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Inter-Island Submarine Pipelines for Clean Water in Indonesia: Bridging Technical Feasibility and Basic Service Provision (Case of Lae-Lae Island)

Abstract

The provision of clean water in Indonesia's archipelagic regions remains a significant challenge, particularly for small islands lacking adequate freshwater resources. Lae-Lae Island in Makassar represents a critical case, where all groundwater sources have been classified as lightly polluted due to seawater intrusion and domestic activities, while the water supply deficit reaches approximately 95,000 liters per day. This study aims to analyze clean water distribution issues from two main perspectives: technical aspects and basic service provision. The method employed is a literature review combined with comparative analysis of several submarine pipeline installations in Indonesia. The results indicate that the use of High-Density Polyethylene (HDPE) submarine pipelines is a technically feasible solution to distribute clean water from mainland Makassar to Lae-Lae Island, considering the relatively short distance and the availability of an existing municipal water supply network. Furthermore, successful implementations in other regions demonstrate that this technology is reliable and applicable. However, the primary challenges lie in policy and institutional frameworks, where inter-island pipeline systems have not yet been positioned as integrated basic service infrastructure. Therefore, an integrated approach combining engineering planning and public policy is required to ensure sustainable clean water services. Lae-Lae Island is considered a strategic starting point for implementation, with the potential to be replicated across other small islands in Indonesia.

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1. Introduction

Clean water is a fundamental human necessity that cannot be compromised. In the context of an archipelagic country such as Indonesia, fulfilling this need faces unique structural challenges: the majority of Indonesia's more than 17,000 islands lack adequate natural freshwater resources, forcing communities to rely on sources that are unsafe, unstable, or unaffordable [1]. This is where the core issue lies not merely a technical problem of water distribution, but a matter of fulfilling basic citizen rights that has yet to be systematically addressed.

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Lae-Lae Island, a small island covering approximately 6.5–8.9 hectares within the Spermonde Archipelago and located only about 1.3–1.5 km from Makassar City, represents a clear manifestation of this paradox. Despite its close proximity to a metropolitan center, approximately 1,876–1,898 residents living on the island lack access to adequate and sustainable clean water. Beyond mere supply shortages, research by Liani [2] scientifically demonstrates that all sampled groundwater sources on Lae-Lae Island fall into the category of lightly polluted (Pollution Index value $1.0 < PIj \leq 5.0$), with parameters such as TDS, BOD, COD, chloride, and hardness exceeding established quality standards. Common diseases affecting residents due to this condition include ascariasis, diarrhea, dermatitis, and allergies [2].

This condition raises a fundamental question at the heart of this article: if the technology to address the issue already exists, the distance from clean water sources is very short, and scientific data on pollution is available, why has inter-island clean water distribution through submarine pipelines not been treated as a basic service priority equivalent to electricity and roads?

This perspective article argues that inter-island submarine pipelines for clean water must be understood simultaneously as both a technical issue and a basic service issue. These two dimensions are inseparable. An approach that considers the problem purely from a technical perspective will overlook the dimensions of rights and social justice behind it. Conversely, an approach that emphasizes service provision without considering technical feasibility will result in policies that cannot be implemented. Lae-Lae Island serves as the most appropriate context to illustrate this argument.

2. Discussion of Main Issues

The issue of clean water on Lae-Lae Island fundamentally has two interrelated dimensions. The first is the technical dimension, which concerns the source of clean water, the method of distribution to the island, and the technology required to ensure reliable and efficient delivery. The second is the basic service dimension, which relates to who is responsible for ensuring that every resident has access to adequate clean water, and through what mechanisms this right can be fulfilled sustainably.

In the Indonesian context, clean water is recognized as a basic necessity and a state responsibility. The National Medium-Term Development Plan (RPJMN) 2020–2024 targets universal access to safe and adequate drinking water; however, in reality, only about 20% of the population has access to piped water systems [1]. This disparity is even more pronounced in archipelagic regions that are geographically isolated from mainland infrastructure.

On Lae-Lae Island, the failure to fulfill basic clean water services manifests in two forms simultaneously: a quantitative failure (a deficit of approximately 95,000 liters per day out of a total demand of 190,000 liters per day) and a qualitative failure (all available groundwater sources are classified as lightly polluted). This dual failure elevates the issue beyond a technical problem that can be postponed, transforming it into an urgent public health concern.

From a technical perspective, groundwater sources on small islands like Lae-Lae have inherent limitations that cannot be resolved solely through local infrastructure improvements. With a land area of only 6.5–8.9 hectares and a very high population density, the island faces unavoidable seawater intrusion. The pressure exerted by seawater from all directions compresses the boundary between freshwater and saltwater within the aquifer. Consequently, excessive groundwater extraction inevitable under such population pressure further exacerbates the intrusion [2].

Research by Liani [2] indicates that high chloride (Cl) concentrations in all sampled bore wells on Lae-Lae Island serve as direct evidence of seawater intrusion. Elevated Total Dissolved Solids (TDS) levels further reflect the high concentration of dissolved substances, including minerals originating from seawater, within the island's aquifer. Meanwhile, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values exceeding standard limits indicate that organic pollution from domestic activities has also contaminated these already limited groundwater resources.

In other words, the classification of Lae-Lae Island's groundwater as lightly polluted is not merely the result of negligence or poor maintenance, but rather a structural consequence of the limited capacity of small island aquifers under high population pressure. No locally based resource solution can fundamentally alter this reality.

In this context, inter-island submarine pipelines emerge as a solution that addresses both dimensions of the problem simultaneously. From a technical standpoint, a submarine pipeline connecting the municipal water supply network of Makassar to Lae-Lae Island would enable the direct distribution of treated clean water with controlled pressure and flow. From a basic service perspective, such a system would establish a physical connection between the island and the city's public service infrastructure, representing a form of service equity that has long been absent.

A submarine pipeline is a piping system installed on or beneath the seabed and can be used to transport various fluids, including clean water [3]. The material commonly used for inter-island clean water pipelines is High-Density Polyethylene (HDPE), which offers several advantages such as high flexibility, resistance to seawater corrosion, lightweight properties, food-grade safety for drinking water, and durability under hydrostatic pressure [4].

In the case of Lae-Lae Island, the relatively short distance of only 1.3–1.5 km from mainland Makassar results in minimal head loss along the pipeline, thereby requiring only a modest pumping system. This represents a significant technical advantage compared to other inter-island cases in Indonesia, where distances are considerably longer.

3. Review and Critique of Existing Approaches

Indonesia has established several precedents in the installation of inter-island submarine pipelines for drinking water, demonstrating that this technology is neither unfamiliar nor experimental, but rather proven under various archipelagic marine conditions. One of the earliest and most notable examples is the Drinking Water Supply System (SPAM) project on Gili Ketapang Island, Probolinggo, East Java recognized as the first submarine drinking water pipeline installation in Indonesia, initiated by the Ministry of Public Works through the Directorate General of Human Settlements. This project successfully reduced the cost of clean water for approximately 11,400 residents from IDR 50,000 to only IDR 6,000–7,000 per cubic meter [5], demonstrating not only technical feasibility but also significant improvements in affordability as a basic service.

Another highly relevant case is the installation of a submarine pipeline between Tidore Island and Maitara Island in North Maluku using the pull-and-sink (TT) method. Maitara Island, located only 1 km from Tidore similar to the proximity of Lae-Lae Island to Makassar lacks its own freshwater source. In this project, HDPE pipelines were successfully installed along the seabed of the Maitara Strait, extending 1.6 km per line with three parallel pipelines, despite strong ocean currents [6].

In Bali, a study by Suarda and Dwijana [7] designed a clean water pipeline system for Nusa Ceningan and Nusa Lembongan. Due to extreme marine conditions, including depths reaching 200 meters and busy shipping lanes, the pipeline had to be suspended at a depth of 20 meters using a stainless steel sling bridge system. This case illustrates that even under far more complex installation conditions than those of Lae-Lae, inter-island clean water pipeline technology remains feasible.

The most contextually similar case to Lae-Lae is the study by Azisah et al. [8] on submarine pipeline installation for Kayangan Island in Makassar. This project utilized HDPE pipes with a diameter of 140 mm (PN 16) in accordance with Indonesian National Standards (SNI), spanning approximately 1,500 meters and sourcing water from the Makassar municipal water supply system an almost identical configuration to what is required for Lae-Lae Island.

Furthermore, research conducted on Lengkang Kecil Island in Batam by Suryawan and Afifah [9] confirms that operational inter-island submarine pipeline systems can sustainably meet clean water demand while maintaining hydraulic performance within acceptable distribution design criteria.

Despite these technical precedents and the availability of scientific data on water pollution in Lae-Lae Island [2], the persistence of the problem indicates that the primary barriers are not technical, but institutional and policy-related. First, there is no clear and specific regulatory framework governing inter-island submarine pipelines for clean water. Existing SPAM programs are predominantly designed for urban mainland contexts, leaving financing schemes, technical standards, and management responsibilities for inter-island distribution in a policy gray area. As a result, successful projects such as those in Gili Ketapang and Tidore–Maitara have been implemented on an ad hoc basis rather than as part of a structured national program.

Second, infrastructure policies tend to treat small inhabited islands as isolated units that

must independently develop their own solutions, rather than as components of an integrated public service network connected to the mainland. This island-by-island approach is both inefficient and socially inequitable, particularly when systematic solutions through infrastructure connectivity are already available.

Third, academic discourse on subsea pipelines in Indonesia remains heavily dominated by oil and gas applications. Technical studies focusing on inter-island pipelines for clean water are still limited and have not received proportional attention from the marine engineering community. Yet, as demonstrated in the case of Lae-Lae, the social impact of clean water issues is far more immediate and widespread than most oil and gas pipeline applications.

Finally, government-proposed solutions for small islands in the Spermonde Archipelago tend to be partial and limited in capacity. For example, a solar-powered desalination system implemented on Barrang Lompo Island produces only 3,000 liters of water per day [10], which is far from sufficient to meet community needs especially when compared to the 190,000 liters per day required by Lae-Lae Island. Such small-scale and unintegrated solutions cannot replace the need for permanent, large-scale water distribution infrastructure.

4. The Author's Perspective Argument

The main argument of this study is that inter-island submarine pipelines for clean water must be explicitly positioned as basic service infrastructure rather than merely engineering projects. This distinction is not merely semantic; it has tangible implications for budget prioritization, institutional responsibility, and the speed of implementation.

When electricity is treated as a basic service, the state-owned utility company (PLN) develops transmission networks to remote islands, including operating diesel power plants on Lae-Lae Island, even when such systems may not be economically efficient. The same logic should apply to clean water provision. When residents of an island lack access to adequate clean water and this has been scientifically demonstrated in the case of Lae-Lae Island the state has an obligation to establish the necessary infrastructure connections, regardless of the technical complexities involved [11].

The pollution index data presented in [2] should therefore be viewed not only as an academic finding, but also as a moral and practical basis for infrastructure intervention. The classification of groundwater as lightly polluted across all sampling points indicates not only substandard water quality, but also the potential for long-term chronic health impacts on approximately 1,876–1,898 residents if such water continues to be used.

A common conceptual error in discussions of inter-island pipelines is to begin with the question of "how to install the pipeline," rather than "what the pipeline must achieve." In the context of clean water provision for Lae-Lae Island, the objective is clear: to deliver water that meets drinking water quality standards from the Makassar municipal water network to all households on the island in a continuous, reliable, and affordable manner [12].

All technical decisions should be derived from this function. Pipeline materials must be food-grade (such as HDPE) because they transport drinking water. Design discharge must account for total population demand as well as future growth. Leak monitoring systems are essential, as leakage not only causes hydraulic losses but also risks contamination from seawater. Maintenance systems must be easily accessible, as disruptions in clean water services have direct consequences for public health [13].

Unlike oil and gas pipelines, which are primarily designed to maximize energy transfer efficiency and minimize spill risks, inter-island clean water pipelines must be designed with public service standards as the primary reference, where reliability, affordability, and water quality at the point of delivery are the key indicators of success [14].

To achieve this, the development of inter-island clean water pipelines particularly for Lae-Lae Island and other small inhabited islands in Indonesia requires an integrated framework that bridges two domains that have traditionally operated separately: marine engineering and water service policy.

From a technical perspective, this framework should include bathymetric and seabed condition assessments, appropriate material selection and installation methods, hydraulic distribution analysis, and the design of monitoring and maintenance systems. From a policy perspective, it should encompass

affordable tariff schemes for coastal and fishing communities, the designation of managing entities (such as local water utilities or specialized units), infrastructure financing mechanisms (national budget, regional budget, or public–private partnerships), and guarantees of service continuity [15].

Without such integration, inter-island pipeline projects risk becoming technically successful installations that fail to function as effective public services due to unaffordable tariffs, weak management, or inadequate maintenance. Experiences from various water infrastructure projects in Indonesia indicate that post-construction operational failures occur more frequently than technical failures during installation.

Based on these considerations, Lae-Lae Island emerges as the most suitable starting point for implementing an inter-island clean water distribution system using submarine pipelines in the Spermonde Archipelago. From a technical standpoint, the short distance of only 1.3–1.5 km from mainland Makassar reduces installation complexity and cost; relatively shallow waters allow for simpler bottom-lay installation methods; and the availability of an existing municipal water network eliminates the need to construct new treatment facilities.

From a basic service perspective, the high population density (1,876–1,898 residents) ensures that infrastructure investment will benefit a significant number of people; scientific evidence of water pollution [2] provides strong justification for prioritization; and proximity to the city facilitates monitoring, operation, and rapid response to service disruptions.

From a policy impact perspective, successful implementation on Lae-Lae Island would serve as a replicable model for other islands in the Spermonde Archipelago and across Indonesia, while also demonstrating that inter-island clean water pipelines deserve to be established as part of a structured national program rather than sporadic, isolated projects.

5. Conclusions

The provision of clean water on Lae-Lae Island through an inter-island submarine pipeline system represents a strategic solution to address the limitations of local freshwater resources and the inadequacy of existing supply systems. From a technical perspective, this system is capable of delivering a more continuous, efficient, and controlled water supply compared to conventional distribution methods. However, its implementation is not without challenges, including risks of corrosion, damage due to marine conditions, pressure loss, as well as high initial investment and maintenance costs.

Therefore, the success of such a system depends on comprehensive planning, appropriate material selection, and the implementation of effective risk management and long-term maintenance strategies. In addition, this approach should not stand alone, but rather be integrated with complementary water supply solutions to enhance system resilience. The utilization of rainwater harvesting, small-scale desalination technologies, and other locally available water resources can serve as effective supporting systems.

By diversifying water sources, dependency on a single infrastructure system can be reduced, allowing communities to maintain water reserves during potential disruptions. Such an integrated approach strengthens the overall reliability and sustainability of clean water services.

By comprehensively integrating technical, economic, and institutional aspects, the submarine pipeline system has strong potential to serve as an effective and sustainable long-term solution for meeting the clean water needs of Lae-Lae Island. Beyond increasing water availability, this system contributes to improving public health, enhancing quality of life, and supporting future regional development. Therefore, well-planned implementation and professional management are essential to ensure the long-term success and sustainability of this infrastructure.

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