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Integration of Spatial and Social Analysis for Safe Sanitation in Cemorokandang Urban Village to Support the Achievement of Sustainable Development Goal 6.2.1

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Abstract: Safe sanitation is crucial for protecting public health and the environment, particularly in densely populated urban areas where inadequate facilities heighten contamination risks. Cemorokandang Urban Village represents such a vulnerable area, requiring a comprehensive assessment to inform local sanitation planning. This study evaluates the condition of safe sanitation and identifies spatial and social factors influencing its achievement using a mixed-method approach that integrates surveys, field observations, water quality testing, and GIS-based spatial analysis. Primary data covered household sanitation facilities, open defecation practices, and water quality, while secondary data were obtained from local institutions. Findings indicate that although all households have toilets with domestic wastewater systems, only 3,25% (211 of 6.497 buildings) met safely managed sanitation criteria despite 96.75% having adequate facilities. Spatial analysis reveals significant variation in sanitation risk across neighborhoods, strongly linked to differences in education, income, and community behavior. Communities with stronger socio-economic capacity demonstrate better understanding and adoption of safe sanitation practices, supported by training and balanced gender participation. Integrating spatial and social data provides a detailed picture of local challenges and supports the design of community-based, location-specific, and gender-responsive interventions. The study recommends targeted actions in high-risk areas, strengthened behavioral training, and inclusive financing mechanisms to accelerate progress toward Sustainable Development Goal 6.2.1.

Keywords: Cemorokandang Urban Village; Geographic information system-based risk zoning; Safe sanitation; Social analysis; Spatial analysis; Sustainable development goal 6.2.1

Introduction

Safe sanitation is a fundamental determinant of public health and environmental quality, yet regional progress remains uneven despite global and national commitments. This issue is emphasized in Sustainable Development Goal (SDG) 6.2.1, which targets universal access to safe sanitation and the elimination of open defecation by 2030 (WHO, 2024). In support of SDG 6.2.1, evidence from Indonesia shows persistent gaps driven by infrastructure deficits, community behavior, and socioeconomic constraints at multiple scales (Kustanto, 2020; Sedyowati et al., 2023; Sidjabat et al., 2020).

Access to safe sanitation not only serves as an indicator of environmental health but also reflects socio-economic progress and the sustainability of development within a region (WHO, 2023). Nationally,

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Indonesia continues to face major challenges in achieving safe sanitation for the entire population, where limited investments, fragmented service delivery, and weak enforcement often impede progress toward SDG targets and urban health goals (Kementerian PPN RI, 2023; Sidjabat & Gunawan, 2020; Murwendah et al., 2020; Sunaryo & Soewondo, 2024). This situation is also reflected in Malang City. According to official records from the Malang City Office of Public Works, Spatial Planning, Housing, and Settlement Areas (DPUPRPKP), only a minority of households currently have access to safe sanitation. The proportion of households with safe sanitation access was recorded at 25.64% in 2022, increasing to 35.56% in 2023 and 36.17% in 2024 (DPUPRPKP, 2023; Pemerintah Kota Malang, 2024). These figures remain far below the target established in Malang City Regional Regulation No. 6 of 2024 concerning the Regional Long-Term Development Plan (RPJPD) 2025–2045, which mandates an increase from 34.41% in 2025 to 95% in 2045 (Pemerintah Kota Malang, 2024).

The consequences of inadequate sanitation access are not merely technical deficits; they translate into heightened vulnerability to waterborne diseases, stunting, and broader environmental degradation, reinforcing the need for integrated, place-based strategies that align governance, community engagement, and sustainable financing (Fitri et al., 2025; Kustanto, 2020; Yushinta et al., 2022). Comparative analyses from urbanizing Indonesian settings further highlight the potential of community-led sanitation approaches, innovative funding mechanisms, and targeted sanitation marketing as important strategies to accelerate access in dense, informal, and periurban neighborhoods, where conventional infrastructure expansion alone often has limited reach (Rakhman, 2023). Taken together, these findings indicate that achieving Malang City's SDG sanitation targets requires not only expanded sewerage and wastewater treatment capacity but also demand-side interventions, governance reforms, and cross-sector collaboration that address equity, resilience, and the social ecology of sanitation behavior (Ari et al., 2024).

Cemorokandang Urban Village is one of the priority areas with significant sanitation issues. Data from Gribig Public Health Center (2018) (GRIBIG, 2018) indicate that some households continue to practice open defecation and use unimproved pit latrines, posing risks of groundwater contamination. Previous studies have shown that fecal containment systems left without desludging for more than eight years can increase coliform and E. coli levels above quality standards (Edriawan, 2018). According to the 2022 Sanitation Strategy Book (Buku SSK) (Bappeda Kota Malang, 2022), Cemorokandang Urban Village is classified at risk level 4 (very high) for domestic wastewater hazards. As of 2023, the percentage of households with access to safe sanitation in this area remains at 0% (Dinas Kesehatan Kota Malang, 2023).

The absence of spatial mapping of sanitation conditions in Cemorokandang creates a data gap that can hinder area-based policy planning and the allocation of limited resources. In this context, Geographic Information Systems (GIS) offer a powerful means to visualize the spatial distribution of sanitation conditions and their determinants, supporting evidence-based decision making at local scales. Beze et al. (2021) demonstrate that GIS is effective for environmental health modeling, risk analysis, and designing targeted interventions, underscoring its utility for translating data into actionable policies (Fonseca et al., 2023). Integrating social and spatial analyses within a GIS framework enables researchers to detect spatial patterns of sanitation access and to identify disparities among neighborhoods, informing equity-focused strategies and prioritization of underserved areas (Fonseca et al., 2023; Nayak et al., 2025).

In Indonesia, several studies highlight how GIS-enabled analyses reveal clustering of sanitation-related risks and the influence of contextual factors such as infrastructure, density, and service delivery networks on access to safe sanitation (Demoze et al., 2025; Amaral et al., 2019; Deshpande et al., 2020). For Malang City and the broader region, incorporating GIS-based mapping with SDG targets can facilitate monitoring of progress toward universal access, reveal pockets of vulnerability, and guide integrated interventions that combine infrastructure expansion with community-driven sanitation marketing and governance reforms to close the spatial equity gap (Yushinta et al., 2022; Rakhman, 2023; Zainuddin et al., 2025). Ultimately, a GIS-informed, place-based approach can support more precise policy design, targeted investments, and continuous monitoring to accelerate progress toward SDG 6.2.1 in Cemorokandang and similar urban-adjacent neighborhoods (Manivasagan, 2025; Schluth et al., 2020; Talukdar et al., 2024).

Based on this background, this study aims to analyze the social, economic, and behavioral factors influencing household sanitation conditions in Cemorokandang Urban Village, and to integrate these findings into spatial mapping using GIS. The results are expected to provide a scientific basis for formulating area-based sanitation improvement strategies aligned with the policy direction of the Malang City RPJPD 2025–2045 and the SDG 6.2.1 targets.

Method

Research Area

The research was conducted in Cemorokandang Urban Village, Kedungkandang District, Malang City, located at longitude 112.697964°, latitude -7.966378° which consists of 11 neighborhood units (RW) and a total population of 15,362 residents. The research was carried out from April to August 2025 Figure 1.

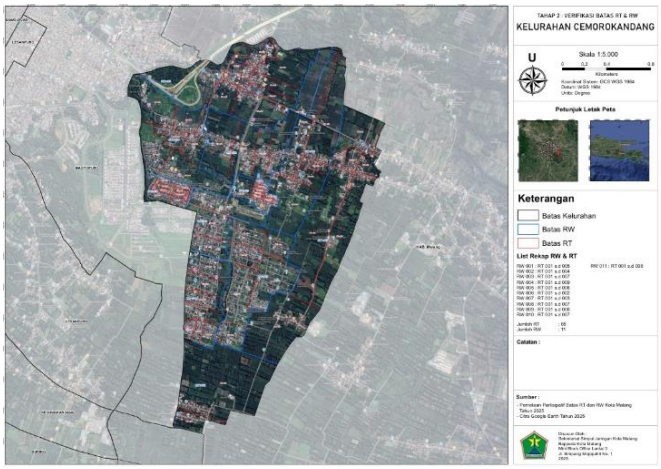

Figure 1. Research area

The research procedures are shown in Figure 2 below.

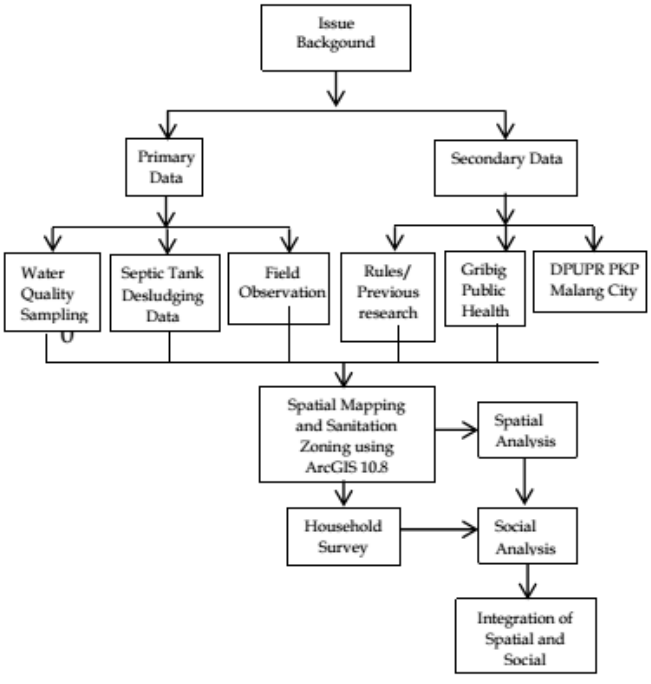

Figure 2. Research flow chart

Research Design

This study employed a mixed-methods approach using a sequential exploratory design, wherein qualitative data were collected in the initial phase to understand the physical condition of sanitation facilities, followed by quantitative data collection to analyze social and behavioral factors within the community. The qualitative approach included document analysis, field observations, and water quality testing, while the quantitative approach was conducted through a questionnaire survey. The integration of these methods provides a comprehensive understanding of safely managed sanitation conditions in Cemorokandang Urban Village.

Data Collection

Secondary Data

The initial stage of the study was carried out through a review of secondary data obtained from the Malang City Office of Public Works, Spatial Planning, Housing and Settlement Areas (DPUPRPKP), the Malang City Health Office, and Gribig Public Health Center. These data included: the achievement of households with safe sanitation facilities (2022–2024), beneficiaries of the DAK sanitation program (2021–2024), ownership of pour-flush latrines, SPALD-S systems, and Permanent Healthy Latrines (JSP). This information served as the basis for understanding the initial sanitation conditions and determining the focus for field verification.

Primary Data

Collection of Septic Tank Desludging Data

Data related to fecal sludge desludging practices were obtained using a digital form (Google Form) distributed by neighborhood (RW) leaders to residents. The data included the name of the building owner, address, and confirmation of desludging within the past five years, which were used to assess sanitation eligibility based on the criteria for safely managed sanitation.

Field Observation

Field observations were conducted to verify secondary data and assess the actual condition of sanitation facilities. These activities included identifying open defecation (OD) practices, documenting the condition of household sanitation facilities and the surrounding environment, and recording relevant location points using geographic coordinates through a location-based mapping application.

Water Quality Sampling

Water sampling was conducted at 17 water sources (HIPPAM and household wells) selected based on the variation of clean water providers used in each neighborhood (RW). The selected points were intended to represent the condition of residential water sources in Cemorokandang Urban Village. The sampling

procedure followed microbiological testing standards for detecting the presence of E. coli. Laboratory analyses were performed by sanitarians from Gribig Public Health Center, referring to the Indonesian Ministry of Health Regulation No. 492/MENKES/PER/IV/2010 on Drinking Water Quality Requirements, which mandates E. coli = 0/100 ml.

Spatial Mapping and Sanitation Zoning

All primary and secondary data were integrated into a Geographic Information System (GIS) to generate sanitation risk zoning maps at the neighborhood (RW) level (green, yellow, and red zones). This mapping served as the basis for determining respondent allocation for the quantitative survey. Based on the GIS analysis, the percentages of access to basic sanitation and safely managed sanitation can be calculated as follows (Bappenas, 2022):

Access to Basic Sanitation

$$ABS\ (\%) = \frac{Number\ of\ Households\ with\ Access\ to\ Basic\ Sanitation}{Total\ Number\ of\ Households} x\ 100\% \quad (1)$$

Access to Safely Managed Sanitation

$$\text{ASMS}\ (\%) = \frac{Number\ Households\ with\ Access\ to\ Safely\ Manage\ Sanitation}{Total\ Number\ of\ Households} x\ 100\% \quad (2)$$

Population Density

$$Population\ Density = \frac{Total\ Population\ (persons)}{Area\ Size\ (Km^2)} \quad (3)$$

Household Survey (Quantitative)

The survey was conducted after the sanitation zones had been established. The number of respondents was determined using the Slovin formula (Machali, 2021) with a population of 4,990 households (N) and 10% margin of error (e), as follows:

$$n = \frac{N}{1+N(e)^2} \quad (4)$$

The calculation resulted in 98 respondents, who were distributed proportionally according to the number of households in each neighborhood (RW). Data collection was conducted using a Likert-scale questionnaire ranging from 1 to 4 (1 = Strongly Disagree; 2 = Disagree; 3 = Agree; 4 = Strongly Agree) to measure perceptions, behaviors, sanitation-related understanding, and gender roles in safe sanitation.

Data Analysis

Spatial Analysis

The coordinate data were analyzed using GIS to identify spatial patterns, the distribution of sanitation risks, and the environmental conditions across neighborhoods (RW).

Social Analysis

The questionnaire data were analyzed descriptively to assess the relationships among education, income, sanitation behavior, understanding of safe sanitation, and gender roles.

Integration of Spatial and Social Analysis

The results of the spatial and social analyses were integrated to evaluate the consistency of risk patterns and identify the determinants of safe sanitation. This integration was used to formulate location-based intervention recommendations

Result and Discussion

Condition and Mapping of Safely Managed Sanitation in Cemorokandang Urban Village

Mapping of safely managed sanitation shows that all households in Cemorokandang Urban Village have permanent hygienic toilets and use SPALD-S systems, in accordance with the recommendations of Minister of Public Works and Housing Regulation No. 04/PRT/M/2017 for areas with a population density of <15,000 people/km². However, the achievement of safely managed sanitation remains low. Only 21 buildings have conducted fecal sludge desludging within the past five years, while spatial mapping identified 190 sanitation facilities constructed through the 2021–2024 DAK Sanitation Program that are still in use. Of the total 6,497 buildings, 6,286 (96.75%) are categorized as adequate, but only 211 (3.25%) meet the criteria for safely managed sanitation. This condition indicates that although physical access is widespread, maintenance practices particularly periodic desludging as a key component of fecal sludge management are still suboptimal, resulting in non-compliance with SDG 6.2.1 standards (Kementerian PPN RI, 2024; Kementerian PUPR RI, 2017; Nadar et al., 2024).

Water quality testing revealed *E. coli* contamination in several water sources, particularly in areas with non-watertight septic tanks or insufficient distance between septic tanks and wells. This finding aligns with (Edriawan, 2018), who linked groundwater contamination in Batu City to septic tank leakage and substandard construction. Nlemolisa et al. (2025) and Putri et al. (2025) further emphasizes that the elimination of groundwater contamination risks is exceedingly difficult when effluent from on-site sanitation (OSS) systems is discharged below the ground surface. The study also demonstrates that fecal bacteria originating from OSS migrate into groundwater, with *E. coli* contamination showing pronounced temporal

variability and rising substantially during the rainy season, with the highest intensities observed at locations closest to OSS units. These observations indicate that fecal seepage constitutes a principal pathway of contamination in urban areas that rely on on-site sanitation systems lacking adequate fecal sludge management (FSM) services.

Although administrative population density is categorized as low, spatial analysis demonstrates clustering of residential areas that creates high micro-level density. GIS mapping identified RW 1 and 4 as red zones (high risk), RW 2, 3, 5, and 6 as yellow zones (medium risk), and RW 7–11 as green zones (low risk). The red and yellow zones are concentrated in areas with dense housing, inadequate drainage, and proximity to water bodies patterns consistent with the 2021 Slum Area Designation (SK Kumuh) by the Malang City Government (Pemerintah Kota Malang, 2021). Previous studies also indicate that dense settlements with limited space face challenges in meeting SPALD-S specifications for watertight construction and desludging accessibility (Nadar et al., 2024; Pamungkas et al., 2022).

Table 1. Results of Safely Managed Sanitation Mapping in Cemorokandang Urban Village

	RW1	RW2	RW3	RW4	RW5	RW6	RW7	RW8	RW9	RW10	RW11	Total
Total Population (persons)	1297	1581	1651	2425	1845	570	1098	1398	1575	1068	854	15.362
Number of Households	421	514	536	788	599	185	357	454	512	347	277	4.990
Number of Buildings	518	548	682	856	804	225	486	657	984	398	339	6.497
Adequate Buildings	492	516	654	813	773	194	484	646	984	398	332	6.286
Overview of Basic Sanitation	94%	94%	95%	94%	96%	86%	99%	98%	100%	100%	97%	96%
Safely Managed Buildings	26	32	28	43	31	31	2	11	0	0	7	211
Overview of Safely Managed Sanitation	5.02%	5.84%	4.11%	5.02%	3.86%	13.78%	0.41%	1.67%	0.00%	0.00%	2.06%	3.25%
Area Size (Km²)	0.56	0.47	0.96	0.71	0.49	0.50	0.24	0.27	0.51	0.10	0.09	4.88
Population Density	2,311.1	3,379.6	1,720.8	3,397.3	3,802.5	1,138.8	4,619.2	5,214.4	3,101.6	11,218.4	9,693.5	3,144.86
Population Density > 15.000	No	No	No	No	No	No	No	No	No	No	No	No
Types of SPALD According to the Ministry of Public Works and Housing Regulation	SPALD-S	SPALD-S	SPALD-S	SPALD-S	SPALD-S	SPALD-S	SPALD-S	SPALD-S	SPALD-S	SPALD-S	SPALD-S	SPALD-S
Overview of Contamination *E-Coli*	Yes	No	No	Yes	Yes	No	No	No	No	No	No	
Overview of Open Defecation Practices	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	
Risk Zone	Red	Yellow	Yellow	Red	Yellow	Yellow	Green	Green	Green	Green	Green	

Note: Red = High Risk; Yellow = Medium Risk; Green = Low Risk

Open defecation still occurs along riverbanks and in informal settlements, influenced by spatial constraints, semi-permanent housing structures, and low awareness of safe sanitation. This is consistent with sanitation behavior studies highlighting the influence of social norms, risk perception, and knowledge on open defecation practices (Nastiti et al., 2025; Ruba et al., 2021).

Poor compliance with periodic desludging further contributes to the low achievement of safely managed sanitation. Many septic tanks have not been desludged for more than five years, despite technical guidelines requiring desludging every 3–5 years (Kementerian PUPR RI, 2017). Studies by Kementerian PPN RI (2024) and Nadar et al. (2024) reaffirm that infrastructure development alone is insufficient without sustained maintenance services.

The mapping of safely managed sanitation in Cemorokandang demonstrates that sanitation risks are primarily influenced by technical and spatial factors, including septic tank construction quality, maintenance practices, distance to water sources, drainage conditions, and clustered settlement patterns. These findings are consistent with the Citywide Inclusive Sanitation (CWIS) framework (The World Bank, 2023), which underscores the importance of sustainable operational services, routine maintenance, and spatial analysis to achieve safely managed sanitation.

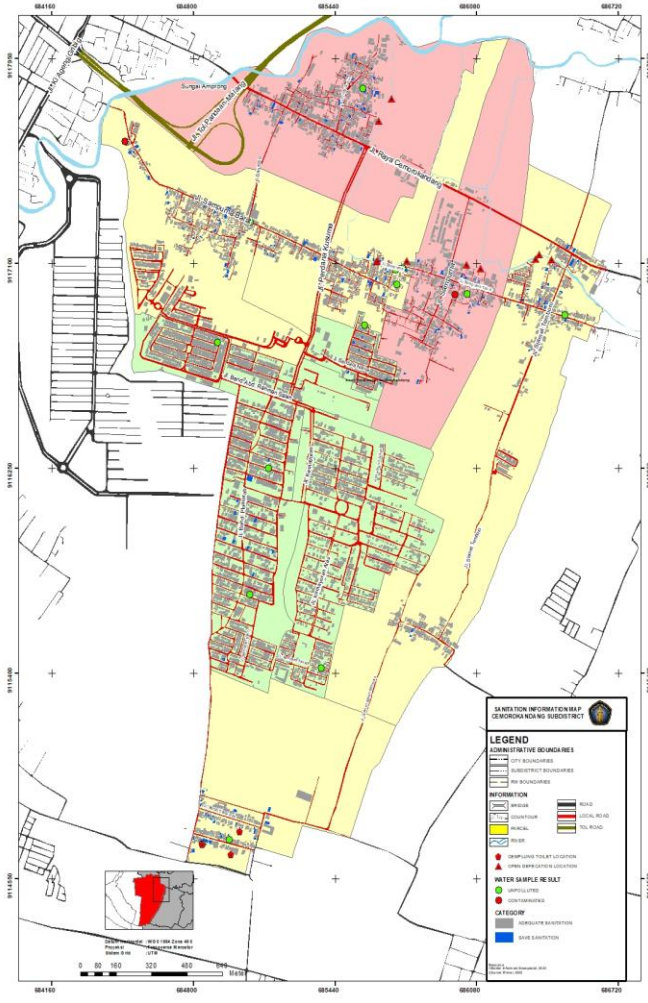

Figure 3. Zoning of safely managed sanitation risks in Cemorokandang Urban Village based on GIS analysis

Social Analysis

GIS Mapping Results, Socio-Economic Conditions, and Educational Levels

The results of the social analysis show a clear distinction between RW 1–6 and RW 7–11 in Cemorokandang Urban Village, consistent with prior work that urban neighborhood structure correlates with differential human resource characteristics across RWs and micro-areas (Logsdon, 1974; Suwarno et al., 2019). In terms of education (Figure 4), RW 7–11 is dominated by heads of households with higher educational attainment, with 54% holding undergraduate degrees and 8% holding postgraduate degrees, figures that align with patterns reported in urban slum upgrading and community development studies where higher education levels cluster in more advantaged micro-units within cities (Anggara et al., 2023; Sedyowati et al., 2023; Suwarno et al., 2019). In contrast, RW 1–6 has a larger proportion of individuals with lower educational attainment, with 27% having completed junior secondary school and 35% senior secondary school, while only 13% hold undergraduate degrees; similar distributions have been observed in disaster-prone or slum-adjacent settlements where education levels are lowest among residents in more peripheral RW units (Type-3 typologies) and higher in central or upgrading-targeted areas (Type-1 typologies) (Amin et al., 2018; Augustin et al., 2023; Yuliastuti et al., 2023). These differences indicate a disparity in human resource capacity between the two clusters of neighborhoods, a pattern that is repeatedly documented when contrasting RW-level distributions of education with downstream outcomes such as staying intention, economic activity, and resilience in urban settlements (Amin et al., 2018; Augustin et al., 2023; Mahmudah et al., 2024; Yuliastuti et al., 2023).

A similar disparity is evident in the economic dimension (Figure 5) RW 1–6 is dominated by low to middle income households (Rp 1,500,001–Rp 3,000,000), comprising 52% of respondents, whereas in RW 7–11 the proportion of low-income households is only 31%. Households earning more than Rp 3,000,000 are more frequently found in RW 7–11, indicating stronger economic capacity to access higher quality sanitation services.

The lower socio-economic conditions in RW 1–6 are consistent with the Malang Mayor's Decree of 2021 (Pemerintah Kota Malang, 2021), which classified parts of RW 001, RW 003, and RW 006 as light to moderate slum areas covering ±3.55 hectares, characterized by damaged neighborhood roads, unconnected drainage systems, and limited access to clean water and domestic wastewater services. These characteristics indicate that social vulnerability and the physical condition of settlements reinforce one another.

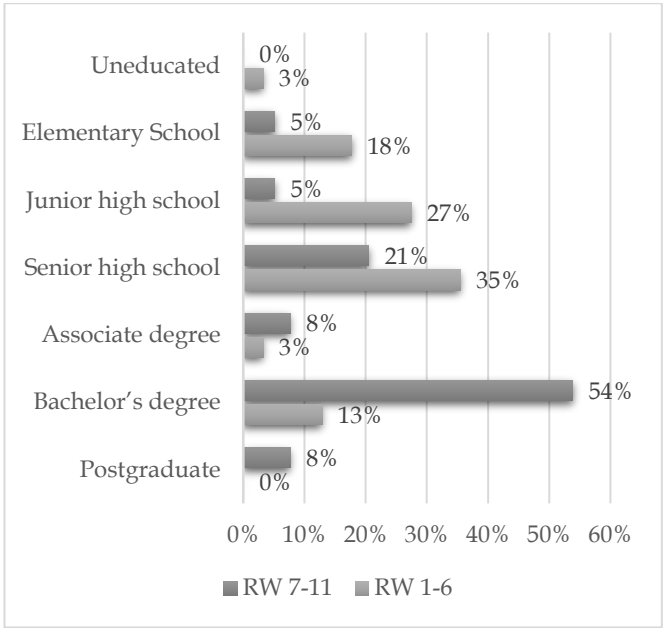

Figure 4. Comparison of educational levels

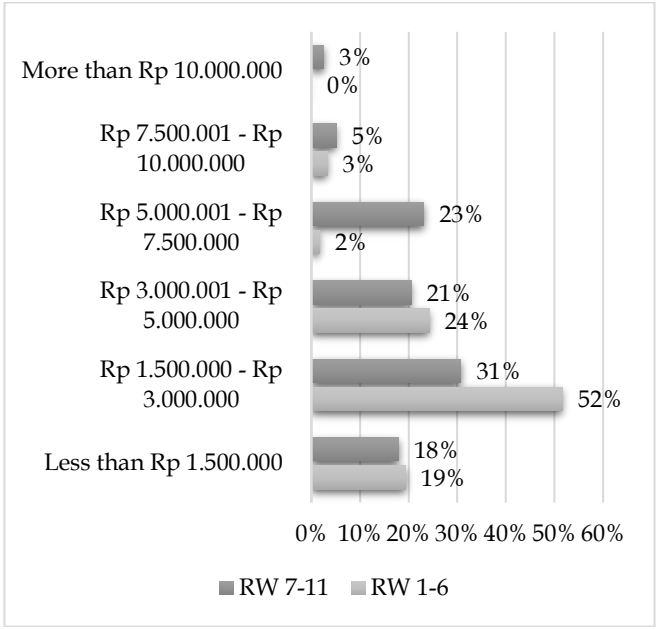

Figure 5. Comparison of economic levels

When linked to the spatial findings, RW 1–6 characterized by lower levels of education and income overlaps with zones exhibiting higher sanitation risks. This pattern demonstrates that socio-economic conditions contribute to the distribution of environmental risks, where high vulnerability areas tend to display sanitation practices that do not meet standards, lower quality facilities, or inadequate maintenance. Thus, sanitation risks are influenced not only by technical factors but also by the socio-economic capacity of the community.

These findings are consistent with previous research. Widyastuti et al. (2023) showed that educational attainment improves access to adequate sanitation. Tehupeiory et al. (2023) found that Gross Regional Domestic Product (GRDP) and the Human Development Index (HDI) are significantly associated with increased sanitation access. Kumar et al. (2024) reported that households with stronger economic conditions are more capable of constructing and maintaining sanitation facilities that meet standards. WHO (2025) also documented that open defecation rates in low-income countries are four times higher than the global average.

The social analysis in Cemorokandang affirms that education, economic status, and settlement environmental quality play substantial roles in shaping sanitation risks. These results strengthen the spatial findings, indicating that safely managed sanitation can only be achieved through technical interventions accompanied by improvements in the community's socio-economic capacity.

Community Sanitation Behavior and Awareness

The findings of the sanitation behavior survey reinforce the socio-economic analysis, which shows a disparity in capacity and awareness between the two groups of neighborhoods. In terms of understanding safe sanitation (Figure 6), 69% of respondents in RW 7–11 agreed and 21% strongly agreed, considerably higher than RW 1–6, where only 48% agreed and 10% strongly agreed. Conversely, 42% of respondents in RW 1–6 disagreed, reflecting limited understanding of safe sanitation in areas with lower socio-economic conditions. This low sanitation literacy is influenced by restricted access to education and information, consistent with the findings of Nastiti et al. (2025), which indicate that households with access to hygiene information are more likely to practice improved sanitation. Warlenda et al. (2021) also demonstrate that individuals with low knowledge levels have a 2.778-times higher risk of practicing open defecation.

This capacity gap is also evident in the motivation for periodic fecal sludge desludging (Figure 7). A total of 73% of respondents in RW 7–11 agreed and 41% strongly agreed on the importance of desludging every 3–5 years, whereas RW 1–6 recorded only 46% agreement and 11% strong agreement, accompanied by a higher proportion of disagreement. This indicates that understanding of the urgency of maintaining sanitation facilities is not evenly distributed. This pattern is aligned with (Nadar et al. (2024), which state that low motivation and demand for desludging services, along with an underdeveloped fecal sludge management (FSM) market, constitute major barriers to achieving safely managed sanitation. WHO (2025) similarly emphasize that low-income groups tend to lag in utilizing FSM services.

This behavioral gap is consistent with GIS analysis results, which show that areas with the highest *E. coli* contamination are located in RW 1–6, particularly in densely populated areas near drainage channels. This pattern illustrates a correlation between limited sanitation understanding and maintenance motivation with elevated environmental contamination risks resulting from open defecation and inadequate domestic wastewater management systems. These findings are consistent with (Holcomb et al., 2020; Mertens et al., 2023), who reported that areas with poor hygiene behavior and limited sanitation infrastructure are at greater risk of fecal contamination.

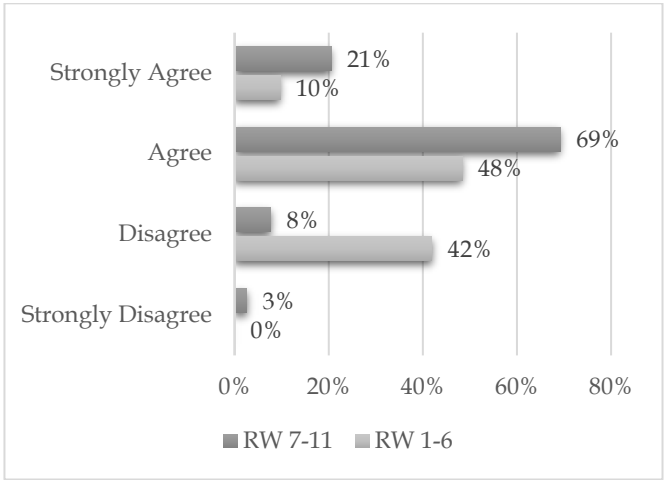

Figure 6. Comparison of understanding of safe sanitation practices

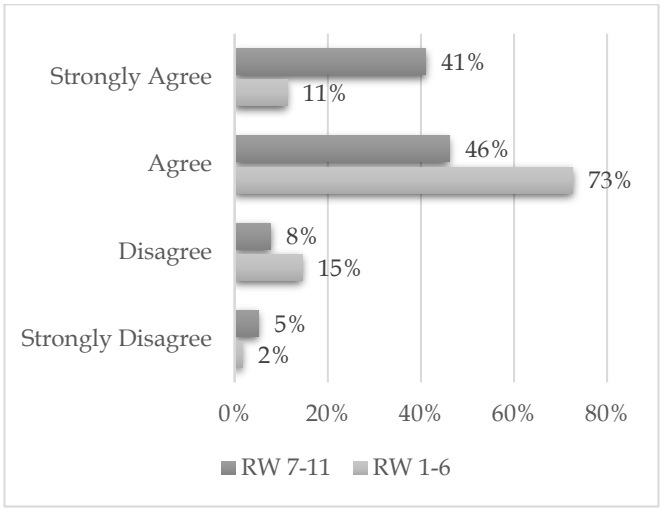

Figure 7. Comparison of motivation to desludge septic tank

From the perspective of social norms (Figure 8), both RW 1–6 and RW 7–11 demonstrate relatively strong application of social sanctions related to cleanliness and environmental health, with approximately 68–69% of respondents expressing agreement. However, the higher level of disagreement in RW 1–6 (27%) indicates weaker social oversight in parts of this area. This is supported by Indrayadi et al. (2024), who assert that cultural factors such as norms, values, and beliefs, as well as social institutions including family, education, and community organizations, have a significant influence on shaping public awareness and behavior related to sanitation. Ruba et al. (2021) further highlight that key factors supporting the implementation of open defecation free (ODF) programs in the working area of Maronggela Health Center include the availability of resources, attitudes and beliefs, availability of facilities, the role of household heads, health workers, community health volunteers, community leaders, and village government, all of whom are expected to model proper sanitation practices. Given these findings, strengthening sanitation outcomes in Cemorokandang will require reinforcing positive social norms through consistent community monitoring, empowerment of local leaders as behavioral role models, and integrating sanitation messages into existing social institutions such as neighborhood meetings, religious gatherings, and women's groups to normalize safe sanitation practices. Enhancing collective accountability and fostering a shared sense of responsibility can further increase adherence to sanitation standards and reduce behaviors that contribute to environmental contamination

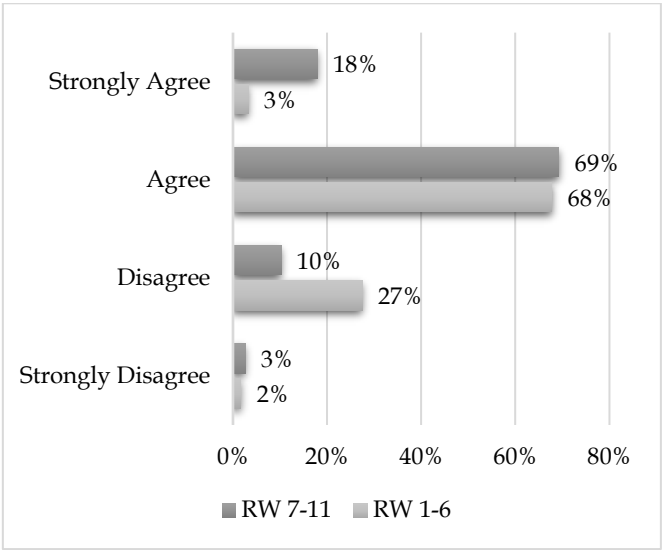

Figure 8. Comparison of social norms related to cleanliness and health

Willingness to invest in the construction of sanitation facilities indicates that the initial financial burden is a key determinant of community participation. Under the lump-sum payment scheme (Figure 9), households in RW 1–6 tended to be unwilling (55% disagreed), whereas RW 7–11 showed higher acceptance. However, when offered savings-based installment schemes (Figure 10), willingness increased in

both areas, particularly in RW 1–6, indicating that installment-based mechanisms are more compatible with the economic capacity of low-income households. According to the Safe Sanitation Market Assessment in Indonesia (Nadar et al., 2024), existing microcredit schemes can only be used to finance the construction of toilets and compliant septic tanks. The 2022 Malang City Sanitation Strategy (Bappeda Kota Malang, 2022) also highlights that one of the urgent constraints in managing domestic wastewater in Malang City is the lack of affordable and sustainable financing alternatives. This underscores the need to promote accessible financing mechanisms to improve the achievement of safely managed sanitation.

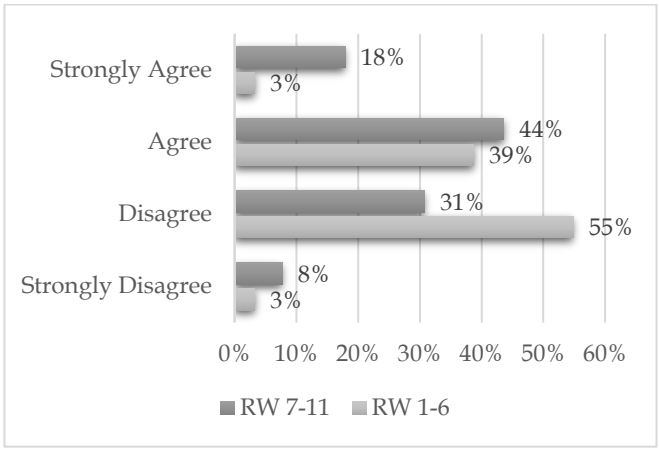

Figure 9. Comparison of willingness to invest in sanitation infrastructure through lump-sum payments schemes

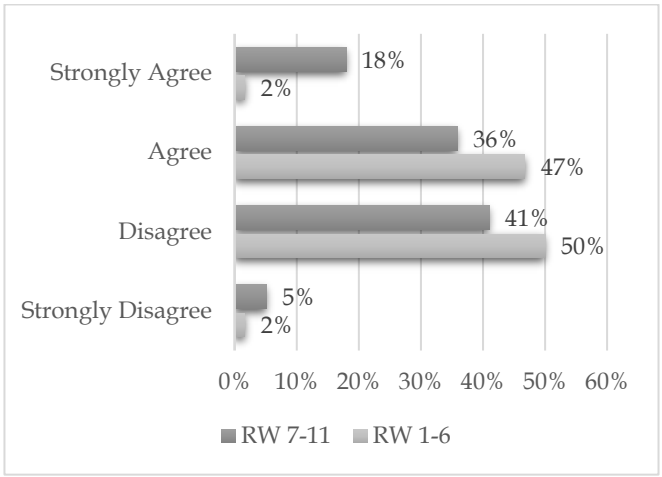

Figure 10. Comparison of willingness to invest in sanitation infrastructure through savings based installment schemes

Willingness to invest in fecal sludge desludging shows that payment mechanisms influence household decision making. Under the lump-sum payment scheme of Rp 500,000 every 3 to 5 years (Figure 11), RW 7–11 exhibited higher acceptance compared to RW 1–6, consistent with their stronger economic capacity. Conversely, under the savings scheme of Rp 10,000 per month (Figure 12), the level of willingness was higher among residents of RW 1–6, indicating that small installments are more suitable for low-income households. The 2030 Safe Sanitation Roadmap (Kementerian PPN RI, 2024) outlines seven key strategies for achieving safe sanitation targets by 2030, with Strategy No. 4 prioritizing the development of regulations, models, and mobilization of microcredit financing for household level sanitation infrastructure, as well as the advancement of blended finance mechanisms that allow lower interest rates or subsidies for microcredit schemes needed by certain community groups. Accordingly, these findings demonstrate that adaptive financing designs whether through community savings schemes or periodic payments need to be incorporated into strategies for improving fecal sludge desludging services in Cemorokandang Urban Village.

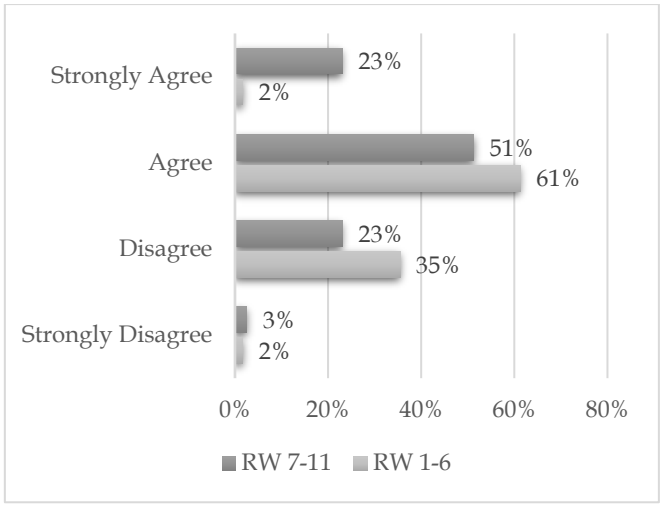

Figure 11. Comparison of willingness to invest in fecal sludge desludging through lump-sum payments schemes

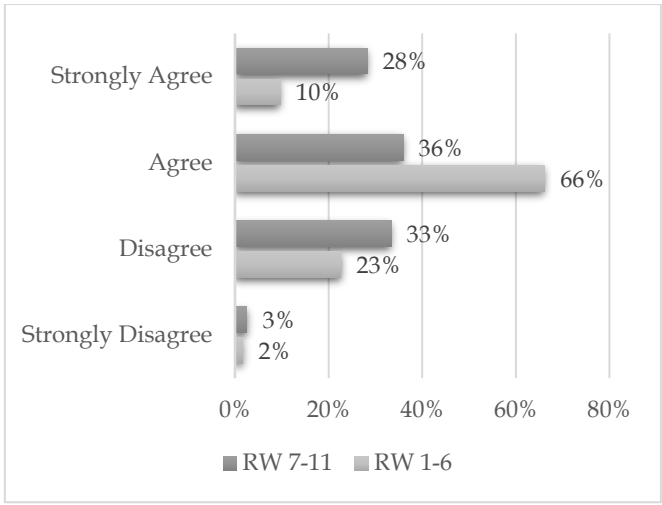

Figure 12. Comparison of willingness to invest in fecal sludge desludging through savings-based installment schemes

Gender Roles in Sanitation Promotion and the Impact of Training

Gender roles are shown to influence changes in sanitation behavior (Figure 13 and 14). The majority of respondents recognized the importance of men's involvement in sanitation promotion, with 82% in RW 1–6 and 95% in RW 7–11 agreeing, indicating that sanitation is increasingly viewed as a shared responsibility rather than solely a woman's role. The role of women is also considered highly important, with agreement levels of 76% in RW 1–6 and 85% in RW 7–11; however, the higher rate of disagreement in RW 1–6 (21%) suggests the need to strengthen women's capacity in areas with higher socio-economic vulnerability. Nastiti et al. (2025) reported that households in which husbands and wives contribute equally to decision making regarding household expenditures are more likely to practice improved sanitation and utilize latrines properly. Nadar et al. (2024) also emphasize that social and cultural factors such as the role of women in behavior change, community norms, and the influence of local leaders are significant determinants of increased sanitation access. These findings affirm that sanitation promotion strategies in Cemorokandang must consider gender roles in a balanced and integrated manner.

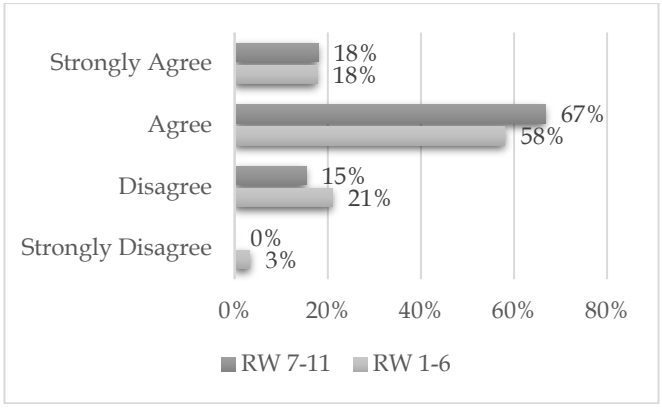

Figure 13. The roles of women in sanitation promotion

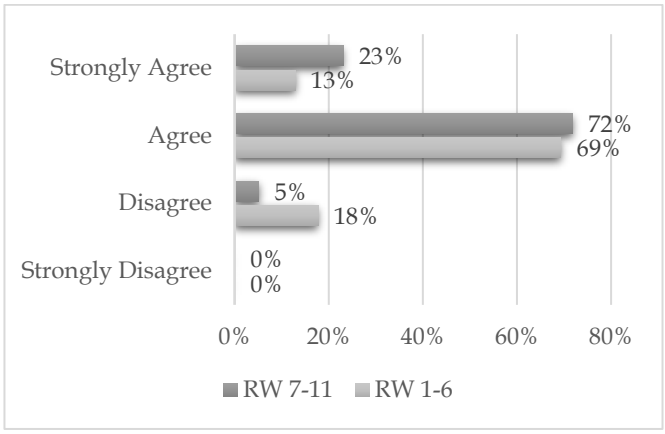

Figure 14. The roles of men in sanitation promotion

Training or socialization received by the community was perceived to have a positive impact on changes in sanitation behavior (Figure 15). A total of 91% of respondents in RW 1–6 and 93% in RW 7–11 stated that training contributed to improvements in hygienic behavior and better sanitation practices. RW 7–11 also demonstrated stronger internalization of knowledge, reflected in a higher proportion of respondents who strongly agreed (26% compared to 15% in RW 1–6), consistent with their higher levels of education and social support. Pamungkas et al. (2022) and Widyastuti et al. (2023) concluded that educational campaigns and socialization regarding the importance of sanitation access are necessary to raise community awareness. Accordingly, the data from Cemorokandang indicate that high quality and sustained training is a key factor in in strengthening sanitation behavior change. strengthening sanitation behavior change.balanced and integrated manner.

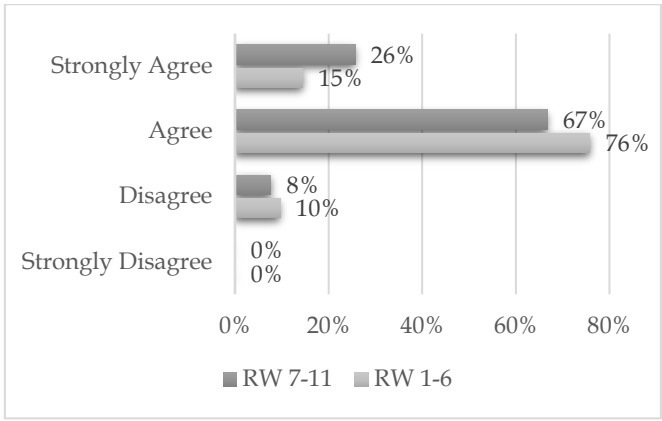

Figure 15. Comparison of the impact of training on behavioral and hygiene improvements

Synthesis and Implications

The synthesis of the research findings indicates that the low achievement of safely managed sanitation in Cemorokandang Urban Village is driven by a combination of technical, socio-economic, behavioral, and spatial settlement factors. RW 1–6, which is characterized by dense settlement clusters, lower economic capacity, and limited sanitation literacy, falls within higher risk sanitation zones, including findings of *E. coli* contamination and open defecation practices. In contrast, RW 7–11 exhibits better sanitation conditions in line with stronger economic capacity, higher educational attainment, and more robust maintenance behaviors. This pattern is consistent with previous findings on the relationship between infrastructure quality, sanitation literacy, and environmental risk (Nadar et al., 2024; Nastiti et al., 2025; Pamungkas et al., 2022).

The low motivation for fecal sludge desludging in socio-economically vulnerable areas demonstrates that

sanitation behavior is strongly influenced by risk perception and the affordability of services. This aligns with the recommendations of the Safe Sanitation Roadmap (Kementerian PPN RI, 2024), which emphasizes that maintenance services must be accompanied by intensive education and flexible financing mechanisms to increase service adoption. The recognized roles of gender and training among the majority of respondents further illustrate the significant potential for driving household and community based behavioral change.

These findings underscore that strategies to improve safely managed sanitation must integrate technical improvements to SPALD-S systems, regular desludging services, behavioral education, strengthening of social norms, and inclusive financing models. An integrated approach that is responsive to the local context, as recommended in the Citywide Inclusive Sanitation framework (The World Bank, 2023), represents a critical step in accelerating progress toward safely managed sanitation at the urban village level.

Conclusion

This study demonstrates that although access to basic sanitation facilities in Cemorokandang is widespread, the achievement of safely managed sanitation remains low due to weak maintenance practices, variability in septic tank construction quality, and fecal contamination risks at several water sources. Spatial analysis confirms that sanitation risks are concentrated in RW 1–6, which exhibit higher socio-economic vulnerability and dense settlement patterns, while RW 7–11 show more favorable conditions. The social analysis reveals that education, income, sanitation related understanding, willingness to invest, and support through gender roles and training play important roles in strengthening safe sanitation behavior. Accordingly, improving safely managed sanitation requires an integrated strategy that combines technical interventions, behavioral education, regular desludging, and inclusive financing schemes to support the achievement of SDG 6.2.1.

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Author Contributions
All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
All authors declare that they have no conflict of interest.

References

Amin, C., Sukamdi, S., & Rijanta, R. (2018). Exploring Typology of Residents Staying in Disaster-Prone Areas: A Case Study in Tambak Lorok, Semarang, Indonesia. *Forum Geografi*, *32*(1), 24–37. https://doi.org/10.23917/forgeo.v32i1.5817

Anggara, T., Anshory, W., & Kusumaningtiar, D. (2023). Spatial Analysis of Children's Diarrhea in Urban Areas. *Journal of Health and Medical Sciences*, *6*(1). https://doi.org/10.31014/aior.1994.06.01.254

Ari, I. R. D., Wijatmiko, I., Santosa, H., & Prayitno, G. (2024). Empowering Smart Health Cities Through Innovative Water Management Strategies. *International Journal of Sustainable Development and Planning*, *19*(8), 2991–3005. https://doi.org/10.18280/ijsdp.190816

Augustin, A. N., & Sunarti, S. (2023). Covid-19 pandemic effect on MSMEs in Rawa Bambu Slums, Kalibaru Village, Bekasi City. *Region : Jurnal Pembangunan Wilayah Dan Perencanaan Partisipatif*, *18*(1), 164. https://doi.org/10.20961/region.v18i1.57449

Bappeda Kota Malang. (2022). *Strategi Sanitasi Kota Malang*. Malang: Bappeda Kota Malang.

Bappenas. (2022). *Meta Data Target Indikator Sanitasi Kupas Tuntas SDG 6.2 dan 6.3 Sanitasi*. Retrieved from https://shorturl.at/3oP5R

Beze, H., Hamka, Yulianto, Nurmarini, E., & Salusu, H. D. (2021). Implementasi SIG Untuk Monitoring Kesehatan Lingkungan Studi Kasus Kelurahan Harapan Baru. *Buletin Poltanesa*, *22*(1), 33–37. https://doi.org/10.51967/tanesa.v22i1.464

Edriawan, E. (2018). Dampak Pengelolaan Air Limbah Domestik Terhadap Kualitas Air Tanah Di Wilayah Pemukiman Kecamatan Junrejo Kota Batu. *Institut Teknolgi Sepuluh November*, 1–131.

Fitri, M., Zuraidi, E., & Yusuf, M. (2025). Quantitative analysis of sanitation infrastructure and stunting prevalence: Building rural community resilience in Bener Meriah Regency, Aceh-Indonesia. *IOP Conference Series: Earth and Environmental Science*, *1510*(1), 012065. https://doi.org/10.1088/1755-1315/1510/1/012065

Holcomb, D. A., Knee, J., Sumner, T., Adriano, Z., de Bruijn, E., Nalá, R., Cumming, O., Brown, J., & Stewart, J. R. (2020). Human fecal contamination of water, soil, and surfaces in households sharing poor-quality sanitation facilities in Maputo,

Mozambique. *International Journal of Hygiene and Environmental Health*, *226*(February), 113496. https://doi.org/10.1016/j.ijheh.2020.113496

Indrayadi, Yuhansyah, & Asih, H. A. (2024). Faktor Budaya Terhadap Kesadaran Masyarakat Dalam Mengatasi MasalahBuang Air Besar Sembarangan: Literature Review. *Jurnal Promotif Preventif*, *7*(2), 320–328. Retrieved from http://journal.unpacti.ac.id/index.php/JPP

Kementerian PPN RI. (2024). Rencana Teknokratik Peta Jalan Sanitasi Aman. *UNICEF Indonesia*, 102. Retrieved from https://www.unicef.org/indonesia/id/wash/laporan/rencana-teknokratik-peta-jalan-air-minum-dan-sanitasi-aman-indonesia

Kementerian PUPR RI. (2017). *Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia Nomor 4/PRT/M/2017 Tentang Penyelenggaraan Sistem Pengelolaan Air Limbah Domestik*. Retrieved from https://peraturan.bpk.go.id/Details/104453/permen-pupr-no-04prtm2017-tahun-2017

Kumar, P., Hasan, N., & Rajak, R. (2024). Socio-economic disparities in the utilization of improved sanitation facilities among Indian households. *Scientific Reports*, *14*(1), 31659. https://doi.org/10.1038/s41598-024-80949-3

Kustanto, A. (2020). *The role of socioeconomic and environmental factors on the number of tuberculosis cases in Indonesia*. https://doi.org/10.31219/osf.io/ad3uv

Logsdon, M. G. (1974). Neighborhood Organization in Jakarta. *Indonesia*, *18*, 53. https://doi.org/10.2307/3350693

Machali, I. (2021). *Metode Penelitian Kuantitatif*. Yogyakarta: Fakultas Ilmu Tarbiyah dan Keguruan UIN Sunan Kalijaga Yogyakarta.

Mahmudah, H., Subejo, & Santosa, K. A. (2024). Urban Farming to Ensure Food Security and to Generate Cash Income During the Covid-19 Pandemic: A Case Study in Bausasran Urban Village Indonesia. *Jurnal Inotera*, *9*(2), 302–313. https://doi.org/10.31572/inotera.Vol9.Iss2.2024.ID367

Mertens, A., Arnold, B. F., Benjamin-Chung, J., Boehm, A. B., Brown, J., Capone, D., Clasen, T., Fuhrmeister, E., Grembi, J. A., Holcomb, D., Knee, J., Kwong, L. H., Lin, A., Luby, S. P., Nala, R., Nelson, K., Njenga, S. M., Null, C., Pickering, A. J., … Ercumen, A. (2023). Effects of water, sanitation, and hygiene interventions on detection of enteropathogens and host-specific faecal markers in the environment: a systematic review and individual participant data meta-analysis. *The Lancet Planetary Health*, *7*(3), e197–e208. https://doi.org/10.1016/S2542-5196(23)00028-1

Nadar, K., & Listyasari, M. (2024). *Penilaian Pasar untuk Sanitasi yang Dikelola dengan Aman di Indonesia*. Jakarta: Bappenas.

Nastiti, A., Daniel, D., Oktavia, H., Fathiyannisa, H., & Sudradjat, A. (2025). Contextual and psychosocial factors predicting sanitation behaviours in rural Indonesia. *BMC Public Health*, *25*(1). https://doi.org/10.1186/s12889-025-21893-3

Nlemolisa, O. R., Ogbulie, J. N., Orji, J. C., Nweke, C. O., Kemka, U. N., Gaius-Mbalisi, V. K., & Ihenetu, F. C. (2025). Groundwater contamination and health risks near waste dumps and mechanic workshops: A seasonal perspective. *Cleaner Water*, *4*(June), 100090. https://doi.org/10.1016/j.clwat.2025.100090

Pamungkas, D. S., Fadillah, N. A. Z., Julia, A., & Ferbianty, D. (2022). Strategi Peningkatan Kualitas Sanitasi Layak Bagi Rumah Tangga Di Kecamatan Sukajadi Kota Bandung. *Jurnal Planologi*, *19*(1), 37. https://doi.org/10.30659/jpsa.v19i1.19211

Putri, G. L., Ilmi, A. M., Handayani, R., Iskandar, D., Priadi, C. R., Willetts, J., & Foster, T. (2025). On-site sanitation systems and fecal contamination in shallow groundwater in urban Indonesia: assessing influence of distance and rainfall variables. *Water Research*, *287*(PB), 124431. https://doi.org/10.1016/j.watres.2025.124431

Rakhman, R. A. (2023). Streamlining USAID IUWASH-Jawa Barat: Kolaborasi Sustainable Development Goals dalam Infrastruktur Air Bersih dan Sanitasi. *Global Local Interactions: Journal of International Relations*, *3*(2), 103–114. https://doi.org/10.22219/gli.v3i2.27373

Ruba, Y. E., Joko, T., & Budiyono, B. (2021). Faktor Pendukung dan Penghambat Program Stop Buang Air Besar Sembarangan (BABS) di Wilayah Kerja Puskesmas Maronggela Kecamatan Riung Barat Kabupaten Ngada. *Jurnal Riset Kesehatan Masyarakat*, *1*(2), 1–11. https://doi.org/10.14710/jrkm.2021.13315

Sedyowati, L., Yuniarti, S., & Sufiyanto, S. (2023). Is local wisdom able to build sustainable communities in informal flood-prone settlements? Evidence from Glintung Kampong, Malang City, Indonesia. *Local Wisdom : Jurnal Ilmiah Kajian Kearifan Lokal*, *15*(1), 41–52. https://doi.org/10.26905/lw.v15i1.9008

Sidjabat, F. M., & Gunawan, M. (2020). Evaluation of Community-based Sanitation Program Implementation in Central and East Java. *Al-Ard: Jurnal Teknik Lingkungan*, *5*(2), 62–69. https://doi.org/10.29080/alard.v5i2.849

Suwarno, W., Suharto, & Wahyu, W. (2019). Strengthening Institution of Local Communities in Empowerment of Village Communities in

Semarang Central Java (Case Study in Muktiharjo Kidul, Pedurungan). *Proceedings of the 1st International Conference on Education and Social Science Research (ICESRE 2018)*. https://doi.org/10.2991/icesre-18.2019.60

Tehupeiory, A., Sianipar, I. M. J., Sari, M. M., Septiariva, I. Y., Suhardono, S., & Suryawan, I. W. K. (2023). Estimasi Karakteristik Sosial-Ekonomi Wilayah dalam Capaian Pembangunan Berkelanjutan untuk 100% Akses Sanitasi di Provinsi Kepulauan Riau. *Jurnal Ilmu Lingkungan*, *21*(1), 220–227. https://doi.org/10.14710/jil.21.1.220-227

The World Bank. (2023). *Citywide Inclusive Sanitation Towards Safely Managed Urban Sanitation Services Project* (Issue 1). Retrieved from https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099101123141024140

Warlenda, S. V., Radifa, R. A. D., Sari, N. P., & Wahyudi, A. (2021). Hubungan Sanitasi Dasar, Pengetahuan, Perilaku Dan Pendapatan Terhadap Kebiasaan BABS di Kelurahan Laksamana Wilayah Kerja Puskesmas Dumai Kota Tahun 2020. *Photon Jurnal Sains Dan Kesehatan*, *11*(2), 6. https://doi.org/10.37859/jp.v11i2.2530

WHO. (2025). Progress on household drinking water, sanitation and hygiene 2000-2025: special focus on inequalities. *UNICEF Journal*, 1–188. Retrieved from https://www.who.int/publications/m/item/progress-on-household-drinking-water--sanitation-and-hygiene-2000-2024--special-focus-on-inequalities

Widyastuti, D., Jamaluddin, H. N., Arisanti, R., & Kartiasih, F. (2023). Analisis Pengaruh Faktor Sosial Ekonomi Terhadap Akses Sanitasi Layak di Indonesia Tahun 2021. *Seminar Nasional Official Statistics*, *2023*(1), 105–116. https://doi.org/10.34123/semnasoffstat.v2023i1.1853

Yuliastuti, N., Sariffudin, & Syafrudin. (2023). Social Vulnerability Level Appraisal at Tidal Flood Areas. *International Review for Spatial Planning and Sustainable Development*, *11*(2), 7. https://doi.org/10.14246/irspsd.11.2_99

Yushinta, A. K., Martaleni, M., & Astuti, R. (2022). Implementing sanitation marketing as a form of social marketing: A case scheduled desludging service, Malang City. *Jurnal Manajemen Strategi Dan Aplikasi Bisnis*, *5*(2), 319–338. https://doi.org/10.36407/jmsab.v5i2.647