



Challenges in Adapting Wolbachia Technology for Dengue Control

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Abstract: The global increase in dengue cases has prompted the development of the Wolbachia method as an innovative vector control strategy. In response, the Indonesian Government, through the Ministry of Health, has implemented the Wolbachia method in various regions. The application of this novel strategy requires cross-sectoral collaboration to enhance implementation effectiveness. This qualitative study aims to analyze the implementation of the Wolbachia program in Buleleng Regency, Bali, within a multi-stakeholder collaborative framework. Data was gathered through in-depth interviews and document reviews to investigate the dynamics and challenges of collaboration. The findings reveal significant obstacles to effective collaboration, including weak communication, overlapping roles, bureaucratic complexity, and regulatory deficiencies. These issues have adversely affected community participation and led to resistance toward the program. The study contributes to the public policy implementation literature by highlighting the critical need for clear communication, defined roles, and technical guidelines to improve implementation success. It recommends enhancing communication, coordination, regulation, and misinformation mitigation to optimize cross-sectoral collaboration in the execution of innovative public health policies.

Keywords: Implementation; Public Policy; Wolbachia

Introduction

Dengue hemorrhagic fever (DHF) remains a significant public health concern in Indonesia, with the incidence of the dengue virus, transmitted by the *Aedes aegypti* mosquito, continuing to rise annually (World Health Organization, 2024). In 2021, 73,518 dengue cases were reported, resulting in 705 deaths across 464 regions in 34 provinces (Kementerian Kesehatan Republik Indonesia, 2022). Bali province reported the highest incidence rate, with 569 cases per 100,000 inhabitants in 2022 (Dinas Kesehatan Provinsi Bali, 2021). By January 2023, Bali had recorded 781 dengue cases, with Buleleng Regency reporting 100 cases.

Buleleng Regency, encompassing approximately 24.23% of Bali's total area, is a DHF-endemic region. In 2022, the regency reported 875 DHF cases with a

morbidity rate of 106.04 per 100,000 people. The Buleleng sub-district, with the highest population density, accounted for the majority of cases (314) and exhibited a case fatality rate (CFR) of 0.23% (Dinas Kesehatan Kabupaten Buleleng, 2023).

In response to the global dengue epidemic, the World Health Organization and various countries have been developing innovative strategies to reduce dengue transmission (WHO, 2022). One of the most promising approaches is the use of Wolbachia-infected mosquitoes. This method has shown significant success in reducing dengue cases in several countries, including Australia, Brazil, and Vietnam (O'Neill et al., 2019; Tantowijoyo et al., 2020).

The Indonesian Ministry of Health has embraced this global strategy by developing and implementing the Wolbachia method as an innovative control strategy

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(Kementerian Kesehatan Republik Indonesia, 2016). The implementation of Wolbachia is authorized by the Decree of the Minister of Health of the Republic of Indonesia, providing a legal basis for its pilot implementation in five Indonesian cities.

Wolbachia, a naturally occurring bacterium found in various insects, reduces the ability of *Aedes aegypti* mosquitoes to transmit the dengue virus by inhibiting viral replication (Flores & O'Neill, 2018). Research conducted in Yogyakarta demonstrated a 77% reduction in dengue incidence and an 86% decrease in hospitalizations following the implementation of Wolbachia (Utarini et al., 2021). The World Mosquito Program employs Wolbachia-infected mosquitoes released into local populations, ensuring that their offspring also carry Wolbachia, thereby creating a sustainable protective effect against dengue transmission. This approach represents an innovative vector control strategy, leveraging the natural biological interaction between the Wolbachia bacterium and mosquitoes, rather than relying solely on traditional chemical methods.

The implementation of the Wolbachia method in Indonesia encounters various challenges, largely due to the country's diverse socio-cultural landscape. A noticeable gap exists between the intended outcomes and the actual realization of this health innovation (Smith & Jones, 2023). This spectrum of opinions reflects the multifaceted nature of implementing cutting-edge disease control strategies. The varied perspectives within Indonesian society regarding the Wolbachia method underscore the intricacies involved in introducing novel public health interventions (Kompas, 2023). Certain communities have raised concerns about potential ecological ramifications and unforeseen consequences of introducing modified mosquitoes into the environment. Conversely, other segments of society have embraced this innovative approach to combating dengue fever, recognizing its potential benefits for public health. These divergent viewpoints highlight the complex interplay of scientific innovation, public perception, and cultural context in the successful implementation of new health strategies.

Theoretically, involving multiple sectors, including the pentahelix model (government, private sector, academia, community, and media), is considered capable of enhancing the success of innovative programs like Wolbachia. This collaborative governance approach, characterized by the active participation of diverse stakeholders in the formulation and implementation of public policies, is crucial in addressing these complex challenges (Ansell & Gash, 2018; Emerson et al., 2012).

Pentahelix collaboration has garnered significant attention in research on the implementation of Sustainable Development Goals (SDGs). Glass et al.

(2023) highlighted the growing involvement of non-state actors in global sustainability governance, underscoring the critical role of cross-sector collaboration in achieving sustainable development goals.

In the context of collaborative governance for sustainable development, various stakeholders play distinct roles. Government formulates policies and provides essential support. Local communities contribute valuable knowledge and participate in decision-making processes (Ullah & Kim, 2020). The private sector supplies financial resources, technology, and expertise (Sundqvist-Andberg & Åkerman, 2022). NGOs facilitate dialogue and build capacity (Lukman et al., 2023). The academics conduct research and provide expert advice (Dressel et al., 2020).

Despite the growing body of literature on collaborative governance and pentahelix models, there remains a significant gap in our understanding of how these theoretical frameworks translate into practice, particularly in the context of innovative public health interventions like the Wolbachia method. While studies have explored pentahelix collaboration in various sectors, there is limited empirical research on its application in vector-borne disease control programs, especially in culturally diverse settings like Indonesia. Furthermore, the dynamics of stakeholder interactions and the challenges faced in implementing such collaborative approaches in public health innovations remain understudied.

The research problem at hand stems from the complex interplay between the urgent need for effective dengue control measures, the promising yet controversial nature of the Wolbachia method, and the challenges of implementing collaborative governance in Indonesia's diverse socio-cultural landscape. The gap between the theoretical potential of pentahelix collaboration and its practical implementation in public health innovations presents a critical area for investigation. The primary objective of this study is to analyze and evaluate the implementation of pentahelix collaboration in the deployment of the

Wolbachia method for dengue control in Buleleng Regency, Bali. This research aims to provide a comprehensive understanding of the dynamics, challenges, and effectiveness of multi-stakeholder collaboration in this context.

This study seeks to answer the question: How is pentahelix collaboration implemented in the Wolbachia deployment in Buleleng Regency? By answering this question, the study aims to explore the dynamics of collaboration among government, academia, industry, community, and media in the context of Wolbachia-based dengue control.

The importance of this research lies in its potential to provide a real-world picture of the dynamics of

pentahelix collaboration in the implementation of public policy, specifically the Wolbachia method. While theoretical models suggest that multi-stakeholder collaboration can enhance the success of innovative programs (Bryson et al., 2015), there is a need for empirical evidence to understand how these collaborations actually unfold in practice, particularly in the context of novel public health interventions like Wolbachia.

By addressing these research gaps and objectives, this study seeks to contribute to both the theoretical understanding of collaborative governance in public health innovations and the practical application of pentahelix models in vector-borne disease control. The findings are expected to offer valuable insights for policymakers and practitioners in optimizing collaborative governance approaches to enhance the effectiveness of public health programs in the future, particularly in navigating the complexities of implementing innovative and potentially controversial public health measures (Sørensen & Torfing, 2021). Moreover, this research will provide a case study of pentahelix collaboration in action, offering lessons that may be applicable to other regions facing similar public health challenges and seeking to implement innovative solutions through multi-stakeholder engagement.

Method

This study employed a qualitative case study design chosen for its capacity to illuminate complex social phenomena, specifically the dynamics of collaborative governance within the implementation of the Wolbachia method. The case-study design facilitated an in-depth examination of a specific case, enabling a holistic understanding of the context, processes, and interactions in the program's implementation.

The unit of analysis for this study is the pentahelix collaborative network involved in the Wolbachia implementation in Buleleng Regency. This includes the interactions, roles, and contributions of government agencies, academic institutions, private sector entities, community organizations, and media outlets engaged in the project. The research location was Buleleng Regency, one of the locations that became a pilot project for the implementation of the Wolbachia program in Bali Province.

Informant selection was conducted using purposive sampling with a heterogeneous approach, based on the informants' involvement and knowledge of the Wolbachia program in Buleleng Regency. A total of 11 informants were selected, representing the five main elements of the pentahelix model: government, private sector, academia, media, and the community.

Data collection methods include semi-structured in-depth interviews and document analysis. Interviews were conducted both face-to-face and online via Zoom, depending on the availability and preference of the informants. The duration of each interview ranged from 2 to 3 hours. Primary data were obtained through these semi-structured in-depth interviews with key stakeholders (informants) to explore their experiences, perceptions, and insights related to the implementation of the Wolbachia program. Secondary data were sourced from reports, official documents, and other relevant materials related to collaborative governance and the Wolbachia method.

Data reliability was ensured by cross-checking consistency in informants' responses through comparison of their answers. Discrepancies or contradictions were further explored with follow-up questions during the interviews, helping to validate the responses and provide a more accurate representation of perspectives on the program's implementation. Methodological and data source triangulation enhanced the validity and reliability of the findings (Fusch et al., 2018).

Data analysis was carried out using NVivo software, which was chosen for its ability to manage various data formats and support efficient analysis. NVivo facilitates the processing of large and complex qualitative data, enables thematic coding, and provides visualizations of relationships between data, assisting researchers in drawing conclusions and verifying findings (Jackson & Bazeley, 2019). The categorization process involved open coding, axial coding, and selective coding of the interview data.

This study also emphasized data triangulation to ensure the diversity of perspectives obtained, thus providing a more comprehensive understanding of the challenges and dynamics of the Wolbachia program's implementation. Through this approach, the study aims to offer a clearer picture of the application of pentahelix collaboration in public health contexts, particularly in vector-borne disease control programs like dengue.

Result and Discussion

The implementation of Wolbachia in Buleleng Regency is depicted in figure 1, highlighting essential components and factors.

Communication

Communication is a crucial element in the implementation of Wolbachia in the Buleleng Regency. According to figure 1, four key aspects of communication, transmission, clarity, consistency, and verification, are essential for successful policy implementation. Clear information about a policy is

paramount for its effective implementation, as it enables implementers to understand the necessary steps and preparations. A comprehensive understanding of the policy, facilitated by adequate information, enhances the likelihood of a program's success.

Despite the preparation of comprehensive communication materials by the technical team, gaps remained in the dissemination of information to communities and relevant stakeholders. Existing materials tend to emphasize initial program socialization rather than provide in-depth coverage of technical and managerial aspects. Consequently, communities and stakeholders lack a nuanced understanding of the Wolbachia method, including its potential benefits, risks, and technical procedures.

Considerable uncertainty regarding the Wolbachia program's status also emerged, with speculation about

its continuation or cessation. This ambiguity led to confusion within the community. Furthermore, technical details about the program's implementation, such as schedules, locations, and procedures, were not effectively communicated to all relevant parties. This left key questions unanswered, particularly for those directly involved in implementation.

Program socialization efforts reached various levels, from local governments to villages. However, the distribution remained uneven, failing to engage all segments of society. Some parties were invited only to initial general socialization, resulting in limited comprehension. To enhance public understanding and participation, it is imperative to implement more intensive and targeted socialization initiatives within the broader community.

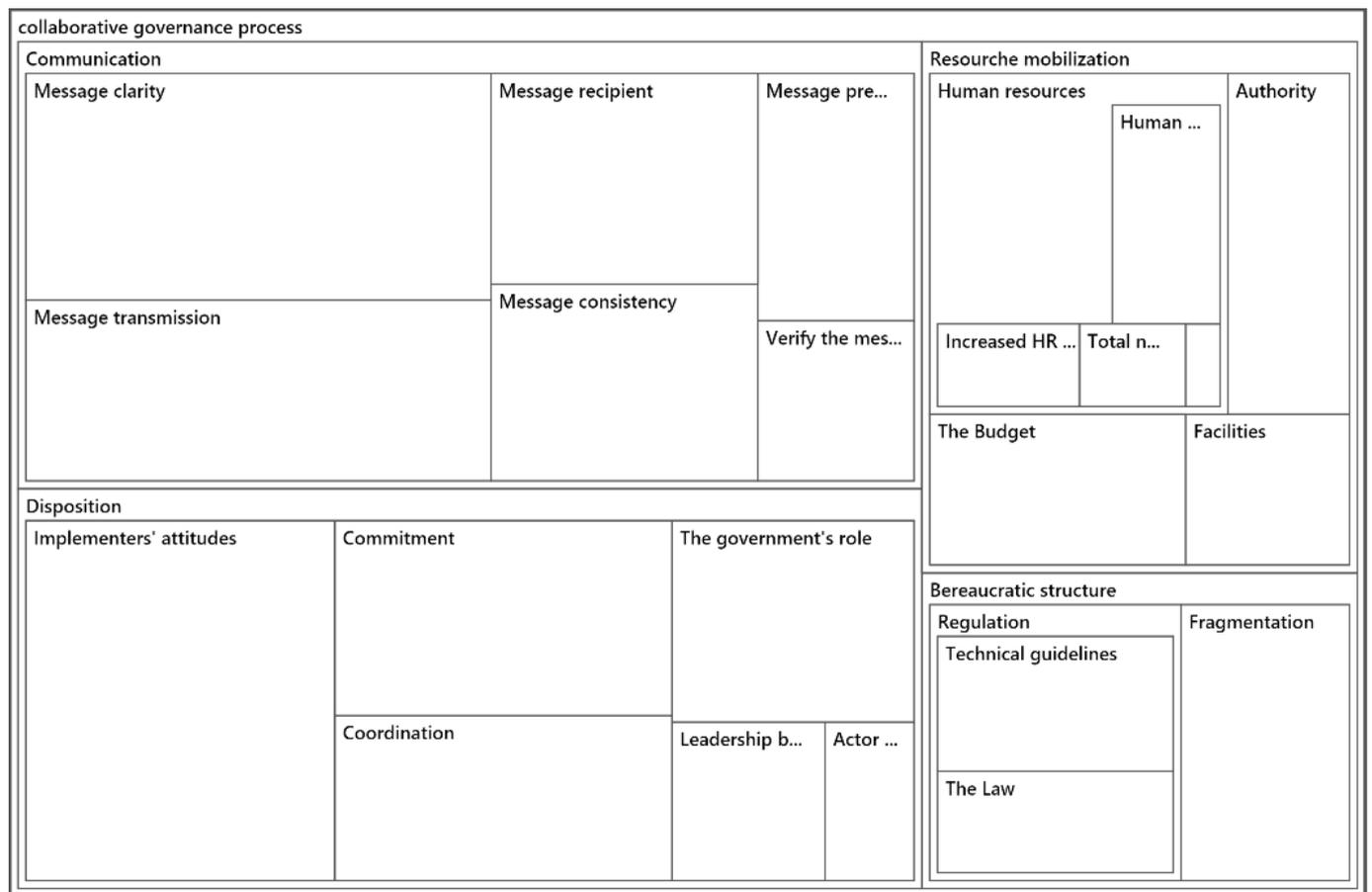


Figure 1. Visualization of The Challenges in Implementation of Wolbachia
Source: Nvivo12+ Processed by Researchers

The use of communication media varied, encompassing meetings, WhatsApp groups, social media platforms, and local mass media outlets. However, the effectiveness of these media in achieving desired outcomes requires further enhancement. Conventional media such as posters and banners have not been optimally employed, particularly in strategic

locations. Furthermore, information disseminated through social and mass media requires a greater structure and direction to avoid confusion and misinformation.

Inter-stakeholder communication was generally satisfactory. Challenges arose in direct communication between the Health Office and certain relevant parties.

This finding highlights the necessity for more frequent and intensive communication, both in-person and through online platforms, to ensure shared understanding and effective coordination among all stakeholders.

A lack of consistency was observed in both information delivery and program implementation. Negative news coverage in mass media significantly influenced community perceptions and acceptance of the program. This emphasizes the need for more rigorous information verification and rapid response mechanisms to address emerging issues. Information verification efforts undertaken by the Health Office and Wolbachia team, in collaboration with local journalists and through social media education, require further refinement and expansion.

The communication gaps are also shaped by social and cultural factors. Local beliefs, values, and education levels influence how the community perceives new technologies, such as genetically modified organisms like Wolbachia-infected mosquitoes. In some areas, traditional beliefs about nature create resistance, especially when the program is seen as an interference with the natural order. Socioeconomic factors, including education, further affect understanding and acceptance. People with higher education or more exposure to scientific literature tend to be more receptive, while those with lower literacy levels may struggle to comprehend the scientific foundation of the program.

Similar challenges have been observed in other regions, where public health innovations, particularly biotechnological interventions, have faced skepticism due to cultural concerns. For example, genetically modified organisms (GMOs) and vaccines have encountered resistance in Southeast Asia due to cultural beliefs, mistrust of authorities, and limited education (Utarini et al. 2021; Sundqvist-Andberg and Åkerman 2022). These studies emphasize the importance of addressing cultural values and educational disparities when introducing new health technologies.

To ensure the success of the Wolbachia program, communication strategies must be culturally sensitive and tailored to meet the community's educational needs. Engaging with local beliefs and perspectives in a way that builds trust and understanding will help bridge the gap between scientific knowledge and public acceptance, fostering a more supportive environment for the program. Involving trusted community leaders and health experts in the communication process is essential for addressing skepticism about genetic modification. This strategy can help alleviate fears and build a more supportive framework for the intervention, as highlighted in the success of similar initiatives (Ullah & Kim, 2020; Saarikoski et al., 2018).

Communication strategies should be adjusted to the specific educational levels within communities. In regions where traditional beliefs may hinder acceptance of new technologies, it is essential to incorporate culturally relevant explanations and collaborate with trusted local figures. Providing clear and scientifically accurate information while respecting local values can improve the perception of Wolbachia technology and encourage public participation in the program (Mcnaughton et al., 2014).

Bureaucratic Structure

The bureaucratic structure of the collaborative governance in the Wolbachia program is complex, involving multiple stakeholders across various levels. This complexity has contributed to fragmentation in program implementation due to the unclear delineation of roles and responsibilities among stakeholders.

The organizational structure of the Wolbachia program in the Buleleng Regency is intricate, encompassing a multitude of stakeholders from the central to the local level. This intricacy has engendered ambiguity regarding the division of tasks and responsibilities among various parties, subsequently leading to fragmented program implementation. This fragmentation is evident in the organizational structure, which includes the Bali Project Adviser Committee (BPAC) at the apex and the Community Reference Group (CRG) at the grassroots level. Despite this, the roles and responsibilities of these entities remain undefined.

This lack of clarity extends to the role of individual stakeholders within the implementation team. Some stakeholders report limited meaningful involvement owing to a lack of clarity regarding their expected tasks and contributions. Such ambiguity hinders effective collaboration and coordination between the involved parties throughout the program's execution.

The Wolbachia program is supported by directives from the health office and a cooperation agreement between the non-governmental organization (NGO) and the provincial government. The absence of clear regulations from the Ministry of Health, particularly regarding technical guidelines, has emerged as a significant obstacle. The lack of detailed technical guidelines has resulted in confusion among program implementers, because there is no definitive guidance on the operational steps, standard procedures, or monitoring mechanisms to follow.

The unresolved Memorandum of Understanding (MoU) with the province underscores that administrative and regulatory aspects of the program remain underdeveloped. A circular letter from the Ministry of Health exists, but its lack of binding force and detailed regulatory mechanisms leads to

inconsistent interpretations and implementation at the regional level. This inconsistency could undermine the overall coherence and effectiveness of the program.

The effectiveness of the bureaucratic structure is influenced by external factors, including education and access to scientific information, which shape public understanding and acceptance of Wolbachia technology. Higher education and greater exposure to scientific literature generally lead to more openness toward new technologies, while lower literacy levels can hinder comprehension. Disparities in access to communication platforms, such as local schools, social media, and community organizations, further exacerbate this divide. Studies show that individuals with higher education are more likely to support Wolbachia due to their greater exposure to scientific knowledge (Soh et al., 2021). Tailored communication strategies are necessary to address knowledge gaps and misinformation, ensuring clear, accessible information that enhances the program's effectiveness (Liew et al., 2021).

The impact of the bureaucratic structure on program implementation aligns with Ansell & Gash (2008) assertion that clear role distribution is vital for the success of collaborative initiatives. Emerson et al. (2012) emphasize the importance of an integrated bureaucratic structure to prevent fragmentation and ensure effective coordination. Prehoda et al. (2019) point out that ambiguous bureaucratic structures hinder stakeholder engagement, a challenge observed in the Wolbachia program. Kuye & Akinwale (2021) suggest addressing these issues by establishing clearer guidelines, enhancing communication strategies, and ensuring comprehensive stakeholder engagement, which would enable the program to better meet its objectives and improve its impact on public health.

The Dispositions

The implementation of the Wolbachia method in the Buleleng Regency revealed varying levels of commitment, suboptimal roles among implementers, a dominant governmental role, and inconsistent leadership styles.

Stakeholder commitment to the Wolbachia program in Buleleng Regency exhibited notable variation. While a general consensus in support of the program was observed, the degree of involvement and active participation among the parties differed substantially. Some stakeholders demonstrated strong commitment through direct involvement in program socialization, education, and monitoring activities. However, others expressed verbal support without corresponding tangible actions.

This discrepancy in commitment is evident for several indicators. For instance, not all stakeholders involved in the program were willing to formally

endorse it by signing integrity pacts. Furthermore, some parties participated only in the initial general socialization, suggesting a lack of sustained interest in the program's implementation. The variability in commitment observed in this study aligns with findings from previous research, which underscore the importance of active community engagement and participation in ensuring the success of vector control interventions, such as the Wolbachia method. A study conducted in Yogyakarta, Indonesia, demonstrated a significant reduction in dengue cases through the implementation of the Wolbachia method, highlighting the necessity of strong community support to ensure the effectiveness of such interventions.

Despite the inclusion of a diverse range of implementers in the Wolbachia program, encompassing local government officials to community members, the roles and contributions of each party were not optimally delineated. This lack of clarity regarding the division of tasks and responsibilities engendered feelings of ambiguity among some implementers who perceived that their roles within the program were neither clearly defined nor substantively significant. Such ambiguity may have negatively impacted their motivation and enthusiasm to contribute optimally to the program's objectives. Research has shown that clearly defined roles and responsibilities are essential for the success of public health interventions, particularly those that involve emerging technologies like Wolbachia (Rumaizah et al., 2022).

At the local government level (Table 1), the dominant role is characterized by decision-making and policy formulation. However, there remains potential for enhancing the involvement of local communities in the technical implementation and field monitoring of the program. At the community level, the role of beneficiaries has not been fully realized because of a lack of understanding and awareness of the Wolbachia method and its associated benefits. Sustained community engagement and education play a critical role in garnering support for vector control methods, including Wolbachia, with the establishment of robust engagement frameworks being essential to addressing public concerns and fostering acceptance of novel interventions (Id et al., 2021; Mcnaughton et al., 2014).

The local government, specifically the Regent of Buleleng, played a pivotal role in the implementation of the Wolbachia program. Support and direction from the regent were the primary drivers of the program's implementation. However, there were also indications of hesitation and ambiguous attitudes from certain parties within the government, particularly following circular letters from the Governor and Regent regarding the program's postponement. This ambiguity engendered confusion and uncertainty at the

implementation level, potentially hindering smooth execution of the program. The importance of consistent leadership and clear communication in public health initiatives is well-documented, as it directly impacts the effectiveness and sustainability of interventions (Costa et al., 2021).

Shifts in government leaders' attitudes, specifically concerning program continuation, engendered difficulties and confusion at the operational level. The absence of clear and decisive guidance from leadership hinders implementers' ability to make informed

decisions and execute their responsibilities effectively. The lack of clarity regarding the program's direction and objectives can undermine the implementer's motivation and commitment. This highlights the need for stable and supportive leadership structures in implementing innovative public health strategies like the Wolbachia method. Effective community engagement and leadership are critical for the success of such programs, as demonstrated by successful implementations in other regions (Rumaizah et al., 2022; Costa et al., 2021).

Table 1. Role of The Pentahelix Elements in The Implementation of Wolbachia

Pentahelix elements	Stakeholder roles in Wolbachia implementation
Government	The person in question held a crucial role in the decision-making process and policy development. Their impact was significantly strengthened by the backing of the Regent of Buleleng, despite uncertainty from certain government officials regarding the program's future after the circular letter from the Governor and Regent.
Private sector	This individual was additionally responsible for the development of communication and socialization materials and securing primary funding for the program. Despite the individual's efforts, the socialization efforts have not proven as effective as intended, and certain segments of the population have not been fully reached.
Local communities	Community participation appears to be confined to a select group of community leaders, with a scarcity of representation from diverse segments of society.
Media	The media holds a vital position in the dissemination of information to the general public. Unfortunately, the presence of inconsistencies in reporting and the absence of strict verification procedures impede the media's ability to fulfill this crucial function.
Academics/research institutions	The relative involvement of academics in this study has been comparatively limited.

Resource Mobilization

Funding for the Wolbachia program in Buleleng Regency was primarily sourced from foundations and local government. This foundation serves as the primary contributor, highlighting reliance on external sources for program implementation. The local government's participation in providing additional budgetary support indicates its commitment to and endorsement of the program. However, detailed information on the proportional contribution of each funding source, budget management mechanisms, and potential obstacles to program funding remains undisclosed. Resch & Hecht (2018) demonstrated that shifting the financial responsibility for health programs from external donors to domestic governments is essential for sustainability, though it presents challenges, including setting equitable funding expectations and mobilizing local resources.

The program involves personnel from various agencies, including the Health Office, primary healthcare, and health cadres. This cross-agency involvement demonstrates collaboration and synergy in the program implementation. Capacity-building initiatives for cadres and health centre surveillance personnel have also been implemented to enhance cadre competence. The critical role of multi-stakeholder coordination mechanisms in ensuring the successful

implementation of health programs is emphasized, particularly when addressing complex health issues that require intersectoral collaboration (World Health Organization, 2015; UN_Habitat, 2021).

Furthermore, the program utilizes a range of facilities including operational vehicles, field equipment, and meeting rooms. The availability of these resources suggests adequate logistical support for the program implementation. However, information regarding the adequacy and quality of these facilities as well as their management and maintenance protocols is lacking. The role of facilities management in healthcare is critical for ensuring safe, accessible, and efficient environments, which ultimately impacts the delivery of quality care.

The Wolbachia program operates under a tripartite governance structure comprising central, provincial, and district governments. The central government issued a circular letter outlining the program, while provincial and district governments were responsible for its implementation and oversight within their respective jurisdictions. Effective coordination among these three levels of government is essential to ensure smooth operation and alignment of the program. However, information regarding existing coordination mechanisms, potential barriers to coordination, and

conflict resolution processes between governmental levels remains elusive.

The discussion between the results of this study and the literature review is as follows:

Vagueness and Inconsistency of Communication

In policy implementation, clear and consistent transmission of information to stakeholders and the wider public is paramount. Utilizing diverse information media, both conventional and digital, has been employed to achieve this (Ansell and Gash 2018). Research in the Buleleng Regency reveals that mass media significantly influences community acceptance of the Wolbachia program, illustrating a form of social construction through media (Gisler & Sasse, 2022). Discussion forums such as the Bali Project Advisory Committee (BPAC) and Community Reference Group (CRG) serve as effective platforms for information transmission and idea exchange among stakeholders. However, challenges persist in reaching all segments of society, particularly ensuring equitable information dissemination.

Messaging clarity is crucial for policy communication. Despite tiered socialization efforts, doubts and questions regarding the safety of the Wolbachia method persist in the community. The lack of clarity regarding the mechanism of the method and supporting scientific evidence coupled with inadequate technical guidance has contributed to community distrust and resistance.

The implementation of Wolbachia presents a challenge because of the lack of consistency in information. Negative issues circulating within the community regarding the potential adverse effects of Wolbachia can erode public trust and acceptance. The absence of counterinformation from authorities exacerbates this issue, underscoring the need for consistent and responsive communication among relevant parties (Saarikoski et al., 2020).

Overall, this study underscores the significance of efficacious, transparent, and consistent communication in policy implementation, particularly within a pentahelical collaborative framework (Emerson et al., 2012). Deficiencies in communication and coordination can impede effective collaboration and jeopardize program success. Although educational efforts through social media and collaboration with local journalists are promising, further enhancements are necessary to ensure successful policy implementation.

Ambiguity and inconsistency in communication have emerged as major challenges. Although communication materials have been developed to a high standard, the dissemination of comprehensive information to the community and relevant stakeholders is suboptimal. This observation aligns with the research

of Ansell and Gash (2007), which emphasizes the critical role of clear and comprehensive communication in collaborative governance. Ambiguous information, particularly regarding a program's status and technical implementation, can engender confusion and distrust within the community.

While program socialization efforts have reached various levels, inclusivity and equity remain concerns. Some stakeholders were invited only to initial general socialization, resulting in a limited understanding. This finding is consistent with Prehoda et al. (2019), which underscores the importance of inclusive stakeholder engagement in effective communication within collaborative governance frameworks. Therefore, more intensive and targeted socialization initiatives aimed at a broader community are warranted to enhance the understanding and acceptance of the program.

The utilization of communication media has been diverse, yet its efficacy requires further improvement. Conventional media, such as posters and banners, have not been optimally employed, and information disseminated through social and mass media necessitates greater structure and targeted messaging. This aligns with the findings of Ullah and Kim (2020), who emphasized the importance of selecting the most appropriate and effective communication media to achieve communication objectives.

The lack of consistency in messaging and absence of rigorous information verification processes pose significant challenges in program implementation. The dissemination of unverified negative news through mass media channels can create confusion and distrust within the community. This finding aligns with the conclusions of Dressel et al. (2020), who emphasized the importance of message consistency and information verification in fostering public trust. Therefore, it is imperative that the information verification efforts undertaken by the Health Office and the Wolbachia team be refined and expanded.

While communication among stakeholders was generally effective, challenges persisted in the direct communication between the Health Office and certain relevant parties. This finding suggests a need for improvements in the intensity and quality of communication. Ullah and Kim (2020) underscore the importance of open, transparent, and participatory communication among stakeholders within collaborative governance frameworks. Increasing the frequency and intensity of direct communication can strengthen coordination and collaboration among parties, thereby enhancing the program effectiveness.

Clarity, consistency, and effective transmission constitute the three interrelated facets of successful communication. To ensure effective dissemination of information through mass media, discussion forums,

and other channels, messages must be conveyed in a clear and consistent manner. Ambiguity or inconsistency in messaging can lead to misinterpretation and public distrust, as evidenced in the Wolbachia case in Buleleng.

Effective communication plays a pivotal role in fostering positive disposition among policy implementers. When implementers possess a comprehensive understanding of the policy at hand, they are more likely to exhibit support for and commitment to implementation. Therefore, it is imperative to ensure transparent and open communication across all bureaucratic levels from the village to the central government. In the absence of clarity in the communication and coordination between these levels, policy implementation may be significantly hindered.

Non-optimal Coordination and Division of Roles

This study revealed deficiencies in coordination and role delineation among stakeholders involved in the implementation of the Wolbachia method in Buleleng Regency. Suboptimal coordination is evident in the ambiguity surrounding the roles and responsibilities of each party, particularly regarding task allocation at the implementation level. This finding is consistent with that of Siangulube et al. (2023), who demonstrated that unclear roles and responsibilities can lead to conflicts and impede collaborative progress. Inadequate coordination and unclear role delineation can negatively impact policy implementers disposition. When task division is ambiguous, some implementers may perceive their roles as insignificant and feel disengaged from the program. This can diminish their motivation and enthusiasm to contribute, as evidenced by the findings of this study, wherein some informants expressed uncertainty regarding their role in the program.

Furthermore, unclear roles and responsibilities can exacerbate structural issues within the bureaucracy. The complex organizational structure of the Wolbachia program, which involves diverse stakeholders from the central to local levels, can be further complicated by the absence of a clear division of tasks. This ambiguity can result in overlapping responsibilities, confusion in decision-making processes, and potential conflicts of interest among the agencies (Chu et al., 2024).

A lack of clarity regarding roles and responsibilities (a sub-indicator of coordination) can significantly influence the disposition of policy implementers. When implementers lack a comprehensive understanding of their roles and responsibilities, they may exhibit diminished program ownership and motivation to contribute optimally. This can negatively affect the quality of policy implementation, as evidenced by

Woldesenbet (2021), indicating that ambiguous roles and responsibilities can hinder effective collaborative governance.

Unclear roles and responsibilities can also adversely affect the bureaucratic structure. In the absence of a clear division of tasks, overlapping responsibilities and authorities may arise between agencies, potentially impeding inter-agency coordination and communication. This finding aligns with research by Chu et al. (2024), who identified unclear roles and responsibilities as substantial challenges in the implementation of collaborative governance.

Uncertainty of Regulation

Regulatory ambiguity has emerged as a substantial obstacle to the implementation of the Wolbachia method in Buleleng Regency. This lack of clarity was particularly evident in the absence of robust and specific regulations from the Ministry of Health, particularly concerning technical guidelines. This finding aligns with that of Proksik et al. (2023), who identified the absence of legal requirements as a major barrier to the implementation of public health policy. Similarly, Waller et al. (2024) noted a lack of clear policy directives, including technical guidelines, as impediments to successful implementation.

A lack of regulatory clarity directly affects policy implementation. The absence of detailed technical guidelines creates confusion among program implementers who lack clear guidance on operational steps, standard procedures, and monitoring mechanisms. This can lead to inconsistencies in program implementation across different regions, and potentially to deviations from the program's original objectives. Weckström & Mladenović (2020) similarly highlighted that policy implementation challenges can encompass political and financial constraints, as well as insufficient attention to potential policy ramifications.

The pending Memorandum of Understanding (MoU) with the province highlights the inadequacies of administrative and regulatory frameworks. Despite being circular from the Ministry of Health, the lack of stringent regulations leaves the program open to varied interpretations and regional implementation, increasing its overall effectiveness and sustainability. Regulatory ambiguity exacerbates fragmentation among stakeholders, leading to overlaps and conflicts due to undefined roles and responsibilities, as noted by Rochette et al. (2023). This ambiguity also hampers inter-agency coordination, as agencies may adopt inconsistent approaches in the absence of clear implementation directives, thus obstructing the program's smooth execution.

Limited Community Participation

In this study, the three sub-indicators of community participation, including engagement, understanding, and trust, are intrinsically connected. A lack of involvement can engender a lack of understanding and trust. When communities are not actively engaged in decision-making processes and program implementation, they tend to lack sufficient information and a sense of the program ownership. This can result in diminished trust in both the program itself and the parties involved. Conversely, lack of understanding can lead to limited involvement and distrust. When communities are unaware of a program's objectives, benefits, and risks, they may hesitate to engage and participate. This lack of understanding can also foster concern and distrust in the program (Siangulube et al., 2023).

This study revealed that community participation in the implementation of the Wolbachia method in the Buleleng Regency remained limited. This was evident in several respects: the community was not actively involved in the decision-making process or program implementation. Their participation was confined to initial general socialization, and no clear mechanism existed to facilitate their involvement in program planning or evaluation. This finding aligns with the research of Ullah and Kim (2020), who emphasize the importance of community participation in collaborative governance to enhance policy legitimacy and effectiveness.

In this study, the community demonstrated limited understanding of the Wolbachia method, including its potential benefits, risks, and broader public health implications. This may be attributable to the insufficient provision of clear and comprehensive information, as well as their limited involvement in socialization and educational initiatives. This knowledge gap can foster distrust and resistance to the program (Mukhlis & Perdana, 2022).

The community exhibited a lack of trust in the government and parties involved in the implementation of the Wolbachia program. This distrust likely stems from a confluence of factors, including lack of transparency in the decision-making process, ambiguous information dissemination, and prior negative experiences with other health initiatives. This lack of trust poses a significant challenge to program implementation, as individuals are less inclined to support or participate in programs perceived as untrustworthy (Voets et al., 2021).

This study contributes to the policy implementation literature by identifying and elaborating on several aspects that have previously been underexplored. First, it addresses the gap concerning the importance of clarity and verification in policy communication. Our findings

indicate that the clarity and verification of communication have a significant impact on the successful implementation of policies, an aspect that has been insufficiently emphasized in prior literature.

Furthermore, this research expands our understanding of the disposition variable by demonstrating that incentives not only motivate policy implementers but also enhance the clarity of their tasks. This adds a new dimension to our comprehension of how incentives can be effectively utilized in public policy implementation.

Finally, the findings provide new insights into the importance of technical guidelines in policy implementation. The study shows that the availability of technical guidelines allows implementers to adapt procedures to field conditions, thereby increasing the effectiveness of policy implementation. The theoretical implications of these findings suggest the need to revise the policy implementation framework to incorporate technical guidelines as a critical factor.

Conclusion

The implementation of the Wolbachia program in Buleleng utilizing a pentahelix collaborative framework demonstrated its potential to mitigate the incidence of dengue fever. However, the collaborative governance process has not been fully optimized, particularly concerning communication and bureaucratic structures, thus affecting program effectiveness. Challenges related to stakeholder comprehension and role ambiguity require further investigation. To address these challenges, policymakers should consider implementing a structured communication framework that ensures clarity and transparency in policy dissemination, as well as establishing clear roles and responsibilities for all stakeholders involved. Additionally, fostering community engagement through participatory models, such as the Public Acceptance Model used by the World Mosquito Program, can enhance program acceptance and effectiveness.

This study makes significant contributions to the policy implementation literature by addressing key, yet previously underexplored, aspects. First, it highlights the critical role of clarity and verification in policy communication, demonstrating their substantial impact on the successful implementation of policies, an area that has been insufficiently emphasized in prior literature. Policymakers should prioritize developing clear, accessible communication strategies to ensure that all stakeholders are well-informed and aligned with program objectives.

Furthermore, the research expands our understanding of the disposition variable by illustrating that incentives not only motivate policy implementers

but also enhance the clarity of their tasks. This insight adds a new dimension to our comprehension of how incentives can be effectively utilized in public policy implementation. Stakeholders should consider incorporating incentives that promote both motivation and task clarity, potentially through performance-based rewards or capacity-building programs.

Moreover, the findings provide new insights into the importance of technical guidelines in policy implementation. The study indicates that the availability of technical guidelines enables implementers to adapt procedures to field conditions, thereby increasing the effectiveness of policy implementation. These theoretical implications suggest the necessity of revising the policy implementation framework to incorporate technical guidelines as a critical factor. Policymakers should ensure that comprehensive technical guidelines are developed and disseminated to all implementers, facilitating flexible and effective program execution.

The successful implementation of Wolbachia technology can be greatly enhanced by emphasizing educational initiatives, particularly in training health workers and engaging communities. Strategies aimed at increasing scientific literacy through community-based workshops or educational campaigns are essential for fostering broader acceptance of health innovations. Policymakers should integrate these educational efforts into the program to boost public understanding, trust, and participation, ensuring alignment with educational and science dissemination objectives. Effective science education is key to building a strong foundation for public acceptance of new technologies. By enhancing scientific knowledge and addressing local concerns, we can reduce skepticism, improve program success, and strengthen cross-sector collaboration, ultimately establishing a trustworthy foundation for public health innovations.

However, this study has several limitations. The sample size used is relatively small, so generalizing the findings should be done with caution. Additionally, potential response biases, such as social desirability bias or selection bias, may have influenced the results. For future research, it is important to conduct further studies on the impact of incentives in various cultural contexts and to perform longitudinal analyses to examine the effects of technical guidelines on pilot projects. New hypotheses that could be tested include how variations in bureaucratic structures might affect policy implementation at different levels of government.

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Author Contributions

Conceptualization was carried out by LHN and NWW. Data curation was performed by LHN and NWW. Funding acquisition was handled by LHN and NWW. Methodology development was contributed by LHN and NWW. Visualization tasks were undertaken by LHN and NWW. Writing of the original draft was completed by LHN and NWW, while the review and editing process were also conducted by LHN and NWW.

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Conflicts of Interest

We certify that there is no conflict of interest with any financial, personal and other relationships with other peoples or organization related to the material discussed in the manuscript.

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