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Cross-Sectoral Strategies for Freshwater and Sanitation in Supporting Sustainable Environmental Resilience

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Abstract: This study explores the strategic role of freshwater and sanitation management in supporting sustainable environmental resilience in Indonesia. Employing a qualitative systematic review method, the research analyzes interdisciplinary literature, policy documents, and case studies to identify structural challenges and effective responses. Key findings reveal persistent issues including water pollution, unequal distribution, poor sanitation access, and fragmented governance. The study highlights the success of community-based initiatives like SANIMAS and proposes the integration of low-cost technologies such as anaerobic waste treatment and household filtration systems. The novelty of this research lies in its cross-sectoral approach that bridges environmental policy, public health, and social participation. It argues for holistic governance reforms, enhanced stakeholder collaboration, and policy harmonization to ensure efficient freshwater and sanitation management. The study contributes strategic recommendations tailored to Indonesia's context, emphasizing the synergy of government, private sector, and community actors. It also underscores the relevance of water-energy-food nexus thinking in national planning. Ultimately, this research supports Indonesia's progress toward achieving SDG 6 (clean water and sanitation) and SDG 13 (climate action), reinforcing freshwater and sanitation as critical pillars for long-term resilience, public well-being, and sustainable development.

Keywords: Cross-Sectoral Strategies, Freshwater and Sanitation, Sustainable Environmental Resilience

A. Introduction

The issue of freshwater and sanitation management is a central element in the context of global and national environmental resilience. Inadequate freshwater management and poor access to sanitation are major challenges faced by various countries, especially developing countries such as Indonesia. According to the latest report from WHO & UNICEF Joint Monitoring Programme (2021) approximately two billion people

worldwide do not have access to safe drinking water, and more than 4 billion people do not receive safe and adequate sanitation services. This condition illustrates the complex and serious nature of water and sanitation problems that have implications for the decline in environmental quality, public health, and overall ecosystem resilience (WHO & UNICEF Joint Monitoring Programme, 2021; UNICEF, 2023).

Freshwater is one of the most vital natural resources for the sustainability of human life and natural ecosystems. Unfortunately, pressure on water resources continues to increase due to population growth, urbanization, industrial activities, intensive agriculture, and extreme climate change (Hanasaki et al., 2013). This phenomenon shows that freshwater management can no longer be carried out partially or sectorally, but must involve a holistic approach that integrates environmental, social, economic, and policy aspects harmoniously (Kumar, 2021). As the largest archipelagic country in the world, Indonesia has its own challenges in managing freshwater resources that are unevenly distributed. The availability of abundant freshwater in some areas is not proportional to other areas that face chronic water shortages, such as in East Nusa Tenggara, the northern part of Central Java, and urban coastal areas experiencing seawater intrusion (Paladan et al., 2025). This condition is exacerbated by high levels of water pollution due to domestic, industrial, and agricultural waste. A study conducted in several major cities in Indonesia showed that water body pollution has reached an alarming level, with heavy metal and microplastic content exceeding the limits set by the government (Lestari et al., 2025). This pollution has a direct impact on the quality of water that can be used by the community and the sustainability of aquatic ecosystems. Poor sanitation also contributes significantly to the decline in environmental quality and public health (Elysia & Wihadanto, 2020; Amanabo-Arome & Abbas, 2021). In Indonesia, many communities still do not have access to adequate sanitation facilities, especially in rural areas and informal urban settlements. According to data from the Central Bureau of Statistics (Central Bureau of Statistics, 2022), around 27% of Indonesian society still uses inadequate sanitation facilities, including the practice of open defecation. This practice increases the risk of environmental pollution and the spread of infectious diseases such as diarrhea, cholera, and other water-based diseases that can reduce community productivity (Satriani et al., 2022).

In a global context, freshwater and sanitation management has become a major focus in the Sustainable Development Goals (SDGs), especially SDG 6, which is to ensure access to clean water and sanitation for all by 2030. This SDG affirms the importance of collaboration between sectors in achieving sustainable water and sanitation management. Indonesia, as part of the global community, is committed to achieving this target through various national programs and policies such as the Community-Based Sanitation Program (SANIMAS) and the National Strategy for Community-Based Total Sanitation (STBM), which aims to increase public access to adequate sanitation facilities

and clean water (Ministry of Health Indonesia, 2021). However, the implementation of these programs still faces various obstacles, such as minimal community involvement, lack of coordination between agencies, and limited funding (Vitriyana & Budiono, 2018; Purba & Nur, 2022). Therefore, a more integrative approach is needed by involving various stakeholders including government, the private sector, academics, and local communities in the planning, implementation, and evaluation of freshwater and sanitation management programs (Waite et al., 2015).

Conceptually, environmental resilience is defined as the capacity of an ecosystem and a community to face various environmental pressures, whether caused by human activities or natural changes, as well as the ability to recover and maintain its vital functions (Folke et al., 2016). In this case, freshwater and sanitation management directly becomes a determining factor in environmental resilience, because the quality of the environment depends greatly on the availability of clean water and adequate sanitation. Good freshwater and sanitation management also plays a crucial role in mitigating the impacts of climate change. The availability of adequate sanitation infrastructure can help reduce environmental pollution, while effective freshwater management can reduce the risk of floods and droughts, as well as maintain the balance of freshwater ecosystems (Johannessen et al., 2014; Pedro et al., 2020).

The novelty of this article is to identify effective strategies in freshwater and sanitation management that can support sustainable environmental resilience. By exploring various innovative approaches and policies that have been successfully implemented in various countries, this research is expected to provide strategic recommendations that are applicable for Indonesia in facing the challenges of freshwater and sanitation management in an integrated manner. The main focus of this study is to detail the roles of stakeholders in the management of water resources and sanitation systems, as well as to evaluate the effectiveness of existing strategies in strengthening environmental resilience comprehensively. Through an in-depth study of existing conditions and challenges, this article will also provide recommendations for the government, business actors, and civil society regarding the importance of integrating freshwater and sanitation management as a main foundation in achieving sustainable environmental resilience, while also supporting the achievement of SDGs in Indonesia.

B. Methods

This research uses a qualitative approach with descriptive-analytical methods to identify and evaluate effective freshwater and sanitation management strategies in supporting sustainable environmental resilience in Indonesia. This method was chosen because it is able to describe in detail the phenomena related to the actual conditions of freshwater management and sanitation systems and allows for in-depth analysis of cross-sectoral

policies and relevant practices. The data collection technique used in this research is literature study, which includes the collection and analysis of various literature sources such as scientific journals, government reports, policy documents, and publications from international organizations related to freshwater and sanitation management. The main references are taken from publications indexed by Scopus and nationally accredited journals (Sinta) to ensure data validity and relevance. In addition, this research conducts a comparative analysis of international and national case studies that are considered successful in the implementation of freshwater and sanitation management. The data analysis technique in this research uses descriptive-qualitative analysis. Data obtained from literature studies and case study comparisons are then processed and analyzed to identify effective strategies and evaluate their impact on environmental resilience. This analysis process involves in-depth interpretation of relevant findings, so that it is able to provide a comprehensive understanding of current conditions while producing strategic recommendations for policy makers in Indonesia. Thus, this research is expected to produce valid, in-depth, and applicative information for improving sustainable freshwater and sanitation management.

Despite the comprehensive scope of the literature and policy review, this study is limited by the absence of primary field data, such as interviews or direct stakeholder observations. Additionally, contextual generalization may be constrained, as local variations in governance, infrastructure, and community participation can significantly influence outcomes. The study also relies on available secondary sources, which may not reflect the most current or localized policy shifts. These limitations suggest that future research could benefit from mixed-method approaches to validate and expand the findings.

C. Results and Discussion

Current Condition of Freshwater Management

Indonesia is a country rich in freshwater resources, supported by its geographical condition as an archipelagic country with abundant rainfall, as depicted in Figure 1 below. According to statistical report by (World Bank, 2023), the average annual rainfall in Indonesia reaches around 2,000 to 3,000 mm per year. However, behind this potential, the challenges of freshwater management faced by Indonesia are very significant and complex. These challenges are mainly related to the issue of pollution, uneven distribution, and the impacts of increasingly intense climate change.

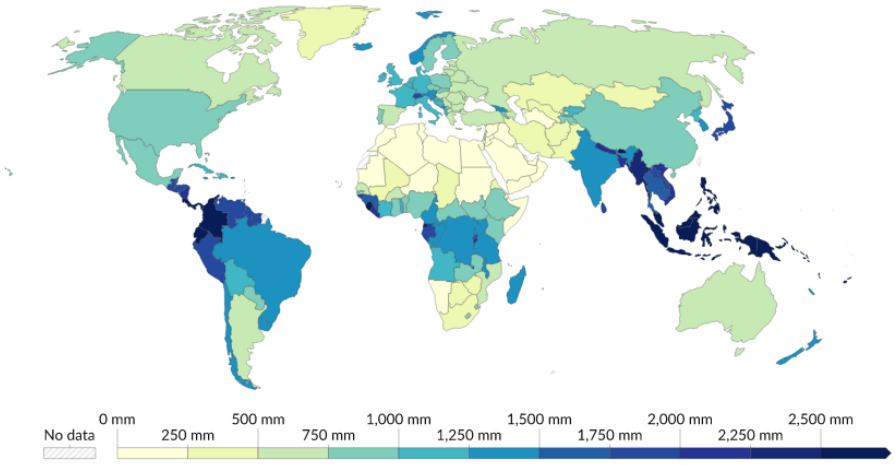

Figure 1. Indonesia, Among Countries with the Highest Rainfall (Source: Ritchie, Roser & Samborska, 2024)

One of the main challenges is water pollution originating from various sources, including domestic, industrial, and agricultural waste. Domestic waste that is not properly managed is the main cause of pollution of water resources, especially in urban areas. Domestic waste containing high organic matter and pathogenic microorganisms, such as Escherichia coli bacteria, causes significant degradation of river and groundwater quality (Sururi et al., 2023). Research conducted in several large rivers in Indonesia, such as the Citarum River and Brantas River, revealed that river water quality has decreased sharply due to pollution from domestic waste that is not managed effectively (Garg et al., 2018). Meanwhile, pollution from industrial waste is also a major threat to freshwater quality in Indonesia. Industrial waste, especially from manufacturing sectors such as textiles, chemicals, and metals, often contains toxic compounds such as heavy metals, phenols, and polycyclic aromatic hydrocarbons (PAH). Research by Juwana et al. (2022) shows that heavy metal content such as lead (Pb), cadmium (Cd), and mercury (Hg) is found at high concentrations in several industrial areas, especially around river areas in West Java and East Java. This heavy metal content not only endangers aquatic life, but also has long-term impacts on human health, including neurological disorders and cancer (Ahmad et al., 2021).

The agricultural sector also contributes to water pollution through the excessive use of pesticides and chemical fertilizers. The use of large quantities of agricultural chemicals without proper management results in the phenomenon of eutrophication in water bodies, especially in lakes and reservoirs. Hadipuro (2022) notes that eutrophication causes an exponential increase in algae growth, which ultimately reduces the levels of dissolved oxygen in the water. As a result, this condition threatens the life of aquatic organisms and reduces the quality of water used by the community for daily consumption. In addition to the problem of pollution, the impacts of climate change are

also increasingly affecting the freshwater cycle in Indonesia. This phenomenon is marked by increasingly erratic rainfall patterns, an increase in the intensity of extreme weather events such as prolonged droughts and flash floods (Ward et al., 2011). According to research by Biswas & Tortajada (2019) these extreme rainfall pattern changes have a direct impact on the availability of freshwater, especially in drought-prone areas such as East Nusa Tenggara. Prolonged droughts cause a decrease in agricultural productivity, scarcity of clean water, and an increase in community vulnerability to various diseases. Conversely, flash floods due to high rainfall intensity are also occurring more frequently, especially in urban areas such as Jakarta, Bandung, and Surabaya. This disaster not only causes significant economic losses but also exacerbates sanitation and public health conditions (Garg et al., 2018). Floods carry domestic and industrial waste into residential areas, creating ideal conditions for the spread of infectious diseases such as leptospirosis and diarrhea.

The problem of uneven water distribution also adds to the complexity of freshwater management in Indonesia. In some areas such as Java and Bali, high population density causes great pressure on water resources, while in eastern Indonesia, such as Papua and Maluku, water resources are relatively abundant but have minimal management infrastructure. This condition is exacerbated by a lack of adequate investment in water infrastructure, which results in gaps in access to clean water between urban and rural areas (Mukherjee, 2020). In a policy context, the Indonesian government has established various regulations and programs to address the issue of freshwater management. An example is the Presidential Regulation on the Management of Water Resources and Domestic Waste, which provides a legal basis for the integration of central and regional policies, as well as encourages private sector involvement in improving clean water services and domestic waste management (Ward et al., 2011).

Overall, the condition of freshwater management in Indonesia shows great potential that has not been fully optimized due to complex and multidimensional challenges. Collaborative efforts from various parties, including the government, society, academics, and the private sector, are needed to develop an effective integrated management strategy in addressing these challenges and ensuring long-term water resilience.

Sanitation Conditions in Indonesia

Adequate sanitation remains a major challenge in Indonesia, especially in rural areas and urban slums. Based on data from the National Development Planning Agency, nearly half of the Indonesian population still experiences limited access to adequate sanitation (National Development Planning Agency, 2021). In urban areas, although access to sanitation is relatively better than in rural areas, the quality of domestic waste management remains a major concern. Many urban areas, especially densely populated

areas and slums, still use inadequate sanitation systems such as conventional septic tanks that do not meet technical standards, or even without any management system at all (Sururi et al., 2023). Figure 2 below depicts the sanitation access condition in Indonesia.

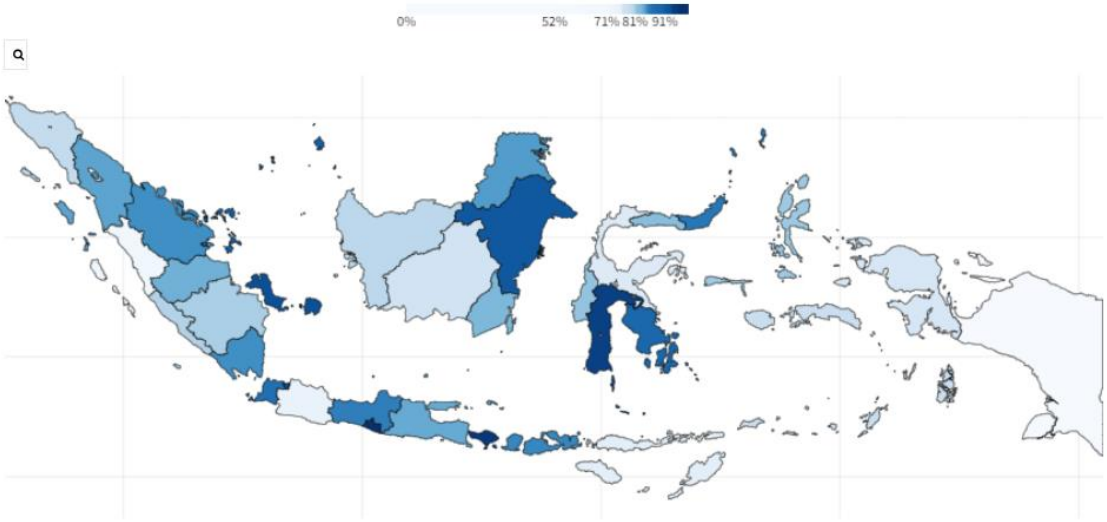

Figure 2. Percentage of 2023 Households with Adequate Sanitation Access (Source: Katadata Insight Center, 2023)

Inadequate domestic waste treatment systems result in significant environmental pollution, especially pollution of groundwater and surface water. Domestic waste that is not properly treated contains various types of pollutants such as pathogenic microorganisms, excess nutrients, and organic chemicals, which if polluting groundwater and surface water sources can endanger human health and the surrounding ecosystem (Garg et al., 2018). This condition is especially prevalent in densely populated areas such as Jakarta, Surabaya, and Bandung, where water pollution due to domestic waste has reached an alarming level (Sururi et al., 2023).

In addition to environmental pollution, the negative impacts of poor sanitation are very influential on community health, especially among vulnerable groups such as children. Poor sanitation directly contributes to an increase in the number of infectious diseases such as diarrhea, cholera, and typhus. Data shows that diarrhea is a leading cause of death in children under five years of age in Indonesia, which is caused by inadequate access to sanitation and contaminated drinking water (WHO & UNICEF Joint Monitoring Programme, 2021). In addition to diarrhea, cholera and typhus diseases also often occur in areas with poor sanitation, which can cause significant disease outbreaks, especially during the rainy season (Adelekan et al., 2015). Besides infectious diseases, poor sanitation is also closely related to high rates of stunting in children. Stunting is a growth disorder characterized by a height that is shorter than the age of the child, which is caused

by chronic malnutrition in the long term and poor environmental conditions, including inadequate sanitation (Adelekan et al., 2015). Stunting has significant long-term impacts, not only on physical growth but also on cognitive development and economic productivity in the future. According to recent research, Indonesia is one of the countries with the highest stunting rates in the world, which is triggered by poor sanitation quality and minimal access to clean water in many areas (Ministry of Health Indonesia, 2021). Furthermore, poor sanitation conditions also have implications for social and economic aspects of society. Poor health due to low sanitation conditions causes a decrease in community economic productivity due to the large amount of time lost due to illness. Health costs also increase significantly because people have to spend more on treating diseases caused by unhealthy environments (Garg et al., 2018).

In addition to technical and health challenges, socio-cultural challenges also complicate sanitation problems in Indonesia. There are still many people, especially in rural and remote areas, who have not realized the importance of good sanitation or even have the habit of defecating openly (open defecation). Data shows that around 9.1 percent of households in Indonesia still practice open defecation, especially in rural areas (Central Statistics Bureau, 2024). This practice not only creates high health risks but also causes significant environmental degradation. Mara (2017) even argues that eliminating open defecation is a moral obligation for the government considering the risks of open defecation that are so high and bad. These evidences simply highlight how far away Indonesia is from meeting its SDG 6 goal. To overcome these various challenges, the government has implemented various national programs, such as Community-Based Total Sanitation (STBM) and Community-Based Sanitation (SANIMAS). These programs aim to increase public awareness of the importance of proper sanitation and provide adequate sanitation facilities through participatory community-based approaches (Ward et al., 2011). However, the implementation of this program still faces obstacles such as limited budgets, lack of infrastructure support, and socio-cultural barriers. Therefore, to overcome the complex sanitation problems in Indonesia, a multidimensional approach is needed involving the government, society, the private sector, and academics in a strong synergy. This approach includes continuous education, adequate investment in sanitation infrastructure, increased sanitation regulations and policies, as well as the application of innovative technologies that are able to answer specific challenges in each region in Indonesia. With this integrated approach, Indonesia is expected to achieve universal access to adequate sanitation and improve public health and environmental quality in a sustainable manner.

Freshwater and Sanitation Management Strategy

To overcome the various challenges in freshwater and sanitation management, it is necessary to apply appropriate technology that is easily implemented by local

communities. One example of a simple but effective technology is a household water filtration system. This system usually consists of layers of sand, gravel, activated carbon, and other filter materials that are able to reduce contamination of pathogenic microorganisms and harmful chemicals in drinking water (Mukherjee, 2020). This simple filtration technology has been widely applied in various rural areas in Indonesia with positive results, namely improving drinking water quality and reducing the number of diseases related to water pollution such as diarrhea and typhus (Sururi et al., 2023).

In addition to water filtration technology, community-scale domestic waste treatment with a simple anaerobic system has also been trusted in reducing environmental pollution. This anaerobic system is able to process organic waste into biogas, which can be used as an alternative energy source for cooking and household lighting, as well as producing a by-product in the form of organic fertilizer which is useful for agriculture (Hadipuro, 2022). The implementation of this system not only overcomes sanitation problems but also provides additional benefits in the form of alternative energy and agricultural products that have economic value, thus encouraging the community to be more active in protecting the environment. A community-based participatory approach is an important strategy in increasing the effectiveness of sanitation and freshwater management in Indonesia. Active community participation in the planning, construction, and management of sanitation and clean water systems has proven to increase the community's sense of responsibility and awareness of the importance of good sanitation. According to Garg et al. (2018), this approach has succeeded in improving environmental and public health conditions in various areas that have implemented it. One successful example of this approach is the Community-Based Sanitation program (SANIMAS) run by the Indonesian government. The SANIMAS program effectively involves the community in all stages, from planning to operating the sanitation system, which ultimately increases community access to proper sanitation significantly (Ward et al., 2011).

In the aspect of regulation, Indonesian government policies such as the Presidential Regulation on the Management of Water Resources and Domestic Waste are an important legal basis for regulating freshwater and sanitation management. This regulation aims to ensure policy integration between central and regional governments and encourage active private sector involvement in providing better clean water and sanitation services. With this regulation, it is hoped that the implementation of freshwater and sanitation management will be more coordinated, efficient, and effective in answering existing challenges (Ward et al., 2011). To strengthen the national strategy, Indonesia can learn from successful international experiences in integrated water and sanitation management. One relevant international case study is the NEWater model in Singapore. This model is a successful example of wastewater management that is treated into clean water using advanced technologies such as microfiltration, reverse osmosis, and

ultraviolet disinfection. This wastewater recycling process not only overcomes sanitation problems but also guarantees long-term clean water supply resilience amid limited natural water resources (Biswas & Tortajada, 2019). The success of the NEWater model provides a real example that innovative and integrated approaches in wastewater management are able to produce sustainable solutions for urban water and sanitation challenges. The implementation of appropriate technology and community-based participatory approaches requires full support from the government, both in the form of regulations, financing, and community education. A comprehensive education program is a key to ensuring that the technology applied is not only understood technically but also accepted socially and culturally by the community. This education program needs to cover health, environmental, economic aspects, as well as the long-term benefits of implementing sanitation and clean water technology. The government also needs to increase investment in basic infrastructure such as communal wastewater treatment plants (IPAL), clean water distribution networks, as well as other sanitation facilities. This investment will help accelerate the achievement of universal access to proper sanitation and clean water in accordance with the SDGs targets. In addition, private sector participation in the form of public-private partnerships needs to be continuously encouraged so that the implementation of freshwater and sanitation management becomes faster, more efficient, and more innovative.

In the long term, an effective freshwater and sanitation management strategy not only provides environmental benefits but also contributes to improving the overall quality of life of the community. These benefits include improving public health, reducing health costs due to infectious diseases, increasing economic productivity, as well as improving environmental resilience comprehensively. With this integrated strategy, Indonesia is expected to achieve sustainable freshwater and sanitation management, supporting inclusive and environmentally friendly national development. In summary, community-based approaches to freshwater and sanitation management offer strong advantages, including high local ownership, cost-effectiveness, and adaptability to local conditions. They promote behavior change, enhance accountability, and often ensure more sustainable outcomes. However, these initiatives face limitations, such as lack of technical expertise, inconsistent funding, and varying levels of community motivation, which can hinder long-term success. There are also promising opportunities, particularly their alignment with national goals like the SDGs and STBM, the potential for partnerships with NGOs and the private sector, and the use of digital tools for public engagement. Yet, threats remain—such as climate risks, political instability, urban displacement, and the danger of exclusion or elite capture. Addressing these challenges is essential to maximizing the impact of community-led water and sanitation solutions.

To operationalize an integrated and cross-sectoral strategy for freshwater and sanitation management in Indonesia, the following 10-year policy roadmap is proposed, as

presented in Table 1 below. It includes short-term, medium-term, and long-term actions, aligned with national development plans and the SDG 6 target.

Table 1. Proposed 10-year Policy Roadmap

Phase	Timeline	Key Activities	Lead Actors
Phase I Initiation & Capacity Building	2025–2026	• Mapping of water-stressed areas and sanitation gaps • Stakeholder coordination workshops • Community outreach & education campaigns • Pilot projects using low-cost technologies	Bappenas, MoH, MoEF, local governments, NGOs
Phase II Infrastructure & Policy Integration	2027–2029	• Expansion of community-based sanitation (SANIMAS & STBM) programs • Development of communal wastewater systems • Regulatory harmonization across ministries • Public-private partnerships for clean water access	MoPWH, private sector, academic institutions
Phase III Technology Scaling & Monitoring	2030–2032	• Upscaling of appropriate technologies (e.g., anaerobic digestion, filtration) • Integrated monitoring systems using IoT and GIS • Capacity building for local governments	BPPT, local water authorities, research centers
Phase IV Resilience Consolidation	2033–2035	• Institutionalization of cross-sectoral water-sanitation governance • Community co-management and sustainability audits • Final impact evaluation aligned with SDG 6 & SDG 13 targets	Coordinating Ministries, multistakeholder forum

Urgency of Cross-Sectoral Policies in Freshwater and Sanitation Management

The urgency of cross-sectoral policies can be seen from the increasing number of policies that overlap or even conflict with each other in the field. For example, spatial planning that allows the conversion of conservation areas into settlements actually conflicts with the goals of protecting water sources (Rohiani, 2021;Alatas et al., 2024). Agricultural policies that rely on large-scale irrigation are sometimes not aligned with the availability of river water that has decreased due to upstream industrial projects (Rusmayadi et al., 2023; Rachman, n.d.) Meanwhile, the Ministry of Health is encouraging increased access

to sanitation without being connected to an integrated waste management system developed by local governments. This situation shows the need for a regulatory and institutional framework that is able to integrate various interests into an evidence-based holistic policy.

The implementation of cross-sectoral policies also requires a strong coordination platform and inclusive decision-making mechanisms (Sentanu & Yustiari, 2024) (Akhyar, 2024). The central government must strengthen the role of coordinating institutions such as the Ministry of National Development Planning (Bappenas) in preparing a sustainable development roadmap. In addition, the role of local governments as the main implementers in the field must be supported by technical capacity, valid data, as well as fiscal incentives that encourage local innovation. Water and sanitation policies, for example, must be able to link labor-intensive programs, community empowerment, and environmentally friendly technology investment in an integrated manner. This approach not only solves one problem, but creates multiple impacts on poverty reduction, public health, and environmental conservation (Swe et al., 2021). Another important aspect is the involvement of civil society and the private sector. In an increasingly complex world, the government cannot work alone. Collaboration with NGOs, local communities, universities, and business actors is needed to identify context-based solutions (Ambole et al., 2016; Thatcher et al., 2024; Scott & Cotton, 2020). For example, private companies can be involved in corporate social responsibility (CSR) schemes to build sanitation infrastructure or water filtration systems. On the other hand, schools and campuses must be centers for education and campaigns for sustainable lifestyles from an early age. The active participation of various stakeholders will create a sense of ownership and strengthen public accountability for the policies produced (Barr, 2012).

In a global context, cross-sectoral policies also support Indonesia's involvement in achieving the SDGs. In particular, the goals of SDG 6 (clean water and sanitation) and SDG 13 (climate change action) cannot be achieved without full integration with the energy, food, and economic governance sectors (Corbett & Mellouli, n.d.). The water-energy-food nexus approach is very relevant to the context of Indonesia which has ecosystem diversity, social challenges, and economic opportunities based on natural resources (Purwanto, 2021). Therefore, Indonesia must continue to develop a data-based, socially inclusive, and flexible cross-sectoral policy framework for climate change and global economic dynamics. With all these considerations, it is clear that cross-sectoral policies are not just an alternative, but a necessity. In facing the challenges of this century, from the climate crisis to urbanization, only policies that are able to embrace complexity and build cross-sectoral synergies can realize just, resilient, and sustainable development.

The Linkage of Freshwater and Sanitation Management to Environmental Resilience

Integrated freshwater and sanitation management is a strategic approach that has a direct positive impact on environmental resilience, especially in maintaining water resource quality, preventing pollution, and ensuring the sustainable availability of clean water. This strategy plays an important role in maintaining the balance of aquatic ecosystems, protecting biodiversity, and maintaining overall environmental stability (Hadipuro, 2022). Ecologically, the integration of freshwater and sanitation management helps maintain the quality of surface water and groundwater by reducing the pollutant load entering the aquatic environment. Pollutants such as domestic waste, industrial waste, and agricultural waste, if not managed properly, can cause significant water quality degradation. The implementation of effective waste treatment systems, such as anaerobic treatment and wastewater filtration, has been shown to substantially reduce chemical and biological contaminants, thus creating healthier environmental conditions for aquatic organisms and preventing ecosystem degradation (Mukherjee, 2020). Another ecological benefit is the preservation of biodiversity in freshwater ecosystems. Maintained water quality allows aquatic organisms such as fish, aquatic plants, and microorganisms to thrive optimally. Healthy and well-functioning ecosystems also provide various ecosystem services such as clean water provision, flood control, and habitat for various species that are a source of food and economy for local communities (Ward et al., 2011).

From an economic point of view, investment in effective freshwater and sanitation management systems has proven to provide significant economic benefits. Good sanitation management and the provision of stable clean water drastically reduce community health costs. Research by Garg et al. (2018) shows that investment in sanitation and clean water infrastructure can reduce household spending on treating water and sanitation-related diseases, thereby increasing income that can be allocated to other productive needs. In addition, better community health conditions directly impact increased work productivity and reduce the number of work days lost due to illness. Socially, good freshwater and sanitation management significantly improves the quality of life of the community. Access to safe clean water and adequate sanitation facilities reduces the burden of infectious diseases such as diarrhea, cholera, and typhus, as well as reduces stunting rates in children (WHO & UNICEF Joint Monitoring Programme, 2021). Reduced diseases contribute to an increase in community life expectancy, which overall impacts the improvement of the quality of life and welfare of the community.

The integration of freshwater and sanitation management also has broader social implications in strengthening social cohesion and community empowerment. Community-based participatory approaches in the management of water and sanitation have been shown to strengthen social capital by increasing active community

involvement in various stages of water resource and sanitation management. This active participation increases the community's sense of ownership of existing facilities and infrastructure, which ultimately guarantees the sustainability of long-term management and maintenance (Hadipuro, 2022). Furthermore, health benefits derived from good freshwater and sanitation management also have an impact on education and gender aspects. The provision of adequate sanitation in schools, for example, significantly increases student attendance, especially female students, who may previously be constrained due to poor or unavailable sanitation facilities. Thus, freshwater and sanitation management indirectly support increased education participation and women's empowerment (Adelekan et al., 2015).

From a long-term environmental resilience perspective, the integration of freshwater and sanitation management serves as an important adaptive strategy in facing climate change. Good management of water and sanitation helps communities become more resilient in facing various impacts of climate change such as floods, droughts, and pollution from natural disasters. Good integrated management systems enable communities to recover more quickly from environmental disruptions and maintain their economic and social resilience in the long term (Biswas & Tortajada, 2019). Therefore, integration between freshwater and sanitation management is an important foundation in achieving sustainable environmental resilience in Indonesia. This strategy not only provides direct benefits in the form of improved water and sanitation quality, but also supports overall economic, social, and environmental sustainability. Thus, integrated efforts in freshwater and sanitation management must be a top priority in sustainable development policies in Indonesia in order to realize a healthy environment, a prosperous society, and a strong economy.

Policy Implications

The results of studies on freshwater and sanitation management strategies show that environmental resilience cannot be achieved without integrative and adaptive policies. The problems of the availability of clean water and adequate sanitation services have broad cross-sectoral implications, from public health to spatial planning, from education to climate change. Therefore, these findings are very relevant in the formulation of policies at the national and regional levels, especially in realizing the SDGs, especially SDG 6 (access to clean water and sanitation) and SDG 13 (action against climate change). At the national level, these findings reinforce the urgency to strengthen cross-ministerial coordination. The Ministry of Public Works and Housing as an infrastructure provider, the Ministry of Environment and Forestry as a natural resource manager, the Ministry of Health as a guarantor of sanitation and public health, and the Ministry of Home Affairs as a regulator of local government capacity must work in a single integrated water and sanitation policy framework. Without joint planning, program overlaps and inefficiency

in the use of public funds will continue. At the regional level, water management policies must be integrated into the Regional Spatial Plan (RTRW), the Regional Medium-Term Development Plan (RPJMD), as well as annual budget policies to align with national priorities and local needs.

Cross-sectoral planning is also an urgent need. The problem of water and sanitation cannot only be handled by one sector, because it touches the dimensions of infrastructure, community behavior, environmental conservation, as well as socio-economic aspects. Therefore, a coordination framework is needed that connects key sectors such as water, environment, health, education, and regional planning. For example, sanitation programs that are not linked to clean living behavior education programs will produce short-term but not sustainable impacts. Conversely, if sanitation policies are combined with education and infrastructure improvements, the results will be more significant socially and ecologically.

Effective freshwater and sanitation governance must reflect Indonesia's diverse geographical and socio-economic realities. Urban and rural areas face distinct challenges that require tailored policy approaches: In urban contexts, policies should prioritize wastewater infrastructure upgrades, smart water monitoring, and integration with housing and spatial planning to address pollution, density, and climate risks. Coordination among city planning, health, and public works offices is critical to avoid fragmented interventions. In rural areas, where access and behavior-related barriers persist, emphasis should be placed on low-cost, decentralized technologies, community empowerment, and localized sanitation education. Strengthening the role of local leaders and health facilitators can accelerate behavioral change and infrastructure adoption.

The need for regulatory harmonization is also an important point of policy implications. Currently, regulations on water and sanitation are scattered in many laws and regulations, which are often not synchronized or even contradict each other. For example, there are still differences in the definition of "access to safe drinking water" according to BPS and technical standards from the Ministry of Health. Therefore, policy and regulatory harmonization at the national level is needed, as well as simplifying implementation mechanisms at the regional level. In addition, institutional reform needs to be carried out to avoid duplication of tasks between agencies and ensure accountability in water and sanitation program management.

D. Conclusion

Achieving sustainable freshwater and sanitation management is not merely a technical challenge, it is a strategic necessity for Indonesia's environmental resilience, public health, and long-term development. This study emphasizes the need for a synthesis of

cross-sectoral governance, community participation, and innovation. As Indonesia moves toward its 2045 Vision aiming to become a sovereign, advanced, and sustainable nation water and sanitation must be positioned as foundational pillars of resilience and inclusive growth.

To support this transformation, three priority actions are recommended for policymakers. First, institutionalize cross-sectoral coordination by harmonizing policies across water, health, environment, and spatial planning sectors. Second, scale up community-based models like SANIMAS and STBM by integrating them with appropriate technologies and sustained capacity-building. Third, invest in decentralized infrastructure and adaptive systems that are resilient to climate risks and tailored to local needs. Future research should deepen engagement with local governance dynamics and explore scalable financing models for community-driven sanitation. Indonesia's success in building resilient water systems will not only support its SDG commitments but also serve as a keystone in realizing its Golden Indonesia 2045 aspiration—where prosperity is grounded in equity, sustainability, and shared responsibility.

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