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EVALUATING ENVIRONMENTAL AND PUBLIC HEALTH PERFORMANCE AND SAFETY IN THE INSTITUTIONAL CONTROL PHASE OF A RADIOACTIVE WASTE DISPOSAL FACILITY

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Abstract:

This study evaluates the alignment between empirical safety performance and stakeholder perception at Malaysia's first near-surface repository for Naturally Occurring Radioactive Material (NORM) waste in Perak, now in its long-term Institutional Control phase. The research employs a quantitative case study design, conducting a parallel analysis of two data streams: (1) five years of official environmental monitoring data (2020–2024) from Radiological Environmental Monitoring Program (REMP) and Radiological Safety Analysis Report (RSAR) reports, and (2) a structured survey of 42 key stakeholders, including local residents and facility workers. The environmental analysis confirms that the repository operates in full compliance with national standards, with all radiological measurements in soil, water, and air remaining well below regulatory limits and the annual public dose kept below the 1 mSv/year threshold. In stark contrast, the stakeholder survey reveals a critical paradox: while respondents express high levels of trust in the facility's operator and the national regulator, they show significant scepticism and low confidence in the accuracy of the official environmental data that confirms the facility's safety. This study concludes that a significant socio-technical divide exists, where high institutional trust has not translated into informational confidence.

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While the repository is technically safe, its long-term stewardship and social acceptance require moving beyond simply publishing safety reports. To bridge this perception gap, the study recommends implementing targeted communication strategies that make technical data accessible, understandable, and verifiable for all stakeholders, thereby transforming passive trust into active, informed confidence.

Keywords:

Radioactive Waste Management, Institutional Control, Risk Assessment, Environmental Monitoring.

Introduction

The long-term management of radioactive waste is a critical challenge in ensuring environmental health and safety, especially during the post-closure phase of disposal facilities. In Malaysia, this challenge is addressed through facilities like the nation's first engineered near-surface repository for Naturally Occurring Radioactive Material (NORM) waste, located in Perak. This facility, developed to manage residues from industrial activities involving thorium and uranium, has now entered a 300-year Institutional Control phase, which requires continuous monitoring and regulatory oversight to ensure long-term safety and environmental protection. The repository is regulated under Malaysia's Atomic Energy Licensing Act 1984 (Act 304), with the Atomic Energy Licensing Board (AELB) ensuring that national practices align with the standards of the International Atomic Energy Agency (IAEA). These standards mandate long-term environmental monitoring, robust radiation protection programs, and comprehensive risk management. The facility contains long-lived radionuclides such as thorium and uranium, which necessitate vigilant containment to prevent environmental contamination.

Problem Statement

While official data from environmental monitoring programs (REMP) and safety analysis reports (RSAR) consistently demonstrate that the Perak Repository operates safely and in full compliance with national regulatory standards, a critical gap remains in understanding how these empirical safety outcomes are perceived by its key stakeholders. Technical compliance alone does not guarantee public trust or social acceptance, which are vital for the long-term stewardship of a radioactive waste facility. The central problem this study addresses is the potential for a significant disconnect between the documented safety performance of the Repository and the stakeholder perception of that performance. There is a lack of integrated research that quantitatively compares the facility's proven environmental safety record with stakeholder awareness, beliefs, and confidence in its regulatory oversight. Without a systematic analysis of this alignment, it is difficult to determine the effectiveness of current communication strategies or to identify the specific knowledge gaps and misconceptions that may undermine public trust. This study will fill this gap by conducting a parallel quantitative analysis of both environmental compliance data and stakeholder survey data, thereby providing an evidence-based evaluation of the alignment between empirical reality and stakeholder perception.

This study aims to address these gaps by evaluating the long-term environmental and public health safety performance of the Perak repository during its Institutional Control phase. The primary objectives are:

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1. to quantitatively assess the facility's compliance with national radiological safety standards by comparing five years of environmental monitoring data against established regulatory limits.
2. to evaluate stakeholder awareness and perception of the facility's adherence to national safety standards.
3. to critically evaluate the alignment between stakeholder perception of safety and the empirical evidence of environmental performance, in order to formulate targeted recommendations for strengthening stakeholder trust.

This study holds significant value by moving beyond a purely technical assessment of safety to provide an integrated analysis that compares empirical evidence with stakeholder perception. By quantitatively evaluating the alignment between the Repository's documented environmental safety performance and stakeholder awareness, the research offers critical insights for policymakers and facility operators. Its primary significance lies in identifying specific gaps in public understanding and trust, which allows for the development of more targeted, evidence-based communication and engagement strategies. The findings are not only crucial for enhancing the social acceptance and long-term stewardship of the Perak Repository but also provide a valuable, replicable model for assessing and improving stakeholder relations at similar radioactive waste management facilities in Malaysia and internationally.

Literature Review

The long-term management of radioactive waste presents a significant challenge to environmental and public health safety, particularly during the post-closure phase of disposal facilities (Kuzmin et al., 2022). Industrial activities such as mining, oil and gas extraction, and rare earth processing can generate waste containing Naturally Occurring Radioactive Material (NORM) (Borbet et al., 2023; Janković et al., 2024; Puertas et al., 2021). The management of NORM is complicated by the presence of long-lived radionuclides like uranium and thorium, which require long-term containment and monitoring to prevent the contamination of soil, water, and air (Zhao, 2023). This necessitates the development of purpose-built disposal facilities that align with international best practices and a robust governance framework to ensure safety over extended timescales.

A review of recent literature confirms the multifaceted nature of managing radioactive waste facilities, highlighting themes that are central to this study's objectives. As summarized in Table 1, one body of research focuses on the technical aspects of safety, emphasizing that the integrity of engineering barriers and robust Radiation Protection Programs are foundational to ensuring environmental and public health performance. Complementing this, other studies affirm that systematic environmental surveillance is the primary method for validating facility compliance and safeguarding public health. However, the most critical theme emerging from recent literature is the persistent "socio-technical divide," where proven technical safety does not automatically translate into public trust or social acceptance. Factors such as transparency in communication, stakeholder engagement, and trust in both operators and regulatory bodies are identified as the key determinants of public perception. This review validates the significance of the current study, as it directly addresses this divide by empirically comparing the technical safety performance of the Perak Repository with stakeholder perceptions of that performance.

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Table 1: Critical Review of Literature on Radioactive Waste Management, Safety, and Stakeholder Perception

Author(s) & Year	Key Findings from the Literature
Kuzmin et al. (2022)	Emphasizes that the long-term safety of near-surface disposal facilities is fundamentally dependent on the integrity and performance of the system of engineering safety barriers designed to contain waste.
Frane & Bitterman (2021)	Modern Radiation Protection Programs (RPPs) are designed to integrate core principles such as Justification, Optimisation (ALARA), and Dose Limitation to protect both workers and the public from radiological harm.
Adelodun & Anyanwu (2024); Giacobbo et al. (2021)	Argues that integrating radiological technology into environmental health surveillance is crucial for enhancing public safety. Effective management and disposal of NORM waste require robust radiological risk estimation based on monitoring.
Perko et al. (2020)	Concludes that transparency in operations and active stakeholder engagement are essential for building public trust and achieving social acceptance of facilities handling radiological materials. A lack of transparency is strongly linked to negative public perception.
Kasperski (2022)	Finds that public trust in both the facility operators and the independent regulatory authorities is a primary factor influencing the social acceptance of radioactive waste management projects.
Hietala & Geysmans (2020)	Highlights the persistence of a "socio-technical divide" where proven technical safety does not automatically lead to social acceptance. Also notes that long-term challenges include the potential loss of institutional knowledge over time.
Ledford et al. (2024)	Stresses the importance of using clear, accessible, and urgent communication during public health crises to effectively manage public perception and understanding.

Psychometric Paradigm of Risk Perception

A crucial theoretical lens for interpreting the findings of this study, particularly the potential divergence between empirical safety data and stakeholder perception, is the Psychometric Paradigm of Risk Perception. Pioneered by researchers such as Paul Slovic, this framework posits that an individual's perception of risk is influenced less by technical data and expert analysis and more by a complex set of qualitative, psychological factors (Slovic, 1987). For hazards like radioactive waste, these factors often include a high degree of "dread," a sense of involuntariness, a perceived lack of personal control, and the potential for catastrophic consequences. The theory explains that risks associated with radiation are often perceived as more threatening because they are unseen, unfamiliar, and associated with long-term,

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irreversible harm. The relevance of this paradigm to the current study is profound; it provides a robust theoretical explanation for why stakeholders might express concern or uncertainty even when environmental monitoring data confirms that the facility is operating well within safe, regulatory limits. Therefore, this framework allows the study to interpret any gap between technical reality and public perception not as a sign of public irrationality, but as a predictable psychological response to the specific qualitative nature of radiological risk.

Methodology

This study employed a quantitative case study design to evaluate the environmental performance and stakeholder perceptions of Malaysia's first engineered near-surface Repository for Naturally Occurring Radioactive Material (NORM) waste. The research was conducted focusing on the Perak Repository and its surrounding area, with the data collection and analysis covering the period from 2020 to 2024. The methodology was structured into two parallel streams to address the research objectives: one focused on empirical environmental data and the other on quantitative stakeholder perception data. Figure 1 illustrates the research process flow for this study.

Quantitative data were systematically extracted from official institutional reports, primarily the quarterly Radiological Environmental Monitoring Program (REMP) reports and the annual Radiological Safety Analysis Report (RSAR). This dataset included specific radiological measurements for environmental media such as soil, groundwater, surface water, ambient air, and vegetation, providing a comprehensive record of the facility's environmental performance over the five-year period.

A structured survey questionnaire, comprising primarily closed-ended, multiple-choice, and Likert-scale questions, was administered to a sample of 42 respondents. This sample included key stakeholder groups such as workers (radiation and non-radiation), contractors, and local residents living within a five-kilometer radius of the facility, ensuring a balanced perspective from those directly and indirectly affected by the Repository. The survey consists of the following sections:

Section A: Awareness of safety standards and regulation (this section gauges the baseline knowledge of stakeholders regarding the regulatory framework)
Section B: Perception of compliance and performance (This section measures stakeholder beliefs about how the facility performs against the standards. Use a Likert scale).
Section C: Confidence and trust in oversight (This section measures the level of trust stakeholders place in the key organizations responsible for safety. Use a Likert Scale).

The survey instrument used to collect stakeholder data was developed by adapting questions and themes from established research in the field of public perception of risk and technology. To ensure the validity and relevance of the questionnaire, the structure and content were informed by methodologies used in similar published studies that evaluate stakeholder trust, awareness, and perception of radiological facilities. Specifically, the questions assessing public engagement and trust in regulatory authorities were adapted from the frameworks discussed by Perko et al. (2020), while questions gauging the roles of risk, benefit, and trust in shaping public perception were informed by the work of Chen et al. (2020). This approach ensures that the survey measures key theoretical constructs in a manner consistent with validated, peer-reviewed research in the field.

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The data analysis was conducted in three stages. To meet Objective 1, the environmental data were analysed using descriptive statistics (mean, median, range) to summarize radiological levels and a comparative analysis was performed to benchmark these findings against permissible national regulatory limits. For Objective 2, the quantitative survey data were analysed using frequencies and percentages to summarize stakeholder awareness and perceptions, along with cross-tabulations to identify variations in responses across different demographic groups. The final stage of analysis, addressing Objective 3, involved a synthesis and critical evaluation of the findings from the first two stages. This involved directly comparing the results of the environmental compliance assessment with the stakeholder perception analysis to identify areas of alignment and divergence, thereby providing an evidence-based foundation for the study's conclusions and recommendations.

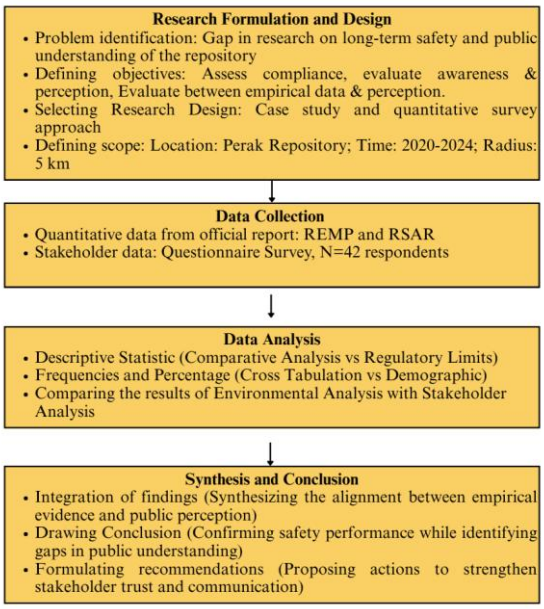

Figure 1: Research Flow Process

Results and Discussion

Environmental Monitoring and Regulatory Compliance

The evaluation of the Repository's environmental performance and compliance with national standards was based on a quantitative analysis of official reports from 2020 to 2024, primarily the Radiological Environmental Monitoring Program (REMP) and the Radiological Safety Analysis Report (RSAR). The analysis confirmed that the Repository operates well within the established national and international safety limits,

Routine monitoring confirmed that radiological levels across all environmental media including soil, groundwater, surface water, and ambient air were consistently below regulatory thresholds. The highest recorded soil activity was 0.55 Bq/g, and airborne dose rates within the Exclusion Zone did not exceed 0.47 mSv/year, both significantly below permissible limits. Furthermore, the total public exposure dose remained well below the annual limit of 1 mSv/year as recommended by both Malaysian authorities and the ICRP. These stable measurements indicate that the facility’s engineered containment systems are performing effectively, with no evidence of offsite radionuclide migration (Figure 2).

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Over the five-year assessment period, only one significant deviation was recorded in the 2023 REMP, which involved elevated radiological levels in specific vegetation samples. This was addressed through prompt corrective actions, and subsequent follow-up assessments confirmed no extended environmental impact. This proactive response further highlights the robustness of the monitoring program. The facility's strong compliance framework is also evidenced by its performance in annual regulatory inspections conducted by the Department of Atomic Energy (Atom Malaysia), where it has consistently received a "Very Satisfied" rating for the past five years (2020–2024).

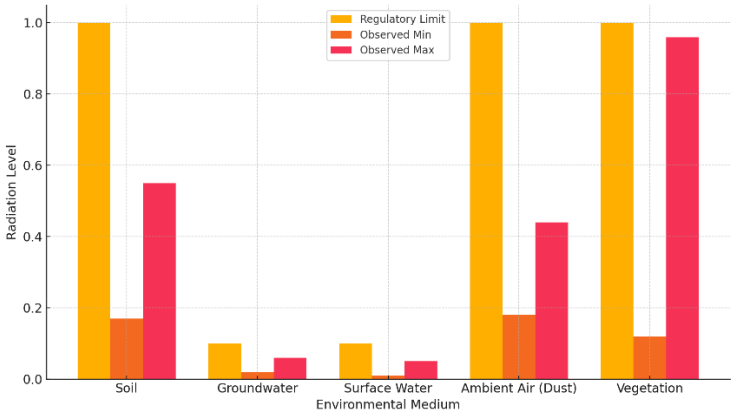

Figure 2: Summary of Environmental Monitoring Results (2020–2024)

A notable deviation was recorded in the 2023 REMP, specifically in vegetation samples collected near the Repository. This was the only significant deviation observed during the monitoring period. In response, further root zone sampling was conducted, and corrective actions were implemented to verify that the anomaly did not indicate a broader environmental issue. Follow-up assessments confirmed that surrounding vegetation remained within permissible radiological limits, with no evidence of extended impact (MB Inc., October 2023).

In addition to the REMP, the Radiological Safety Analysis Report (RSAR) provided further confirmation that radiation levels at the Repository remained below the annual public exposure limit of 1 mSv/year. The RSAR documented that radiation levels at the site consistently stayed within national dose constraints for both public and occupational exposure. Airborne dose rates within the Exclusion Zone did not exceed 0.47 mSv/year, and the highest recorded soil activity was 0.55 Bq/g, well below regulatory thresholds. These results fall significantly below the 1 mSv/year public dose limit recommended by both Malaysian authorities and the International Commission on Radiological Protection (ICRP).

The RSAR also demonstrated consistent radiological measurements across multiple monitoring points, indicating stable performance of the engineered containment systems. No evidence of radionuclide migration beyond the site boundary was identified during the assessment period. The data collectively confirm the continued integrity of the containment systems and that environmental exposures remain within safe limits.

These findings demonstrate that the Repository’s engineered disposal cells are functioning effectively, maintaining isolation of radioactive materials. The results of the environmental monitoring and safety assessments indicate that the facility remains in full compliance with

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national and international radiological safety standards and does not present additional risk to the surrounding environment.

Quarterly monitoring results continue to demonstrate that the facility is meeting its environmental protection goals. Through the REMP, the site not only verifies compliance with regulatory standards but also shows a continued effort to minimise environmental impact (Department of Atomic Energy, 2016). MB Inc.'s prompt corrective actions following the vegetation sampling anomaly at monitoring point M5 further highlight a proactive approach to maintaining a strong and reliable environmental monitoring programme.

The RPP at Malaysia's first engineered near-surface NORM disposal facility in Perak has proven to be an effective and comprehensive framework for managing radiation safety. Backed by consistent regulatory inspection outcomes and operational performance data, the programme has shown its ability to maintain compliance with standards, protect both workers and the public, and preserve environmental safety. These results underscore the key role of the RPP in supporting long-term management during the Institutional Control phase.

According to the RSAR, the facility remains in full compliance with all applicable regulations, including the Atomic Energy Licensing Act 1984 (Act 304) and the Basic Safety Radiation Protection Regulations 2010 (BSRP 2010). Radiological monitoring is carried out in accordance with the approved RPP and EMP, with recorded exposure levels staying well below regulatory limits. These results reflect the effective implementation of safety measures across the site.

These findings are consistent with recent research on the technical requirements for radioactive waste management. The study's confirmation that the repository's engineered containment systems are performing effectively aligns with the conclusions of Kuzmin et al. (2022), who emphasize that the long-term safety of such facilities depends on the integrity of their engineering safety barriers. The effective implementation of the facility's RPP reflects the core principles of modern radiation safety on Justification, Optimisation (ALARA), and Dose Limitation as outlined by Frane & Bitterman (2021). Furthermore, the study's reliance on continuous environmental surveillance to validate safety is supported by Adelodun & Anyanwu (2024) and Giacobbo et al. (2021), who argue that robust radiological monitoring is crucial for risk estimation and ensuring public safety.

Stakeholder Awareness and Perception

The survey covered a total of 42 respondents**,** comprising workers at the Repository, local residents living within a five-kilometre radius of the site, and representatives from nearby institutions. This mixed respondent group provided a balanced perspective on both internal safety practices and external community perceptions. The survey questionnaire was designed to quantitatively evaluate stakeholder perspectives on the Repository's regulatory performance by focusing on three key areas. First, it establishes a baseline of stakeholder awareness by measuring their familiarity with the facility, its governing safety standards, and the roles of the regulatory bodies involved. Building on this, the survey then assesses stakeholder perception of the facility's actual performance, specifically their beliefs regarding its adherence to compliance, operational transparency, and the trustworthiness of its environmental monitoring. Finally, it measures the level of trust and confidence stakeholders place in the oversight

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provided by both the facility operator and the national regulator, gauging their faith in these organizations' ability to ensure safety.

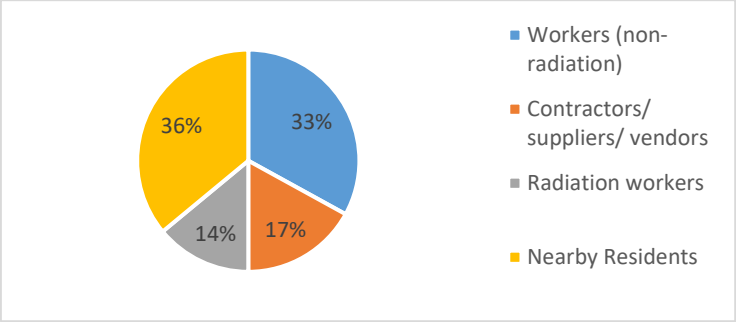

Figure 3: Stakeholder Types

Figure 3 shows that 36% of respondents are nearby residents, 33% are non-radiation workers, 17% are contractors or suppliers, and 14% are radiation workers. This indicates that the largest proportion of participants are members of the public living near the repository, reflecting strong community interest or concern. The next largest group is non-radiation workers, suggesting good internal engagement among general staff. Contractors and radiation workers form smaller portions, which may reflect limited access or a smaller workforce. The distribution highlights the need for targeted communication strategies, with a focus on nearby residents and general workers, while ensuring that technical staff and external contractors remain informed and included in safety efforts.

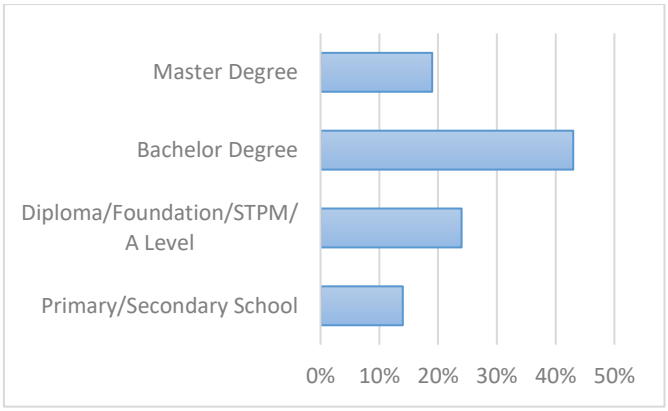

Figure 4: Education Background

Figure 4 shows that 45% of respondents hold a bachelor's degree, followed by 26% with a diploma, foundation, STPM, or A-Level qualification. Around 19% have a master's degree, while 10% completed only primary or secondary school. This suggests that the majority of participants are relatively well-educated, with more than 70% having tertiary education. Such a demographic may influence the level of awareness and understanding of radiation safety issues. The high proportion of degree holders can support more detailed and technical communication, while the presence of those with lower educational backgrounds indicates the need for clear, accessible information for inclusive outreach.

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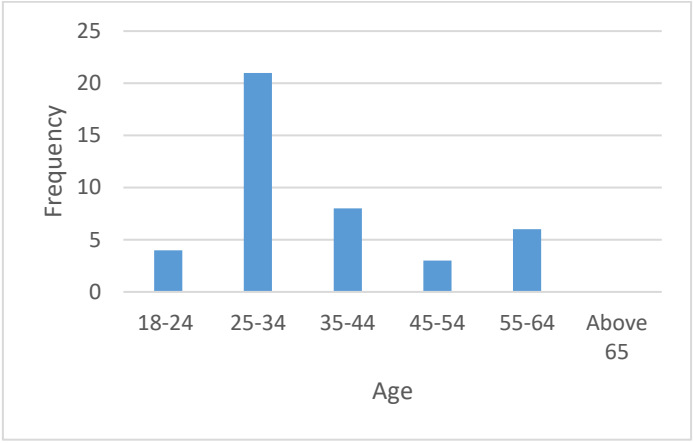

Figure 5: Age Distribution

The age distribution (Figure 5) shows that the largest group of respondents (50%) falls within the 25–34 age range and no participants were above 65. This indicates that the sample is largely made up of younger working-age adults, which may reflect the workforce composition at or around the repository site. The strong representation of those in their late 20s to early 30s may also influence the overall awareness, communication preferences, and attitudes toward radiation safety, as this group is likely to be more active in the workforce and more receptive to structured safety protocols and engagement.

The results show that familiarity with national safety standards and awareness of the Atomic Energy Licensing Board (AELB)/Atom Malaysia among respondents are generally moderate to high. About 33.3% rated their familiarity at the highest level (5), with another 42.8% selecting levels 3 and 4, indicating that most participants have some understanding of the standards. Similarly, awareness of AELB's regulatory role was highest at level 4 (30.9%) and level 5 (23.8%), while only a small portion (11.9%) reported very low awareness. This suggests that while a core group is well-informed, there remains a segment of workers, particularly those outside direct radiation roles who may benefit from further engagement or training.

Respondents showed a generally positive perception of the repository's safety compliance and the operator's transparency. For the statement on whether the Repository strictly follows all national safety regulations, 61.9% agreed with ratings of 4 or 5. A similar trend appeared for MB Inc.'s transparency, with 66.6% giving scores of 4 or 5. In contrast, confidence in the accuracy of official environmental monitoring results was relatively low; 71.4% gave low to neutral scores (1 to 3), with 38.1% choosing the lowest score. This suggests a trust gap in the published environmental data. On the other hand, trust in regulatory oversight from Atom Malaysia was strong, with 45.2% selecting the highest rating and another 16.7% selecting level 4. These responses indicate that while participants trust the authorities and operators to follow regulations, they remain sceptical about the accuracy of environmental reporting. This highlights the need for clearer communication and more accessible monitoring results to improve public confidence.

Respondents expressed high levels of confidence in both the facility operator (MB Inc.) and the national regulator (Atom Malaysia). For MB Inc., 87.5% of participants gave ratings of 4 or 5, with 45.8% selecting 4 and 41.7% selecting 5. Confidence in Atom Malaysia was similarly strong, with 93.3% choosing 4 or 5—56.7% at level 4 and 36.7% at level 5. Only a small

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proportion gave neutral ratings (3), and none selected lower scores. These findings suggest that most participants trust both the operator and the regulator to manage and oversee the safety of the radioactive waste repository responsibly and effectively. The stronger confidence in the regulator reflects public belief in Atom Malaysia's enforcement role, while MB Inc. is also seen as a reliable party in maintaining facility safety

The evaluation of stakeholder awareness and perception, conducted to address the second research objective, reveals a complex and dual-sided view of the Repository. On one hand, the findings indicate a high level of institutional trust, with the majority of stakeholders expressing strong confidence in both the facility operator (MB Inc.) and the national regulator (Atom Malaysia) to manage the site safely and enforce regulations effectively. This is coupled with a generally positive perception that the facility adheres to national safety standards.

However, this high-level confidence coexists with significant gaps in specific, functional knowledge. While most respondents are aware of the facility's existence, far fewer understand its primary purpose, the specific risks involved, or the appropriate actions to take in an emergency. The most critical finding is the notable distrust in the accuracy of published environmental monitoring results, which stands in stark contrast to the high level of trust placed in the regulatory bodies themselves.

This complex relationship between trust, knowledge, and perception is a prominent theme in recent literature. The high level of trust in the operator and regulator aligns with findings from Kasperski (2022), who identifies trust in these specific bodies as a primary factor influencing the social acceptance of radioactive waste projects. However, the concurrent distrust of monitoring data underscores the arguments made by Perko et al. (2020), who conclude that transparency in operations is essential for building genuine public trust and social acceptance. The knowledge gaps identified in the study highlight a need for clearer and more accessible communication, a point supported by Ledford et al. (2024), who stress that such communication is critical for managing public understanding during public health-related matters.

Therefore, this study concludes that while stakeholders trust the institutions to perform their duties, they lack the specific knowledge and transparent data needed to independently verify the facility's safety performance, highlighting a critical disconnect between institutional trust and informational confidence.

The Paradox of Trust: Confidence in Institutions vs. Scepticism of Data

The critical evaluation of the findings from the environmental compliance assessment and the stakeholder perception survey reveals a significant and nuanced socio-technical divide. On the surface, there appears to be a strong alignment: the empirical data confirms the Repository is operating safely within all regulatory limits, and stakeholders, in turn, express a high level of confidence in the facility operator and the national regulator to manage the site responsibly. This indicates a foundational level of institutional trust. However, a deeper analysis exposes a critical paradox. Despite their confidence in the institutions, a notable portion of stakeholders expressed scepticism and a lack of trust in the accuracy of the official environmental monitoring results. This disconnect, trusting the organizations but not the data they produce is a classic manifestation of the socio-technical divide, where technical evidence of safety does not automatically translate into public belief or acceptance of that evidence.

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This paradox can be understood through the lens of the Psychometric Paradigm of risk perception. The unseen, involuntary, and potentially catastrophic nature of radiological hazards makes the associated data feel abstract and difficult to verify for non-experts (Hietala & Geysmans, 2020). Stakeholders may find it easier to place their faith in the perceived integrity of the institutions responsible for oversight rather than in complex scientific measurements they cannot independently validate (Kasperski, 2022). This suggests that their confidence is rooted in institutional reputation rather than informational transparency. The primary implication of this perception gap is that the current high level of trust is vulnerable. Should any event occur that erodes confidence in the operator or regulator, there is no underlying trust in the empirical data to serve as a safety net. Therefore, simply publishing safety reports is an insufficient communication strategy. To ensure robust, long-term public acceptance, the facility and its regulators must move beyond presenting data and focus on making that data accessible, understandable, and verifiable for all stakeholders, thereby bridging the gap between institutional trust and informational confidence. The study concludes that because this trust is vulnerable, current communication strategies of simply publishing safety reports are insufficient. This conclusion is reinforced by Perko et al. (2020), whose research suggests that active stakeholder engagement and transparency are necessary to bridge this divide and transform passive institutional trust into active, informed confidence.

Conclusion

This study set out to provide an integrated evaluation of the environmental and public health performance of the Perak Repository by comparing its empirical safety record with stakeholder perceptions of its operations. The analysis of five years of environmental monitoring data unequivocally demonstrates that the facility operates in full compliance with national and international safety standards, with all radiological measurements remaining well below permissible limits. In parallel, the stakeholder survey revealed a high degree of institutional trust in the facility's operator and regulator, yet also exposed significant gaps in public knowledge and a notable scepticism regarding the accuracy of the very data that proves the facility's safety. This research has successfully achieved its three core objectives. It quantitatively assessed the facility's compliance with national standards, evaluated stakeholder awareness and perception of its performance, and most critically, evaluated the alignment between the empirical evidence and stakeholder perception. For worker safety, longitudinal studies are recommended to track worker health and evaluate the long-term efficacy of Occupational Safety and Health (OSH) training programs. Further research could also investigate emerging hazards associated with new technologies or changing environmental conditions around the site. From a policy perspective, a comparative study of Malaysia's regulatory framework against those of neighbouring countries and international best practices could identify strengths, weaknesses, and opportunities for policy enhancements, particularly regarding long-term storage and emergency preparedness.

This study makes several significant contributions to the field of radioactive waste management by providing a comprehensive evaluation of the Repository in Perak. Its primary contribution is moving beyond a purely technical assessment to offer an integrated analysis that quantitatively compares empirical evidence of environmental safety with stakeholder perception. This approach provides valuable data to support the development and refinement of radiation safety regulations for regulatory authorities and offers actionable insights for facility operators to identify potential areas for improving their RPP. By identifying specific gaps in public understanding and trust, the research allows for the development of more

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targeted and evidence-based communication strategies, which helps in assuring local communities of the facility's safety and mitigating their concerns. Ultimately, this work informs policymakers about the complexities of managing such a facility and serves as a replicable model for assessing and improving stakeholder relations at similar radioactive waste management facilities in Malaysia and internationally

In conclusion, the study finds that while the Perak Repository is technically safe, a significant socio-technical divide exists, where institutional trust currently outweighs informational confidence. The long-term sustainability of such a critical facility depends not only on maintaining its excellent safety record but also on bridging this perception gap. The findings underscore that for the successful long-term stewardship of radioactive waste, technical compliance must be complemented by a robust, transparent, and continuous dialogue that empowers stakeholders with accessible and verifiable information, thereby transforming passive trust into active, informed confidence.

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References

Adelodun, M. O., & Anyanwu, E. C. (2024). Integrating radiological technology in environmental health surveillance to enhance public safety. *International Journal of Applied Research in Social Sciences, 6*(9), 2191–2215.

Borbet, J., Veciana, J., Stiels, C., & Schmidt, R. (2023). *Reduction of NORM Waste in the Oil and Gas Industry with Indirect Heated Vacuum Distillation Technology*. Paper presented at the SPE/IADC Middle East Drilling Technology Conference and Exhibition, Abu Dhabi, UAE.

Chen, W., Ma, J., & Guo, X. (2020). Public perception of a nuclear power plant in China: The role of risk, benefit, trust, and public engagement. *Energy Policy, 136.*

Department of Atomic Energy. (2016). *Guidelines On Radiological Monitoring for Oil and Gas Facilities Operations Associated with Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM)* (Report No. LEM/TEK/30 Sem.3). Selangor, Malaysia: Author.

Frane, N., & Bitterman, A. (2021). *Radiation Safety and Protection*. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK557499/

Giacobbo, F., Da Ros, M., Macerata, E., & Mossini, E. (2021). A case study of management and disposal of TENORMs: radiological risk estimation by TSD Dose and RESRAD-ONSITE. *AIMS Environmental Science, 8*(5), 465–480.

Hietala, M., & Geysmans, R. (2020). Social sciences and radioactive waste management: acceptance, acceptability, and a persisting socio-technical divide. *Journal of Risk Research*, 1–16.

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DOI 10.35631/IJIREV.722024

International Atomic Energy Agency. (2009). *Classification of Radioactive Waste* (IAEA Safety Standards Series No. GSG-1). Vienna, Austria: Author.

International Atomic Energy Agency. (2014). *Near Surface Disposal Facilities For Radioactive Waste* (IAEA Safety Standards Series No. SSG-29). Vienna, Austria: Author.

International Atomic Energy Agency. (2018). *Prospective Radiological Environmental Impact Assessment for Facilities and Activities* (IAEA Safety Standards Series No. GSG-10). Vienna, Austria: Author.

Janković, M. M., Todorović, N., & Nikolić, D. (2024). Characterization and management of NORM waste from the oil and gas industry in Serbia. *Environmental Geochemistry and Health*, *46*(1), 23

Karam, P. A. (2021). Radiological Assessment and Public Health Response. In S. E. C. Sorenson & R. J. L. Penn (Eds.), *Public Health and Disasters: A Guide to Prevention, Preparedness, and Response* (pp. 221–231).

Kasperski, T. (2022). Trust, distrust and radioactive waste management in contemporary Russia. *Journal of Risk Research, 25*(5), 648–665.

Kuzmin, E. V., Minin, A., Bamborin, M. Yu., & Trofimova, Y. (2022). System of Engineering Safety Barriers of the Facilities for Near-Surface Disposal of Radioactive Waste. *Безопасность Трудa в Промышленности, 6*, 46–51.

Ledford, V., Ramírez, A. S., & Nan, X. (2024). Urgent Communication During Public Health Crises. In *The International Encyclopedia of Health Communication* (pp. 511–531).

Menteri Besar Incorporated, Perak. (2023, October). *Radiological Environmental Monitoring at Repository, Periodically Report, Fourth Monitoring of Year 2023*. Perak, Malaysia: Author.

Menteri Besar Incorporated, Perak. (2024, April). *Radiological Safety Analysis Report (2023) at Repository, Mukim Belanja, District of Kinta, Perak Darul Ridzuan*. Perak, Malaysia: Author.

Perko, T., Martell, M., & Turcanu, C. (2020). Transparency and stakeholder engagement in nuclear or radiological emergency management. *Radioprotection, 55.*

Puertas, F., Alonso, M. M., & García-Díaz, I. (2021). NORM waste valorisation by alkaline activation: A review. *Construction and Building Materials*, *273.*

Slovic, P. (1987). Perception of risk. *Science, 236*(4799), 280–285.

Zhao, C., Fan, D., Liu, Y., Jia, J., & Wang, Y. (2023). A review on the management of uranium mill tailings. *Journal of Environmental Radioactivity*, *263*,