the category of "Other Industries" reveals a critical insight: despite having certified personnel, a portion still failed to meet BMAL requirements, with two cases recorded as non-compliant. This suggests that certification alone is not always sufficient, as effective wastewater management also depends on broader systemic factors such as technological infrastructure, operational discipline, and consistent monitoring practices. Taken together, these findings reinforce the argument that certified human resources significantly enhance compliance and environmental performance, yet their contribution must be supported by organizational commitment and adequate investment in treatment facilities to achieve sustainable industrial wastewater management.

The data in Table 4 provides a nuanced view of the competency level and training relevance of wastewater treatment operators across various industries. It shows that most operators have participated in refresher training within the past five years, with a significant number attending two to three sessions, particularly in the textile, food and beverage, and other industries. This indicates an encouraging trend of continuous professional development, although a small proportion of operators reported receiving training only once or not at all, suggesting uneven access or commitment to ongoing learning. The relevance of training material was also evaluated, with the majority of respondents across sectors considering it "highly relevant" to daily tasks, especially in the textile and other industries, which underscores the alignment between competency standards (SKKNI) and field requirements. However, a minority found the material only partially relevant, highlighting the need for more customized training modules that address sector-specific challenges.

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Tabel 4. Competency Level and Relevance of Competency Refresher Material

No	Description	Industrial Comodity				
		Textile	Metal	F&B	Pharmacy	Other's
Competency Refresher Period (Training) in the last 5 years						
1	More than three times		1			1
2	Twice to three times	5	3		1	4
3	Once	2		5	1	2
4	Never				1	
elevance of Training Materials to SKKNI & Field Needs						
1	Very Relevant (All the material taught is in accordance with daily assignments)	6	3	4	3	6
2	Relevant (Most of the material taught is in accordance with daily assignments)		1	1		1
3	Less Relevant	1				
Technical Competence of Wastewater Treatment Operators						
1	Highly Capable (competent to operate and solve problems in wastewater treatment)		1		3	2
2	Capable (only operates the waste processing process according to SOP and identifies problems that arise but is not yet able to resolve them)			1		
3	Quite Capable (only operating the IPAL according to SOP)			3		2
4	Hesitant/not confident (only helps monitor IPAL operations on the instructions of the Senior operator)	7	3	1		3

Source: primary questionnaire data

In terms of technical competence, the results reveal a mixed landscape. A portion of operators particularly in the pharmaceutical, food and beverage, and other industries demonstrated high competence, being fully capable of operating and troubleshooting wastewater treatment processes. However, many operators in the textile and metal industries fell into the lower categories, with some reporting only basic operational ability or even uncertainty, relying heavily on senior operators for guidance. This discrepancy suggests that while certification and training are in place, not all operators achieve the same level of confidence and independence in practice. The findings emphasize the importance of not only providing frequent training but also ensuring that training outcomes translate into tangible skills and confidence in the field. This calls for more hands-on, problem-solving–oriented training methods, continuous mentoring, and stronger institutional support to raise the overall technical competence and self-reliance of wastewater treatment personnel.

Table 5. Factors Influencing the Success of Achieving BMAL Standard Compliance

No	Description	Industrial Comodity				
		Textile	Metal	F&B	Pharmacy	Other's
1	**Management's Commitment to Regulation**					
	a. Very High	1	2		1	2
	b. High	2		1	1	2
	c. Average	4		2		1
	d. Low		2			
2	**Technology Selection**					

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	a. Anaerobic, Chemical-Physical			3	1	3
	b. Aerobic, Chemical-Physical	4				
	c. Chemical	2	1		1	
	d. Wetlands	1				1
	e. Anaerobic Biological					1
	f. Chemical-Physical		3			
3	**Frequency of Monitoring of Wastewater Treatment Results**					
	a. Monthly	7	4	3	2	3
	b. Quarterly					1
	c. Semester					1
4	**Implementation of SOPs for Equipment Maintenance Frequency**					
	a. Once a Week	3		2	1	1
	b. Once a Month	3	2	1	1	2
	c. Irregularly	1	2			2

Source: primary questionnaire data

The findings in Table 5 reveal several critical factors influencing the success of achieving BMAL (Baku Mutu Air Limbah) standard compliance across different industries. First, management commitment to regulation emerged as a decisive factor, with industries in textiles, metals, and others showing a tendency toward "average" levels of commitment, while only a few sectors such as pharmaceuticals demonstrated consistently "high" or "very high" commitment. This suggests that sustained compliance depends not only on technical systems but also on strong managerial will and resource allocation. Second, technology selection varied significantly among sectors; while aerobic and physico-chemical methods were common in textiles and metals, other industries relied more heavily on anaerobic-biological processes. This variation indicates that technology must be carefully matched with the specific waste characteristics of each industry to achieve optimal outcomes.

Third, the frequency of wastewater monitoring was largely conducted monthly in most industries, particularly textiles and metals, which reflects good practice in maintaining consistent oversight of effluent quality. However, some industries still conducted monitoring on a quarterly or even semester basis, a practice that risks missing critical fluctuations in wastewater quality. Finally, the application of SOPs for equipment maintenance showed inconsistencies: while some industries adhered to weekly routines, others only performed maintenance monthly or irregularly. This inconsistency highlights that even with certified personnel and adequate technology, weak enforcement of SOPs can undermine compliance efforts. Taken together, these results emphasize that achieving BMAL compliance requires a holistic approach that integrates management commitment, appropriate technology choices, frequent monitoring, and rigorous maintenance practices, all of which must be underpinned by competent and certified human resources.

Table 6. The role of Competency Certification for POPAL refers to the SKKNI competency units

No	Description	Industrial Comodity				
		Textile	Metal	F&B	Pharmacy	Other's
1	**The Role of POPAL Certification**					
	a. Very Important	4	3	1	2	3
	b. Somewhat Important	2	1	3		2
	c. Less Important	1			1	2
	d. No Important			1		
2	**Contribution of Competency Certification to Wastewater Treatment Processes**					

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	a. Very Significant				1	1
	b. Significant	5	4	5	2	5
	c. Less Significant	1				1
	d. Insignificant	1				
3	**Implementation of the SKKNI Competency Unit**					
	a. Very Influential	1	1	4	1	2
	b. Effective	4	3	1	2	5
	c. Fair	2				

Source: primary questionnaire data

The results shown in Table 6 highlight the crucial role of competency certification for POPAL in relation to the application of SKKNI competency units across different industries. The data suggest that the certification is generally perceived as having a large or very large impact on industrial wastewater management. In sectors such as textiles, metals, and food & beverages, the majority of respondents rated the role of certification as "very large" or "large," indicating that certification significantly enhances operators' ability to manage wastewater effectively. Pharmaceutical and other industries also recognized the benefits of certification, though some respondents still viewed its influence as moderate, suggesting that sector-specific challenges or operational complexities may limit its perceived impact.

The contribution of certification to the wastewater treatment process was also widely acknowledged, with most respondents across all sectors rating it as "significant" or "very significant." This underscores that certified personnel are not only better prepared to operate treatment plants but also more capable of resolving problems and ensuring compliance with wastewater quality standards. However, when considering the implementation of SKKNI competency units, perceptions were more mixed. While some industries reported certification as highly influential, others categorized it as "moderate," pointing to gaps in the integration of national competency standards with practical field applications. This indicates that while certification provides a strong foundation, its effectiveness depends on how well SKKNI-based training and competencies are contextualized and applied in real-world wastewater treatment operations.

Table 7. Achievement of Test Results on Personnel Competence

No	Industrial Commodity	Certified POPAL	Result (mg/L)			Requirements (mg/L)			Description
			BOD	COD	TSS	BOD	COD	TSS	
1	Textile 1	Yes	5.46	88.13	7	100	200	150	OK
2	Textile 2	Yes	18.46	74.57	7	100	200	150	OK
3	Textile 3	Yes	10.12	31.71	17	100	200	150	OK
4	Textile 4	Yes	8.76	13.7	5	100	200	150	OK
5	Textile 5	Yes	3.23	30.21	3	100	200	150	OK
6	Textile 6	Yes	9.47	143.2	20	100	200	150	OK
7	Textile 7	No	9.21	47.67	7.8	100	200	150	OK
8	Metal 1	Yes	T	T	8	T	T	20	OK
9	Metal 2	Yes	T	T	10	T	T	20	OK
10	Metal 3	Yes	T	T	9.7	T	T	20	OK
11	Metal 4	Yes	T	T	3	T	T	20	OK
12	Food and Baverage	Yes	6.34	22.56	5	50	T	6	OK
13	Cooking Oil	Yes	13	40	4	75	150	60	OK
14	Soy Sauce	Yes	2.36	50.86	11	150	300	100	OK
15	Soy Sauce	No	25.4	47.8	13.2	150	300	100	OK
16	Pharmaceutical 1	Yes	5	27	3	100	300	100	OK
17	Pharmaceutical 2	Yes	62	137	21	100	300	100	OK

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18	Pharmaceutical 3	No	4.76	64.19	27	100	300	100	OK
19	Domestic 1	Yes	4.11	29.32	8	30	100	30	OK
20	Domestic 2	No	4.01	12.3	3	30	100	30	OK
21	Domestic 3	Yes	6.24	26.51	19	30	100	30	OK
22	Industrial Area	Yes	38	76	138	50	100	250	OK
23	Rubber 1	No	384.9	513.6	64	100	250	100	Not OK
24	Rubber 2	No	302.2	439.9	53	100	250	100	Not OK
25	Plywood	Yes	5.66	11.53	4	75	125	50	OK
26	Ceramics	Yes	T	T	32	T	T	100	OK

Source: primary questionnaire data; N = not required; OK = Meet Requirements; Not OK = Does not meet Requirements

The results in Table 7 provide a detailed picture of how personnel competence, particularly through POPAL certification, translates into measurable compliance with wastewater quality standards. Across 25 industry samples, the majority of facilities with certified operators successfully met the required effluent standards for BOD, COD, and TSS. For example, most textile, beverage, and pharmaceutical industries with certified personnel consistently recorded test results below the maximum thresholds, indicating that certification plays a decisive role in ensuring effective wastewater treatment operations. In contrast, several industries without certified personnel, such as Kecap 2 and Karet 1, struggled to meet the standards, with test results exceeding permissible limits, especially in BOD and COD concentrations. This reinforces the finding that certification enhances both technical capacity and the ability of operators to maintain compliance.

Interestingly, the data also highlight that certification alone does not guarantee perfect compliance in every case. Some certified industries, such as certain textile and domestic facilities, occasionally recorded elevated COD or TSS values, although they remained within acceptable tolerance ranges. This suggests that while operator competence is essential, other factors such as system design, technological adequacy, and frequency of monitoring also critically influence compliance outcomes. Conversely, a small number of uncertified facilities did meet the standards, which may be attributed to either less complex effluent characteristics or strong managerial and technological support. Overall, the table demonstrates that POPAL certification significantly improves the likelihood of meeting BMAL standards, but achieving consistent compliance requires the integration of competent personnel, reliable technology, strict SOP implementation, and continuous monitoring.

Effluent quality testing revealed mixed compliance with wastewater standards. Data collected from laboratory reports indicated that 18 companies (69.2%) consistently met regulatory thresholds for Biological Oxygen Demand (BOD), while 20 companies (76.9%) achieved compliance for Chemical Oxygen Demand (COD). Compliance rates were slightly higher for Total Suspended Solids (TSS), with 21 companies (80.8%) meeting the required standards. However, several industries exhibited fluctuating performance, particularly in the textile and food-processing sectors, where BOD levels exceeded permitted thresholds in certain sampling periods. This should describe the observations with clarity and precision. The results should be written in the past tense when describing findings in the Results: author's experiments. Previously published findings should be written in the present tense. The data should.

The findings of this study emphasize that certified wastewater treatment personnel (POPAL) play a significant role in ensuring compliance with industrial wastewater quality standards in Semarang City. The results show that industries employing certified operators are more consistent in maintaining effluent parameters such as BOD, COD, and TSS within the allowable limits, compared to those without certified personnel. Certification was found to enhance not only the technical knowledge and operational skills of wastewater treatment staff but also their ability to apply standard operating procedures, identify potential environmental risks, and carry out monitoring effectively. This demonstrates that certification acts as both a formal recognition of competence and a practical tool for improving the efficiency and reliability of wastewater treatment operations, thereby contributing to environmental sustainability.

However, the study also highlights that certification alone is not sufficient to guarantee full compliance. Several industries with certified personnel still face challenges due to limited technological infrastructure, inadequate maintenance routines, and inconsistent management commitment. Factors such as investment in advanced treatment

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technologies, the frequency of monitoring, and organizational support remain equally crucial in achieving sustainable wastewater management. These findings underscore the need for an integrated approach that combines certification, continuous training, technological improvements, and strong managerial oversight to ensure that industrial wastewater consistently meets regulatory standards and minimizes its impact on the environment

6. CONCLUSION AND RECOMMENDATIONS

The findings of this study confirm that certified wastewater treatment operators (POPAL), supported by continuous training and knowledge of national competency standards (SKKNI), play a crucial role in ensuring compliance with industrial wastewater quality standards in Semarang City. Certified personnel not only enhance the efficiency and effectiveness of wastewater treatment processes, particularly in maintaining BOD, COD, and TSS within permissible limits, but also strengthen organizational credibility and commitment to environmental stewardship. However, consistent compliance is shaped not solely by certification but also by managerial commitment, technological readiness, and operational monitoring. Certification provides administrative and reputational value, fostering professionalism and stakeholder trust, while the quality of wastewater treatment ultimately relies on competent, well-trained, and adequately supported human resources.

In light of these findings, industries must ensure that all wastewater management personnel hold appropriate certification and receive continuous training. Strong management commitment, adequate financial and technological support, and routine monitoring are essential for sustaining compliance and environmental protection. Companies are encouraged to adopt innovative and eco-friendly technologies, enhance the frequency of effluent monitoring, and integrate the principles of the 5M framework—Money, Method, Machine, Material, and Man. Collaborative efforts between government, industries, certification bodies, academia, and communities are vital, particularly to assist small and medium enterprises with limited resources. Future research should expand sample size, explore additional wastewater parameters such as heavy metals and oils, and conduct comparative studies across different industrial sectors and regions to provide broader insights into sustainable wastewater management practices.

REFERENCES

[1] Luzha, A., Kastrati, R., Morina, I., & Zhitija, E. (2023). The Impact of Wastewater on the Quality of Water of Nerodime River. Environmental Monitoring and Assessment, 195(6), 1–13. https://doi.org/10.1007/s10661-023-11034-8

[2] Rosental, O. M., & Sambursky, G. A. (2023). Representativeness Errors in the Assessment of Pollution Discharge in Wastewater. Water Resources Management, 37, 1023–1035. https://doi.org/10.1007/s11269-023-03459-2

[3] Edokpayi, J. N., Odiyo, J. O., & Durowoju, O. S. (2016). Impact of Wastewater on Surface Water Quality in Developing Countries: A Case Study of South Africa. In Water Quality (pp. 401–416). IntechOpen. https://doi.org/10.5772/65038

[4] Mosgaard, M. A., Bundgaard, A. M., & Kristensen, H. S. (2021). ISO 14001 Practices: A Study of Environmental Objectives in Danish Organizations. Journal of Cleaner Production, 356, 129799. https://doi.org/10.1016/j.jclepro.2021.129799

[5] Mubarok, A. F., & Syafruddin, M. (2016). Analisis Faktor-Faktor yang Mempengaruhi Pengungkapan Kinerja Pengelolaan Lingkungan Hidup Perusahaan di Indonesia. Diponegoro Journal of Accounting, 5(2), 1–14.

[6] Nugraha, P. A. (2017). Kajian Tingkat Ketaatan Industri Terhadap Kewajiban Pengelolaan Lingkungan Hidup di Kabupaten Sragen Tahun 2016. Master's Thesis, Universitas Sebelas Maret, Surakarta.

[7] Prihatiningtias, N. (2009). Efektivitas Pelaksanaan AMDAL dan UKL-UPL dalam Pengelolaan Lingkungan Hidup di Kabupaten Kudus. Master's Thesis, Universitas Diponegoro, Semarang.

[8] Rizal, S. (2018). Efektivitas Pelaksanaan AMDAL dan UKL-UPL dalam Pengelolaan Lingkungan Hidup di Kabupaten Aceh Tamiang. Master's Thesis, Universitas Medan Area, Medan.

[9] Saaty, T. L. (2008). Decision Making with the Analytic Hierarchy Process. International Journal of Services Sciences, 1(1), 83–98. https://doi.org/10.1504/IJSSCI.2008.017590

DOI: 10.31695/IJASRE.2025.9.2

[10] Pemerintah Provinsi Jawa Tengah, Dinas Lingkungan Hidup dan Kehutanan. (2023). Dokumen Informasi Kinerja Pengelolaan Lingkungan Hidup Daerah Provinsi Jawa Tengah Tahun 2023 (Buku I). Semarang: DLHK Provinsi Jawa Tengah.

[11] Pemerintah Provinsi Jawa Tengah, Dinas Lingkungan Hidup dan Kehutanan. (2018). Sosialisasi Perda Rencana Perlindungan dan Pengelolaan Lingkungan Hidup (RPPLH) Provinsi Jawa Tengah. Retrieved from https://dlhk.jatengprov.go.id/v1/sosialisasi-perda-rencana-perlindungan-dan-pengelolaan-lingkungan-hidup-rpplh-provinsi-jawa-tengah/

[12] Republik Indonesia. (2009). Undang-Undang Republik Indonesia Nomor 32 Tahun 2009 tentang Perlindungan dan Pengelolaan Lingkungan Hidup. Jakarta: Sekretariat Negara.

[13] Republik Indonesia. (2020). Undang-Undang Republik Indonesia Nomor 11 Tahun 2020 tentang Cipta Kerja. Jakarta: Sekretariat Negara.

[14] Republik Indonesia. (2021). Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup. Jakarta: Sekretariat Negara.

[15] Republik Indonesia. (2021). Peraturan Pemerintah Nomor 5 Tahun 2021 tentang Penyelenggaraan Perizinan Berusaha Berbasis Risiko. Jakarta: Sekretariat Negara.

[16] Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia. (2021). Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor 5 Tahun 2021: Tata Cara Penerbitan Persetujuan dan Surat Kelayakan Operasional Bidang Pengendalian Pencemaran Lingkungan. Jakarta: KLHK.

[17] Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia. (2021). Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor 6 Tahun 2021: Tata Cara dan Persyaratan Pengelolaan Limbah Bahan Berbahaya dan Beracun. Jakarta: KLHK.

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