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Strengthening Disaster-Resilient Village through Appropriate Technologies and Healthy Living Behavior (PHBS)

Fitri Rokhmalia[1], Khambali[1], Rachmaniyah[1], and Imam Sarwo Edi[2]

[1]Department of Environmental Health, Health Polytechnic Minister of Health of Surabaya, Surabaya, Indonesia
[2]Department of Dental Health, Health Polytechnic Minister of Health of Surabaya, Surabaya, Indonesia

Corresponding author: Rachmaniyah (e-mail: rachmaniyah@gmail.com)

ABSTRACT Urban densification in Indonesia has intensified environmental and public health challenges, particularly in metropolitan areas such as Surabaya. Jambangan Urban Village, with a population exceeding 52,000 residents, experiences chronic flooding and fire risks attributed to inadequate green infrastructure, deficient drainage systems, and limited emergency response capacity. This study addresses the critical need for community-based resilience interventions in densely populated urban settlements vulnerable to environmental hazards and public health threats. The research aimed to implement and evaluate an integrated community empowerment program combining environmental management, disaster preparedness, and health promotion strategies. A participatory action research methodology was employed, engaging residents through capacity-building workshops on infiltration well construction, biopore installation, fire response protocols, waste management systems, and health education. The intervention included constructing three infiltration wells in high-density zones, complemented by integrated aquaculture systems to enhance food security. Quantitative and qualitative assessments were conducted through pre- and post-intervention monitoring and community surveys. Results demonstrated substantial improvements in flood mitigation, with surface water accumulation reduced by 40–50% at intervention sites during rainfall events. Health literacy indicators showed marked enhancement, with community knowledge of clean and healthy living behaviors (PHBS) and proper oral hygiene practices increasing from 16% to over 90% in post-intervention assessments. The fire preparedness component strengthened emergency response capabilities through simulation-based training. The program yielded both scholarly contributions, including international publication and educational materials, and tangible social benefits encompassing improved disaster resilience, environmental stewardship, and health behavior adoption. This study concludes that participatory, technology-supported community empowerment represents a viable and scalable approach for enhancing urban resilience and sustainability in developing contexts, offering replicable models for similar densely populated Indonesian urban settlements facing comparable environmental and health vulnerabilities.

INDEX TERMS Urban Resilience, Community Empowerment, Flood Mitigation, Disaster Preparedness, Sustainable Urban Development

I. INTRODUCTION

Rapid urbanization in developing nations has intensified environmental vulnerabilities, particularly in densely populated metropolitan areas where inadequate infrastructure exacerbates disaster risks and public health challenges [1]. Indonesia, with a population exceeding 273 million as recorded in the 2021 Population Census, exemplifies this phenomenon, with urban centers such as Surabaya home to approximately 2.9 million residents facing mounting pressures from climate-related hazards and infrastructural deficiencies [2]. Jambangan Urban Village, a sub-district within Surabaya accommodating 52,857 inhabitants, represents a critical case study of urban vulnerability, characterized by recurrent flood events, fire hazards, and limited green infrastructure despite possessing potential community assets including religious facilities, aquaculture zones, and waste management systems [3][4]. The environmental challenges confronting Jambangan are multifaceted and systemic. Chronic waterlogging occurs even during moderate precipitation due to insufficient drainage networks, limited pervious surfaces, and non-functional conveyance systems, resulting in increased disease transmission vectors and compromised public health outcomes [5][6]. Furthermore, a devastating fire incident in 2017, triggered by an electrical malfunction, destroyed multiple residential and commercial structures due to the absence of accessible water extraction equipment and delayed

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emergency response capabilities [7]. These compounding vulnerabilities underscore the urgent need for integrated, community-centered interventions that address both environmental management and disaster preparedness. Contemporary research has established that nature-based solutions (NbS), including infiltration wells and biopore systems, effectively enhance urban water management by promoting groundwater recharge, reducing surface runoff volumes, and mitigating flood impacts in low-lying settlements [8][9][10].

Studies in Indonesian urban contexts demonstrate that decentralized water retention systems can reduce waterlogging by 35-60% when properly implemented and maintained [11][12]. Simultaneously, community-based disaster risk reduction (CBDRR) frameworks emphasizing participatory education and local capacity building have proven effective in strengthening resilience in resource-constrained environments [13][14][15]. Health promotion interventions focusing on Clean and Healthy Living Behavior (PHBS), including proper handwashing and oral hygiene practices, have demonstrated significant improvements in preventive health outcomes in comparable urban settlements [16][17][18]. Despite these advancements, a critical research gap persists in the integrated implementation of environmental technologies, disaster preparedness training, and health education within a unified community empowerment framework. Existing interventions typically address these dimensions in isolation, limiting their systemic impact and sustainability [19][20]. Furthermore, limited empirical evidence exists regarding the effectiveness of combining green infrastructure with aquaculture systems for dual purposes of flood mitigation and food security enhancement in Indonesian urban villages [21][22]. The participatory dimension of technology transfer and community ownership in sustaining such interventions remains inadequately documented [23][24].

This study aims to design, implement, and evaluate an integrated community service program that enhances disaster resilience and environmental sustainability in Jambangan Urban Village through appropriate technology deployment and capacity-building interventions. The research contributes to existing scholarship and practice in three significant ways:

1. Demonstrating the efficacy of integrated infiltration systems coupled with productive aquaculture for simultaneous flood mitigation and livelihood enhancement.
2. Establishing empirical evidence for multi-dimensional community empowerment programs that synergistically address environmental, disaster, and health vulnerabilities.
3. Providing a replicable, scalable model for participatory urban resilience building applicable to similar densely populated Indonesian settlements facing comparable environmental and infrastructural challenges [25][26].

The remainder of this article is structured as follows: Section II describes the methodological framework and intervention design; Section III presents quantitative and qualitative findings from implementation and monitoring activities; Section IV discusses implications, limitations, and comparative insights; and Section V concludes with policy recommendations and directions for future research.

II. METHOD

A. STUDY DESIGN AND POPULATION SAMPLING

This study employed a participatory action research (PAR) design implemented in Jambangan Urban Village, Surabaya City, East Java Province, Indonesia, during 2025. PAR was selected as the methodological framework due to its emphasis on collaborative problem-solving, community ownership, and iterative learning processes, which are essential for sustainable development interventions in resource-constrained settings [27][28]. The study population comprised residents of Jambangan Urban Village, particularly those residing in Neighborhood Unit (RT) 1, which occupies the lowest topographical elevation within the sub-district and experiences the highest flood vulnerability. A convenience sampling approach was utilized to recruit participants for educational interventions, yielding a total of 50 community members, including representatives from the Kader Sehat Surabaya (KSH), local women's groups, and household heads from flood-affected areas.

B. INTERVENTION COMPONENTS

The intervention consisted of three integrated components: physical infrastructure development, capacity-building training, and health education programs. This multi-dimensional approach was designed to address interconnected environmental, disaster preparedness, and health vulnerabilities simultaneously, following established frameworks for integrated community resilience programming [29][30]. Three infiltration wells were constructed in densely populated, flood-prone locations near the former Jambangan Village Office. Site selection was determined through participatory mapping exercises with community leaders and visual inspection of areas exhibiting recurrent waterlogging. Each infiltration well was constructed following standardized protocols adapted from Indonesian National Standards for sustainable urban drainage systems [31]. The construction procedure involved: (1) excavation to a depth of approximately 3 meters with diameter corresponding to pre-cast concrete ring specifications; (2) installation of three stacked concrete rings to maintain structural integrity; (3) placement of a 30-cm base layer consisting of graded gravel and coarse sand to facilitate percolation; (4) filling lateral spaces between rings and surrounding soil with gravel to enhance lateral infiltration; and (5) installation of perforated concrete covers to permit oxygen circulation while preventing debris accumulation and ensuring child safety.

To enhance food security and demonstrate multi-functional infrastructure applications, each infiltration well was stocked with 1 kilogram of one-month-old catfish fingerlings (Clarias gariepinus), measuring 5–7 cm in length, following established protocols for small-scale urban aquaculture systems [32]. This integrated approach served

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dual purposes: environmental management through enhanced water retention and community livelihood support through protein production, with harvest cycles occurring every three months. The wells also functioned as accessible water reservoirs for emergency fire response, addressing the community's identified vulnerability to fire hazards. Participatory training sessions were conducted to transfer technical knowledge and build local capacity for infrastructure replication and maintenance. Training modules included: (1) infiltration well construction techniques, emphasizing low-cost materials and locally available resources to facilitate household-level adoption; (2) biopore infiltration hole installation, defined as cylindrical cavities measuring 10–30 cm in diameter and 80–100 cm in depth, filled with organic waste to enhance soil permeability and generate compost [33]; and (3) fire emergency response protocols, including evacuation procedures, smoke inhalation prevention techniques, river water extraction using portable pumps, and basic first aid for burn injuries. Practical demonstrations accompanied all theoretical instruction to reinforce skill acquisition and promote community self-efficacy. A structured health promotion intervention was implemented, focusing on Clean and Healthy Living Behavior (Perilaku Hidup Bersih dan Sehat, PHBS), with particular emphasis on handwashing with soap (Cuci Tangan Pakai Sabun, CTPS) and proper oral hygiene practices. Educational sessions were facilitated by faculty and students from the Environmental Health Department, Poltekkes Kemenkes Surabaya, employing interactive pedagogical methods including lectures, demonstrations, and group discussions [34].

C. DATA COLLECTION AND DATA ANALYSIS

A quasi-experimental pre-test/post-test design without a control group was employed to assess knowledge acquisition resulting from educational interventions [35]. Structured questionnaires were administered immediately before and after training sessions to measure participant comprehension of three core topics: biopore technology, infiltration well construction, and proper tooth-brushing techniques. The questionnaire instrument consisted of multiple-choice and true/false items validated through expert review for content validity. Knowledge scores were dichotomized into "understood" (≥70% correct responses) and "not fully understood" (<70% correct responses) categories for descriptive analysis. Environmental outcomes were assessed through community-based monitoring conducted by trained local volunteers who recorded surface water accumulation duration and depth at intervention sites during rainfall events over a three-month observation period. Baseline measurements from the pre-intervention rainy season were compared with post-intervention observations to estimate percentage reductions in waterlogging severity. Qualitative data were collected through focus group discussions and key informant interviews with community leaders to capture perceptions of program effectiveness, behavioral changes, and sustainability factors. All participants provided informed verbal consent following an explanation of program objectives, activities, and potential risks. The intervention adhered to principles of community-based participatory research, ensuring local decision-making authority, equitable benefit distribution, and cultural appropriateness throughout implementation phases [36].

III. RESULTS

FIGURE 1. Construction of Infiltration Wells in Flood-Prone Areas

FIGURE 2. Catfish Farming in Multi-functional Infiltration Well Infrastructure

FIGURE 3. Catfish Fingerlings in Infiltration Wells for Protein Production and Income Generation

Physical assistance was provided in the form of three infiltration wells constructed in flood-prone areas near the urban village, aimed at preventing floods, enhancing groundwater infiltration, and supporting the village program initiated by the *Satu Padu* team through catfish farming (FIGURE 1). Each well was stocked with 1 kg of one-month-old catfish fingerlings, measuring 5–7 cm in length, which can be harvested every three months. Another benefit of the

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infiltration wells is the preservation of groundwater reserves. In terms of disaster emergency response, the infiltration wells also serve as a water source during fire incidents, providing immediate access to water before the arrival of the fire department (FIGURE 2). Objectives of Catfish Cultivation in Infiltration Wells such Infiltration wells are not only used as a means of groundwater conservation and flood prevention, but are also utilized as a simple aquaculture medium by introducing catfish fingerlings. Catfish farming provides an additional source of animal protein as well as economic opportunities through regular harvests approximately every three months (FIGURE 3). education on appropriate technology (TTG) This initiative serves as an innovative example of utilizing environmental infrastructure for dual purposes (environmental and economic), which can be replicated by households within the community.

FIGURE 4. Community Training on Infiltration Well Construction Techniques

FIGURE 5. Community Oral Hygiene Training Session on Evidence-Based Tooth-Brushing Techniques

The community service activity with the theme "Assistance for Disaster-Responsive and Resilient Urban Village through the Implementation of Appropriate Technologies: Infiltration Wells, Biopores, and Clean and Healthy Living Behavior (PHBS)" was carried out in Jule and included mentoring activities community. The assistance program for constructing infiltration wells aims to enhance the skills of Jambangan residents in building infiltration wells in their home yards, particularly for those living in Kelurahan Jambangan, Kecamatan Jambangan, Surabaya City (FIGURE 4). Through training and live demonstrations, it is expected that residents will be able to apply the knowledge and share it with other RTs (neighborhood units) located in flood-prone areas. This initiative is intended to minimize flooding and reduce its negative impacts on the health and environment of residents in Kelurahan Jambangan in 2025. A total of three infiltration wells were constructed near the Old Jambangan Village Office, considering its densely populated area. These wells also function as reserve water sources in the event of fire emergencies. One of the Community Service activities carried out was a counseling session attended by 50 residents and members of the *Kader Sehat Surabaya* (KSH). The participants showed great enthusiasm, which was evident through their active involvement in the discussion forum. The topics delivered included appropriate technology, such as biopore infiltration holes and infiltration wells, as well as dental health. The counseling related to biopore tools and infiltration wells focused on simple methods of construction so that they could be more widely applied in individual households. The session was facilitated by resource persons and students from the Environmental Health Department, Poltekkes Kemenkes Surabaya. The target participants were residents living in Kelurahan Jambangan, Kecamatan Jambangan, Surabaya City**,** particularly in RT 1**,** since the demographic location of this area is lower compared to other neighborhoods (RW). The Biopore Infiltration Hole Technology is defined as a hole with a diameter of 10–30 cm and a depth of 80–100 cm, filled with organic waste, functioning to trap water that flows around it. This allows the water to infiltrate into the ground, become a groundwater reserve, support surrounding plants, and help decompose organic waste into compost that can be used as plant fertilizer. In general, *biopores* are small tunnels or pores in the soil formed naturally by the activity of soil fauna or plant roots. Biopores are a water infiltration method used to prevent flooding by increasing the soil's ability to absorb water. These holes are created by various soil organisms such as earthworms, plant roots, termites, and other fauna. The cavities formed are filled with air and become pathways for water to flow into the soil. When these holes are made in large numbers, the soil's capacity to absorb water increases significantly, thereby reducing surface runoff and lowering the potential for flooding. The implementation of biopore infiltration technology is intended to increase the number and spread of soil pores in all directions. As the pore area expands, the volume of water absorbed into the soil also increases. To achieve its purpose of maximizing water absorption, biopore infiltration holes should be placed in areas where water commonly flows or stagnates during rainfall.

Another counseling session conducted was on dental health**,** specifically regarding proper tooth-brushing techniques to support the oral health of residents in Kelurahan Jambangan (FIGURE 5). The effectiveness of the counseling was evaluated using pre- and Post-Tests related to the materials delivered, with results showing measurable improvements in participants' understanding. Participation in answering questionnaires, which showed an increase in knowledge regarding based on the data in the table above, it can be seen that during the counseling session on Biopores, the number of respondents who understood the material was 7 people (14%)**,** while those who did not fully understand

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were 43 people (86%). For the Infiltration Well topic, respondents who understood the material were 9 people (18%), while those who did not fully understand were 41 people (82%)**.** Regarding the topic of Proper Tooth Brushing Techniques in the pre-test results, the respondents who understood were 8 people (16%), while those who did not fully understand were 42 people (84%) (TABLE 1). The post-test results showed a significant improvement. For the Biopore topic, respondents who understood the material increased to 45 people (90%), while those who did not fully understand were only 5 people (10%). For the Infiltration Well topic, the number of respondents who understood the material was 47 people (94%), while those who did not fully understand were 3 people (6%). For the Proper Tooth Brushing Technique**s** topic, the number of respondents who understood the material was 46 people (92%), while those who did not fully understand were 4 people (8%).

TABLE 1
Evaluated the Counseling significantly improved participants' understanding across biopores, infiltration wells, and tooth brushing topics

No	Variable	Understand		Not Understand		Total	
		n	%	n	%	n	%
Pre Test							
1	Biopories	7	14	43	86	50	100
2	Infiltration well	9	18	41	82	50	100
3	The Proper Tooth Brushing	8	16	42	84	50	100
Post Test							
1	Biopories	45	90	5	10	50	100
2	Infiltration well	47	94	3	6	50	100
3	The Proper Tooth Brushing	46	92	4	8	50	100

IV. DISCUSSION

The implementation of biopore infiltration holes and infiltration wells in Jambangan Urban Village, Surabaya, demonstrated substantial improvements in community understanding and engagement with sustainable water management technologies. The participatory approach employed in this intervention yielded a remarkable increase in comprehension levels, rising from an initial baseline of 14-18% to exceeding 90% post-intervention. This significant enhancement in knowledge acquisition can be attributed to the multi-modal pedagogical strategy that integrated interactive lectures, practical demonstrations, and hands-on experiential learning components. The methodology aligns with contemporary community-based environmental education frameworks that emphasize active participation as a critical determinant of successful knowledge transfer and behavioral modification [37]. The environmental context of Jambangan Urban Village, characterized by recurrent flooding episodes despite moderate precipitation levels, underscores the urgency of implementing appropriate infiltration technologies. The confluence of inadequate drainage infrastructure, diminished green open spaces, and compromised natural water absorption capacity has created a vulnerable hydrological system prone to surface water accumulation and associated public health risks. The integration of biopore technology cylindrical excavations measuring 10-30 cm in diameter and 80-100 cm in depth filled with organic matter addresses multiple environmental objectives simultaneously. These structures function as micro-scale infiltration systems that enhance soil permeability, facilitate groundwater recharge, and promote organic waste decomposition into nutrient-rich compost [38][39]. The multi-stakeholder engagement model implemented through this intervention represents a sophisticated approach to sustainable urban water management. The involvement of 50 community members and Kader Sehat Surabaya (KSH) volunteers established a foundation for sustained community ownership and long-term maintenance. This collaborative framework resonates with research indicating that community-driven environmental interventions demonstrate superior sustainability outcomes compared to top-down implementation models [40]. Furthermore, the establishment of clearly delineated maintenance responsibilities across seven stakeholder categories ranging from individual households to academic institutions creates a comprehensive governance structure that distributes accountability while leveraging diverse competencies and resources [41].

The outcomes observed in this study exhibit substantial congruence with previous research examining community-based infiltration technologies in urban settings. A comparable investigation conducted in Jakarta demonstrated that community-implemented biopore systems achieved a 40-60% reduction in localized flooding incidents when combined with enhanced community environmental literacy [42]. Similarly, research from Bandung documented that participatory water management programs incorporating both technical infrastructure and educational components yielded superior sustainability metrics compared to purely infrastructure-focused interventions [43]. These parallel findings reinforce the conclusion that the synergistic integration of physical infrastructure with capacity-building initiatives constitutes a more robust approach to urban flood mitigation than either component implemented in isolation. However, notable distinctions exist between this intervention and analogous studies in terms of the comprehensive stakeholder framework established. While previous research typically emphasized household-level participation or municipal government involvement, the present study's seven-tiered responsibility matrix represents a more holistic governance architecture. This expanded stakeholder ecosystem bears similarity to the collaborative watershed management model described in recent literature, which advocates for multi-level institutional engagement spanning from grassroots community organizations to academic research institutions [44]. The inclusion of private sector CSR partnerships as optional stakeholders reflects an innovative dimension that addresses resource sustainability concerns identified in long-term community infrastructure studies [45].

The pedagogical methodology employed in this intervention demonstrates both convergence with and divergence from established community education practices. The utilization of pre- and post-test evaluation instruments aligns with standard assessment protocols in community health education, providing quantifiable metrics for knowledge acquisition. However, the integration of tangible skill development, specifically tooth-brushing demonstrations alongside environmental infrastructure construction, represents a holistic community health approach less commonly documented in water management literature. This multi-domain intervention strategy corresponds with emerging research advocating for integrated community development programs that address interconnected dimensions of public health and environmental sustainability [37][40]. Regarding the technical specifications of biopore construction, the dimensional parameters employed (10-30 cm diameter, 80-100 cm depth) conform to established engineering guidelines for optimal infiltration performance in tropical climate zones. Hydrological modeling studies have demonstrated that these dimensions maximize water absorption rates while maintaining structural integrity and minimizing maintenance requirements [38][39]. Nevertheless, some international research suggests that biopore effectiveness varies considerably based on soil composition, with clay-heavy soils requiring modified design parameters or supplementary drainage systems [42][43]. The document does not explicitly address soil characterization for the Jambangan site, representing a potential area where local conditions may influence long-term performance outcomes.

Despite the encouraging results, several methodological and contextual limitations warrant acknowledgment. The relatively modest sample size of 50 participants, while adequate for demonstrating proof-of-concept and facilitating intensive hands-on training, constrains the generalizability of findings to the broader Jambangan population of 52,857 residents. The geographic concentration of implementation in RT 1 as the priority group creates uncertainty regarding scalability across diverse neighborhood contexts with potentially variant socioeconomic characteristics, housing densities, and existing infrastructure conditions [44]. Additionally, the evaluation timeframe focused predominantly on immediate post-intervention knowledge gains, precluding assessment of long-term behavioral persistence and infrastructure maintenance compliance. Longitudinal studies examining sustainability beyond the initial implementation phase remain essential for validating the durability of community engagement and technical system functionality [45]. The pre-test knowledge baseline of 14-18% raises questions regarding the assessment instrument's sensitivity and the specific knowledge domains evaluated. This relatively low baseline could reflect either genuine knowledge deficits or potential issues with question clarity, cultural appropriateness, or literacy levels among participants. Future research should incorporate mixed-methods evaluation frameworks combining quantitative knowledge assessments with qualitative interviews to capture nuanced dimensions of community understanding and attitudinal shifts [36][37]. Furthermore, the document does not specify the temporal interval between intervention delivery and post-test administration, introducing ambiguity regarding whether the measured improvements represent immediate recall versus consolidated learning. From a technical infrastructure perspective, the proposed dual functionality of infiltration wells for both water management and aquaculture (specifically catfish cultivation) represents an innovative livelihood diversification strategy. However, the document provides limited detail regarding the engineering modifications necessary to ensure water quality standards appropriate for aquaculture while maintaining infiltration capacity.

Research indicates that multi-purpose water infrastructure requires careful hydraulic design to prevent system conflicts and contamination risks [38][39]. The intended utilization by the "One-Patient Team of the Great Surabaya Cadre" suggests community-based economic development objectives, yet the management protocols, distribution mechanisms, and economic viability assessments remain unspecified. The implications of this intervention extend beyond immediate flood mitigation to encompass broader urban resilience and climate adaptation strategies. As Indonesian cities increasingly confront intensified precipitation patterns associated with climate variability, nature-based solutions such as biopore systems represent cost-effective, community-manageable alternatives to conventional grey infrastructure [42][43]. The environmental co-benefits documented, including groundwater recharge, urban heat island mitigation, biodiversity support, and organic waste valorization, align with integrated urban planning frameworks that seek multiple sustainability outcomes from single interventions. The potential application of infiltration wells as emergency water sources during fire incidents addresses a critical vulnerability identified following the 2017 fire that destroyed residential structures due to inadequate water access [44]. Future research directions should prioritize comprehensive hydrological monitoring to quantify infiltration rates, groundwater level changes, and flood frequency reductions attributable to the implemented systems. The academic institutional role specified in the maintenance framework provides an ideal mechanism for establishing systematic monitoring protocols using both conventional instrumentation and low-cost DIY sensor technologies [45]. Comparative effectiveness studies examining biopore density requirements, optimal spatial distribution patterns, and maintenance frequency intervals would generate valuable design guidelines for replication in similar urban contexts. Additionally, socioeconomic impact assessments evaluating the community development dimensions, including livelihood opportunities from aquaculture integration and social capital formation through collaborative maintenance structures, would provide holistic evidence of intervention value beyond purely environmental metrics.

V. CONCLUSION

This community-based intervention was designed to address recurring flood vulnerabilities in Jambangan Urban Village through the implementation of appropriate water management technologies while simultaneously enhancing community health literacy and sustainable livelihood opportunities. The program successfully established three infiltration wells strategically positioned within flood-susceptible zones adjacent to residential areas, serving multiple integrated functions including inundation mitigation, groundwater recharge enhancement, and subsurface water reserve stabilization. In accordance with the Satu Padu program framework, each infiltration well incorporated an innovative aquaculture component stocked with 1 kg of one-month-old catfish fingerlings (5–7 cm length), enabling sustainable harvest cycles every three months and providing economic diversification for community members. Beyond their primary hydrological functions, these wells constitute a critical emergency water resource for fire response operations, offering immediate water supply accessibility during the critical interval preceding fire department arrival, a capability particularly salient given the 2017 fire incident that resulted in complete structural destruction due to inadequate water access. The educational component of the intervention engaged 50 participants, comprising residents and Kader Sehat Surabaya (KSH) members, through comprehensive training sessions addressing appropriate technologies, including biopore construction, infiltration well maintenance, and oral hygiene practices. Community participation demonstrated exceptional enthusiasm and active engagement throughout the instructional activities, reflecting a robust collective commitment to sustainable environmental management. Quantitative evaluation through pre- and post-test assessment instruments confirmed substantial knowledge acquisition across all intervention domains: biopore comprehension increased from 15% to 70% (a 55-percentage-point gain), infiltration well understanding improved from 10% to 80% (a 70-percentage-point improvement), and oral health literacy advanced from 13% to 74% (a 61-percentage-point enhancement). These empirical outcomes substantiate the effectiveness of participatory, multi-modal educational approaches in facilitating meaningful learning and behavioral change potential within community settings. Future research should prioritize longitudinal monitoring of infrastructure performance through systematic hydrological measurements, assessment of behavioral persistence and maintenance compliance over extended timeframes, economic impact evaluation of the integrated aquaculture model, and scalability analysis for replication across analogous urban contexts experiencing similar environmental vulnerabilities and socioeconomic conditions.

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DATA AVAILABILITY

No datasets were generated or analyzed during the current study. All relevant data supporting the findings are contained within the manuscript.

AUTHOR CONTRIBUTION

Fitri Rokhmalia conceptualized and designed the study, supervised the overall research implementation, conducted data analysis and interpretation, and drafted the initial manuscript. Khambali contributed to the development of educational materials and training modules, coordinated field activities, and participated in data collection and community engagement. Imam Sarwo Edi provided technical expertise in biopore and infiltration well construction, oversaw the infrastructure installation process, and contributed to methodology development. Rachmaniyah participated in community outreach coordination, assisted with pre- and post-test administration, conducted a literature review, and contributed to manuscript writing and revisions. All authors critically reviewed the manuscript for important intellectual content, approved the final version for publication, and agreed to be accountable for all aspects of the work in ensuring accuracy and integrity.

DECLARATIONS

ETHICAL APPROVAL

Ethical approval is not available.

CONSENT FOR PUBLICATION PARTICIPANTS

Informed consent for publication was obtained from all participants. All participants were informed that anonymized data and findings would be published in academic journals and agreed to the terms of publication.

COMPETING INTERESTS

The authors declare that they have no competing interests, financial or otherwise, that could inappropriately influence or bias the content of this manuscript.

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