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Integrated Water and Waste Management: A Systematic Literature Review on the Role of Human Resources and Sustainable Practices

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Abstract

The growing pressure on water resources from urbanization, industrialization, and climate change demands an integrated and sustainable approach to water and waste management. This study explores the relationship between human dimensions, technology, and institutional governance in improving the effectiveness of sustainable water and waste management systems. The research addresses the limited studies that combine Green Human Resource Management (GHRM) practices, smart technology adoption, and adaptive institutional models such as Integrated Water Resources Management (IWRM) within one conceptual framework. This study develops an integrated conceptual model that explains the triadic relationship between green human resources as an enabler, digital technology as a driver, and collaborative governance as a bridge to effective water and waste systems. A Systematic Literature Review (SLR) guided by PRISMA 2020 was conducted using thematic synthesis and bibliometric analysis to identify trends, dominant theories, and relationships among key variables. The findings show that effective water and waste management depends not only on technological innovations such as AI, IoT, smart sensors, big data, and Life Cycle Assessment (LCA), but also on human readiness and institutional capacity. GHRM practices green recruitment, environmental training, and sustainability-based performance appraisals enhance technological adoption and promote an eco-conscious culture. Moreover, the expansion of IWRM into "IWRM extended to waste" emphasizes cross-sector collaboration and community engagement. Sustainable water and waste management can thus be achieved through synergy among humans, technology, and governance within an adaptive socio-technical system.

Keywords: *Integrated Water Resources Management; Green Human Resource Management; Environmental sustainability.*

I. INTRODUCTION

Water management and wastewater treatment have become one of the greatest challenges in the context of sustainable development, both globally and locally. The growing pressures stem from population growth, industrialization, urbanization, and climate change, all of which significantly affect the availability and quality of water resources. Numerous studies have shown that the increasing demand for clean water is not proportional to the available water supply capacity, while pollution from domestic and industrial waste continues to rise over time. Global studies on the implementation of *Integrated Water Resources Management* (IWRM) have demonstrated that integrated water management contributes significantly to the achievement of sustainability indicators, including improved access to basic sanitation, greater water-use efficiency, and the preservation of freshwater ecosystems (Koop et al., 2022). However, the effectiveness of IWRM implementation in many countries, particularly in developing regions, remains constrained by weak institutional coordination, limited technical capacity, and low public awareness of the importance of environmentally friendly behavior. On the other hand, waste management both domestic and industrial continues to be a major source of environmental degradation, especially in densely populated urban areas (Dinsa & Nurhusein, 2023).

Partial and fragmented waste management leads to inefficiencies in treatment processes and causes extensive ecological impacts. This condition indicates that the challenges of water and wastewater management cannot be separated, as both are systemically interconnected and require an integrated approach (Boldrin et al., 2022). Thus, integrated management that combines aspects of water resources and wastewater is not merely a technical necessity but a strategic agenda for achieving environmental sustainability. Within this framework, human factors including human resource competence, institutional governance, and organizational sustainability practices—play an

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increasingly important role in ensuring the successful implementation of such integrated management (Pahl-Wostl et al., 2020).

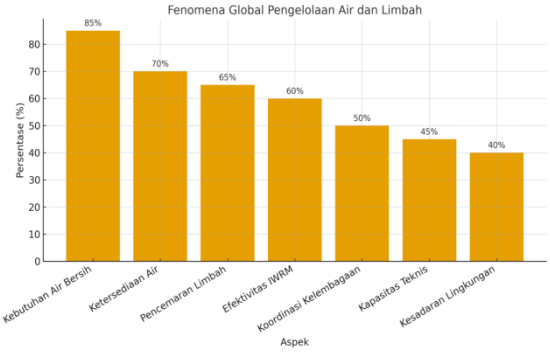

Figure 1. Diagram of Water and Wastewater Management Phenomena

A number of literature studies have attempted to examine the dynamics of water and wastewater management in the era of sustainability. The water industry must move away from the business-as-usual paradigm and transform toward strategies that adopt the principles of the circular economy, digitalization, and Industry 4.0 technologies in order to achieve long-term efficiency and sustainability (Morseletto et al., 2022). In the field of human resource management, the *Green Human Resource Management* (GHRM) approach has begun to attract attention, as it has been proven to enhance an organization's environmental performance through practices such as green recruitment, environmental training, and employee engagement for sustainability (Sharma et al., 2022). These studies illustrate progress in understanding the role of technology and human resources in promoting sustainability. However, research that integrates the three main elements water management, wastewater management, and human resources within the context of organizational sustainability remains relatively limited. The majority of existing studies are still sectoral in nature, focusing primarily on the technical aspects of water or wastewater management without simultaneously addressing human factors and organizational practices.

From this review, several research gaps emerge that need to be addressed. First, most studies emphasize technological innovation or water and wastewater management systems but have not thoroughly examined the role of human resources in shaping behavior, organizational culture, and adaptability toward integrated management practices. Second, the relationship between organizational sustainability practices such as green governance, environmental culture, and stakeholder participation and the effectiveness of water and wastewater management remains underexplored empirically. Third, systematic review literature that simultaneously investigates the integration of "water and wastewater management," "the role of human resources," and "organizational sustainability practices" is still scarce. Therefore, this study occupies a unique position in the literature by attempting to bridge these gaps through a systematic review that unites the three dimensions within a single integrated conceptual framework.

Gambar 2. Conseptual Framework

To address these gaps, this research is built upon a solid and interconnected theoretical foundation. The study draws upon *Human Resource Management Theory* and *Organizational Learning Theory*, which emphasize the importance of developing human capabilities to manage change and embed sustainability values within organizations. In the context of water and wastewater management, human resources are no longer positioned merely as technical operators but as change agents who shape an environmentally oriented organizational culture. Green human resource management practices—such as environmental training and sustainability-based performance management—have a significant impact on the effectiveness of sustainability programs and the implementation of environmentally friendly technologies (Kuo et al., 2022).

Furthermore, this study adopts the Technology Acceptance Model (TAM) and Information Systems Success Model approaches, which explain the relationship between human resource readiness,

technology acceptance, and system success within an organization. This theory is relevant in the context of modern water and waste management innovations based on digital technology, such as smart water monitoring, sensor-based wastewater management, and integrated data platforms. The successful adoption of these technologies is greatly influenced by the readiness of human resources to understand, accept, and operate these technology-based systems effectively (Bediako et al., 2018).

This study then utilizes the Integrated Water Resources Management (IWRM) framework as its primary operational model. IWRM emphasizes the importance of coordination between water, land, and related resources to achieve a balance between economic development, ecological sustainability, and social equity. Successful IWRM implementation depends on cross-sector collaboration, adaptive governance, and community participation, all of which are inseparable from human and organizational factors (Islam et al., 2023).

By combining these three theoretical layers, this research seeks to build an integrated conceptual framework that links the human dimension (human resources and organizational behavior), the technological dimension (system adoption and success), and the environmental dimension (sustainable water and waste management). This integrative approach not only strengthens the theoretical foundation of the research but also provides practical guidance for local governments, the water industry, and waste management institutions to optimize human potential and sustainable practices in achieving efficient and effective integrated environmental resource management.

II. RESEARCH METHODOLOGY

This study employed a Systematic Literature Review (SLR) approach, developed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines and methodological guidelines (Kitchenham & Charters, 2007). This approach was chosen to obtain a comprehensive overview of the relationship between integrated water and waste management, the role of human resources (HR), and organizational sustainability practices. A literature search was conducted in the Scopus, Web of Science, and ScienceDirect databases using a combination of keywords such as "integrated water resources management," "wastewater management," "human resource management," and "sustainability practices." The selection process included three stages of screening: title, abstract, and full content, with the inclusion criteria being Scopus-indexed journal articles that address managerial, HR, and sustainability dimensions in the context of water or waste management. The screening results yielded 19 relevant articles from the 2018–2024 period for further analysis.

The analysis was conducted using a thematic synthesis approach and bibliometric analysis to identify trends, dominant theories, and the relationship between human resources, technology, and sustainability practices. The results of this SLR serve as the basis for developing a conceptual model explaining the contribution of human resources and sustainability practices to the effectiveness of integrated water and waste management.

III. RESULTS AND DISCUSSION

1. Overview of Systematic Review Results

The review shows that research on water and waste management has undergone a significant evolution from a technical focus to a socio-technical approach that places human and institutional aspects as central factors in achieving sustainability. Thematic and bibliometric analyses indicate three dominant clusters in the current literature. First, there is the growing interest in technological innovations such as smart water systems, sensors, digital twins, and artificial intelligence (AI) to improve the efficiency and effectiveness of water and waste management. Second, there is the development of Green Human Resource Management (GHRM) practices that focus on the role of human resources in encouraging pro-environmental behavior, green innovation, and sustainability performance. Third, there is the emergence of discussions on cross-sectoral governance that emphasize the importance of institutional integration and public participation in water resource management. These three themes demonstrate that the effectiveness of modern water and waste management systems cannot rely solely on technical innovation but must also be supported by adaptive human and institutional capacity.

Based on the literature selection process using the PRISMA 2020 guidelines, 19 articles met the inclusion criteria for further analysis. A summary of each article, including its research focus, methods, and key findings, is presented in Table 1 below.

Table 1. Literature Review

No	Title	Results	Key Word
1	Implementation and Integration of Sustainability in the Water Industry (MDPI Sustainability) (Jorge Alejandro Silva, 2024)	The integration of the circular economy (6R model) and Industry 4.0 technologies (AI, IoT, big data) improves the sustainability of the water sector by reducing waste and increasing efficiency and decentralization.	ircular economy; 6R; Industry 4.0; AI; IoT
2	Bibliometric on wastewater management (Durán-Sánchez et al., 2020)	Bibliometric analysis shows the growth of waste management research, but there are gaps in applied studies and policy-technology relationships.	bibliometrics; wastewater; research trends; research gaps
3	Green HRM & sustainability (Faisal, 2023)	Green HRM practices support an organization's environmental performance through training, policies, and leadership, but effectiveness depends on the organizational context.	Green HRM; environmental performance; training; policy
4	Systematic review Green HRM (Francis, 2024)	Consistent evidence that GHRM encourages corporate green practices, but study methods and contexts vary widely, requiring research in developing countries..	GHRM; systematic review; implementation; methodological variation
5	Smart technologies for water management (Sensors, 2022)	Sensors, IoT, and data platforms enhance real-time monitoring and adaptive decision-making for water resource management.	sensor; IoT; data analytics; monitoring real-time
6	AI in wastewater treatment (review) (Alprol et al., 2024)	AI improves process control, energy efficiency, and disruption prediction, but requires quality data and operational integration.	AI; wastewater; predictive maintenance; data quality
7	Performance evaluation of treatment plants (case study) (Aib et al., 2024)	Treatment plant performance varies between units; physicochemical and microbiological parameters are important for assessing operational effectiveness and optimization	performance evaluation; WWTP; operational parameters
8	Wastewater management in Africa (Omohwovo, 2024)	Tantangan infrastruktur, pembiayaan, dan regulasi utama; rekomendasi: peningkatan kebijakan, investasi, dan solusi kontekstual.	Key infrastructure, financing, and regulatory challenges; recommendations: improved policies, investments, and contextual solutions.
9	eScholarship (case: Zayandehroud basin) — allocation study (Zehtabian et al., 2023)	Integrated Water Resource Management (IWRM) is necessary for equitable and sustainable allocation at the watershed level; stakeholder coordination is crucial.	IWRM; water allocation; basin management; governance
10	Small wastewater treatment plants performance (Frontiers, 2022)	Small-scale facilities often have operational limitations and output variability; they require appropriate simpler technology and increased capacity.	small WWTP; capacity; maintenance; appropriate technology

No	Title	Results	Key Word
11	Urban water reuse & sustainability (Trianni et al., 2021)	Reuse and recovery of urban resources is key to a sustainable urban future; policy-technology integration is necessary.	water reuse; urban sustainability; resource recovery
12	(coastal/estuary management) (Michels-Brito et al., 2023)	Pendekatan sumber-ke-laut dan IWRM saling melengkapi; harmonisasi kebijakan lintas-skala meningkatkan efektivitas manajemen pesisir.	source-to-sea; IWRM; coastal management
13	Circular economy in industry (Zehtabian et al., 2023)	A circular economy approach to industrial waste management increases material/energy recovery and reduces environmental burden when applied within an industrial context.	circular economy; industrial wastewater; resource recovery
14	Assessing level of water resources management based on water supply and availability concepts (Naderi, 2021)	Life cycle analysis shows certain technologies reduce environmental impacts, but trade-offs (energy, cost) must be analyzed on a case-by-case basis.	LCA; trade-offs; green technology
15	Water Supply and Wastewater Treatment and Reuse in Future Cities: A Systematic Literature Review (Jorge A Silva, 2023)	Proactive policies, economic incentives, and technological innovation are needed to accelerate the adoption of wide-scale reuse..	policy; incentives; water reuse; innovation
16	Industrial wastewater treatment: Current trends, bottlenecks, and best practices (Dutta et al., 2021)	Specific recovery technologies (e.g., P/N recovery, energy) can increase the economic value of waste processing if integrated into the supply chain.	resource recovery; phosphorus; energy recovery
17	The role of green human resource management in the translation of greening pressures into environmental protection practices (Vázquez-Brust et al., 2023)	Integration of sustainable business practices (management, investment) improves environmental performance and water service reliability.	business sustainability; governance; investment
18	Green Human Resource Management in Practice: Assessing the Impact of Readiness and Corporate Social Responsibility on Organizational Change (Zihan et al., 2024)	Social and technological integration (community engagement + digital tools) increases the opportunity to implement sustainable solutions..	socio-technical; community engagement; digital tools
19	Green human resource management and sustainable performance with the mediating role of green innovation: a perspective of new technological era (Awwad Al-Shammari et al., 2022)	An integrated approach from upstream to sea improves ecological and social outcomes, encouraging cross-sectoral management.	integrated approaches; source-to-sea; cross-sectoral management

Table 1 shows that research on water and waste management has shown a significant upward trend since 2020, in line with increased attention to sustainability issues and smart technologies. Most studies adopt a technical approach with a focus on operational

efficiency, but only a small proportion examines human resources and organizational governance.

Figure 3. Future Water Management Cycle

Overall, these articles demonstrate that sustainable water and environmental management can only be achieved through the integration of a circular economy, smart technology, and inclusive governance (Faisal, 2023), (Francis, 2024). Most studies emphasize the importance of implementing the principles of reduce, reuse, recycle, recover, and restore in industrial water and wastewater treatment to reduce emissions and maximize resource reuse. Technological support such as artificial intelligence (AI), the Internet of Things (IoT), smart sensors, big data, and life cycle analysis (LCA) strengthens operational efficiency through real-time monitoring, disruption prediction, and energy optimization (Jorge Alejandro Silva, 2024), (Sensors, 2022), (Alprol et al., 2024), (Naderi, 2021), (Zihan et al., 2024). On the policy side, the integration of Integrated Water Resource Management (IWRM) and the source-to-sea approach encourages cross-sectoral coordination and equitable distribution of water resources. Several studies also highlight the social and institutional dimensions, where community participation, green management practices, and policy innovation are key drivers in the implementation of sustainable water systems. In summary, these findings converge to the overarching conclusion that future water management needs to be circular, digital, collaborative, and adaptive to local contexts and the global challenges of climate change.

2. Integration of Water and Waste Management from a Sustainability Perspective

The integration of clean water and wastewater treatment systems has become a key issue in sustainability literature. Studies show that the application of intelligent sensor-based and digital technologies, such as smart water monitoring, real-time wastewater control, and digital twin modeling, can improve operational efficiency, optimize energy use, and minimize water loss (Jorge Alejandro Silva, 2024), (Alprol et al., 2024), . This technology also plays a role in supporting a circular economy approach through reuse and resource recovery systems from waste.

However, most research confirms that the success of implementing this technology is largely determined by organizational readiness and the ability of human resources to adapt to the innovation. Many innovation projects fail to achieve long-term sustainability goals due to lack of training, resistance to change, and weak inter-agency coordination. Therefore, technical success must be understood as the result of a socio-technical system that combines technological innovation with human readiness and effective governance. The principles of Integrated Water Resources Management (IWRM) remain relevant, but need to be expanded into the concept of "IWRM extended to waste," which incorporates the social and institutional dimensions of water and wastewater integration..

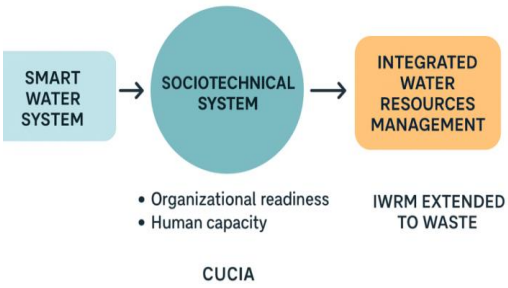

Figure 4. ***Integrated Water Resources Management***

3. The Role of Human Resources and GHRM Practices in Management Effectiveness

The study's findings demonstrate that human resources play a key role in determining the success of sustainable water and waste management systems. Recent literature highlights the importance of Green Human Resource Management (GHRM) practices in shaping organizational behaviors, values, and culture that support sustainability. GHRM comprises a set of practices that include green recruitment, environmental training, green performance appraisals, and employee engagement for sustainability. (Vázquez-Brust et al., 2023), (Faisal, 2023), (Zihan et al., 2024).

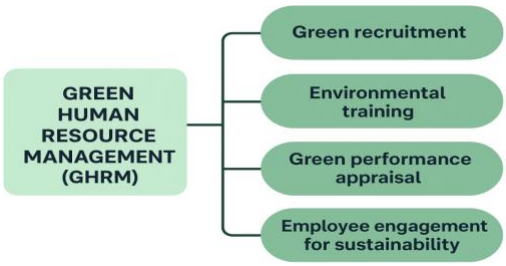

Figure 5. GHRM Practices in Management Effectiveness

Through green recruitment, organizations strive to attract individuals with strong environmental values and commitment, thus establishing a human resource foundation aligned with their sustainability vision. Environmental training plays a role in equipping employees with the technical skills and environmental awareness needed to operate green technologies. Green performance appraisals reinforce sustainability orientation by incorporating environmental indicators into performance evaluation systems, while employee engagement for sustainability encourages active employee involvement in energy conservation, waste reduction, and green innovation programs.

Although numerous studies demonstrate the effectiveness of GHRM on organizational performance and pro-environmental behavior, empirical evidence specifically examining its implementation in the water and wastewater utilities sector remains limited. Most GHRM research focuses on the manufacturing sector, yet the public utilities context presents its own complexities, such as strict regulations, long-term operations, and high reliance on technology. This situation highlights the need to develop a GHRM model relevant to the characteristics of water and wastewater management institutions, one that systematically integrates technical training, employee participation, and green performance indicators.

4. Dynamics of Governance and Institutions in Integrated Management

In addition to technology and human resources, institutional governance is a crucial dimension in ensuring the success of sustainable water and waste management. Studies show that weak inter-agency coordination, overlapping authority, and a lack of collaboration mechanisms are key barriers to policy effectiveness (Michels-Brito et al., 2023), (Zehtabian et al., 2023). Water and waste management systems in many countries remain fragmented between water, sanitation, and environmental authorities, leading to resource inefficiencies and lack of synergy in policies.

Conversely, the implementation of adaptive governance with collaborative mechanisms and public participation has been proven to increase transparency and accountability. The multi-stakeholder governance model enables cross-sector coordination between government, industry, academia, and communities in integrated water resource management. Therefore, the success of IWRM implementation depends not only on the availability of technology but also on institutional capacity to coordinate the involved actors, manage conflicts of interest, and encourage collective learning.

5. Triadic Relationship between HR, Technology, and Governance

The conceptual synthesis of the twenty articles analyzed demonstrates a mutually reinforcing triadic relationship between human resources, technology, and institutional governance. Human resources serve as an enabler, determining readiness and acceptance of new technologies, while technology serves as a driver, driving operational efficiency and improving environmental performance. Meanwhile, institutional governance acts as a governance bridge, ensuring sustainability and cross-sector integration.

Figure 6. Triadic Relationship between HR, Technology, and Governance

These three elements interact dynamically through an organizational learning loop. This process begins with training that enhances employee competency and environmental awareness, which then facilitates the adoption of new technologies. Technology implementation results in increased efficiency and data-driven management, which in turn strengthens institutional capacity for evidence-based decision-making. This cycle creates a culture of innovation and continuous improvement. This relationship is consistent with the Technology Acceptance Model (TAM) and Organizational Learning Theory, which assert that the success of modern organizations is determined by the synergy between people, technology, and institutions

6. Research Gaps and Development Directions

Although numerous studies have revealed the enormous potential of technology and GHRM in supporting sustainability, several gaps remain to be filled. First, there is a lack of empirical research directly measuring the impact of GHRM practices on operational performance of water and wastewater management, such as effluent quality, energy efficiency, or reduced downtime. Second, few studies have developed integrative models that simultaneously link human resources, technology, and governance factors within an IWRM framework extended to waste. Third, there is limited longitudinal research assessing the long-term impact of a combination of technology-based interventions, training, and GHRM policies on system sustainability.

This gap highlights the need for a multidisciplinary research approach, with an empirical design capable of testing the causal relationships between these three key dimensions. This approach will provide a more comprehensive understanding of how the interaction between people, technology, and institutions influences the effectiveness of sustainable water and waste management.

Based on the synthesis of 19 systematically reviewed scientific articles, this study proposes an integrated conceptual model that links the dimensions of human resources (HR), technology, and institutional governance in the context of sustainable water and waste management. This model is built on the integration of empirical and theoretical findings from the literature on Green Human Resource Management (GHRM), the Technology Acceptance Model (TAM), and Integrated Water Resources Management (IWRM).

The primary objective of developing this model is to illustrate the causal mechanisms between human, technological, and institutional factors that simultaneously influence the operational effectiveness and sustainability performance of water and wastewater management organizations. This conceptual model also serves as a foundational framework for future empirical research to examine the interrelationships between variables in the context of public service organizations and environmental infrastructure.

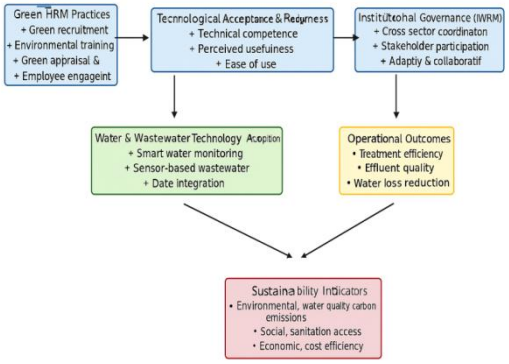

Figure 7. Conceptual Model of Integrated Water and Waste Management Based on Human Resources, Technology, and Governance

As shown in Figure 1, this conceptual model emphasizes that green human resource management (GHRM) practices act as a key enabling factor in building human resource readiness and technology acceptance. GHRM practices encompass activities such as green recruitment, environmental training, green performance appraisals, and employee engagement for sustainability. Implementation of these practices contributes to increased environmental awareness, the development of technical competencies, and strengthened employee commitment to green innovation.

Human resource readiness and technology acceptance, as described in the Technology Acceptance Model (TAM), encompass technical competency, perceived usefulness, and ease of use, which directly determine the extent to which individuals within an organization are able to adopt and operate new technologies. In the context of water and waste management, this readiness is a crucial prerequisite for the successful implementation of technologies such as smart water

monitoring systems, sensor-based wastewater management, and data integration platforms.

Furthermore, governance and institutions based on Integrated Water Resources Management (IWRM) act as moderating and mediating factors, strengthening or weakening the relationship between technological readiness and operational outcomes. Adaptive, participatory, and collaborative governance ensures cross-sectoral coordination between water, sanitation, environmental, and industrial management institutions. This inclusive institutional mechanism enables integrated policy and technology implementation, prevents duplication of authority, and strengthens public accountability.

The combination of these three key dimensions results in the effective adoption and operation of water and wastewater technologies. The implementation of intelligent water monitoring systems, sensor-based data integration, and treatment process optimization enable increased energy efficiency, reduced water leakage, and improved effluent quality. These operational outcomes then directly contribute to sustainability indicators, which encompass three key dimensions:

1. Environmental, through improved water quality, reduced carbon emissions, and resource efficiency;
2. Social, through increased access to sanitation and inclusive public services; and
3. Economic, through operational cost efficiencies and increased system productivity.

Thus, this conceptual model demonstrates a multidimensional and interdependent causal pathway, with institutional governance (IWRM) acting as a moderator that strengthens the relationship between technology adoption and operational outcomes. Theoretically, this model expands the Integrated Water Resources Management paradigm by incorporating human and organizational dimensions as integral components of water and wastewater management systems. This approach bridges the gap between technical research and human resource management research, resulting in a new framework that is socio-technical and governance-integrative.

In practice, this model can serve as a reference for water and wastewater management institutions, both public and private, in designing green human resource strategies, strengthening technology adoption capacity, and developing collaborative cross-sector governance mechanisms. Implementing this model is expected to improve operational efficiency while strengthening the achievement of long-term sustainability goals.

6. Policy and Practical Implications

Practically, the results of this study provide a basis for formulating policies and managerial strategies in the water and wastewater sector. First, strengthening human resource capacity is a top priority through the integration of GHRM practices into organizational performance management systems. Recruitment, training, and performance assessment processes need to incorporate environmental indicators to foster a sustainability-oriented organizational culture. The government can support this through national training programs and incentives for institutions that successfully implement green innovations.

Second, the integration of smart technology needs to be accompanied by a program to increase operator capacity and provide green financing for investments in energy efficiency and wastewater recycling technologies. Standardizing data interoperability between institutions is key to creating an interconnected management system.

Third, cross-sectoral governance and regulatory reforms are needed to unify water and wastewater management authorities within a single integrated coordination framework based on IWRM. The establishment of a multi-stakeholder collaboration forum can provide a platform for cross-sector policy synergy and innovation.

Fourth, strengthening research and organizational learning needs to be done through longitudinal studies, organizational learning mechanisms, and the development of a national database that integrates the results of water, waste, and human resource research to support evidence-based policies.

7. Theoretical and Academic Contributions

From an academic perspective, this research provides a conceptual contribution by integrating three key disciplines—green human resource management, environmental technology systems, and adaptive governance—into a single theoretical framework for sustainable water resource management. This integration yields a new conceptual model that explains the causal pathways between GHRM practices, technological readiness, and governance in improving operational performance and sustainability indicators.

In practice, this model serves as a guide for public institutions and the water and wastewater industry in designing strategies that integrate human, technological, and institutional aspects.

This approach is believed to improve resource efficiency, strengthen institutional resilience, and accelerate the achievement of the Sustainable Development Goals (SDGs), particularly in the areas of clean water, sanitation, and climate change.

IV. CONCLUSION

This systematic review confirms that integrated water and waste management is a strategic agenda for achieving environmental, social, and economic sustainability. The effectiveness of such a management system is determined not only by technological advances or technical approaches, but also by the readiness of human resources (HR) and adaptive institutional governance. The results of a synthesis of twenty scientific articles demonstrate a triadic and mutually reinforcing relationship between HR, technology, and governance. HR acts as an enabler, determining the acceptance and utilization of new technologies; technology acts as a driver for improving efficiency and environmental performance; and institutional governance serves as a governance bridge, ensuring cross-sector integration and system sustainability. Green Human Resource Management (GHRM) practices have proven to be a crucial element in building an environmentally oriented organizational culture. Through green recruitment, environmental training, continuous performance assessment, and employee engagement in green innovation, organizations can improve technological readiness and operational effectiveness of water and waste management. Furthermore, an Integrated Water Resources Management (IWRM) approach extended to waste management provides an institutional framework that is holistic, collaborative, and adaptive to social and ecological changes. From a theoretical perspective, this research broadens the scope of the IWRM paradigm by incorporating dimensions of organizational behavior and green human resource management practices. Practically, the results of this study provide guidance for governments, water management institutions, and industry to develop policies that balance technological innovation with strengthening human and institutional capacity. Therefore, successful sustainable water and waste management can only be achieved through the synergy of people, technology, and governance within an integrative framework that is circular, collaborative, and adaptive to the challenges of climate change and the needs of modern society.

V. RECOMMENDATIONS

Based on the findings of the study, it is recommended that governments, water management institutions, and industries develop integrative policies that balance technological innovation with the strengthening of human resource capacity and institutional governance. The implementation of Green Human Resource Management (GHRM) practices—such as green recruitment, environmental training, and employee engagement in green innovation—should be expanded to enhance technological readiness and operational effectiveness. Furthermore, the Integrated Water Resources Management (IWRM) approach should be adapted into a collaborative and adaptive institutional framework to respond to socio-ecological changes and ensure the overall sustainability of water and waste management systems.

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