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Assessing the Correlation Between Basic Sanitation and Diarrhea Prevalence in Bulurejo Village, Gresik: A Geographic Information System (GIS) Approach

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ABSTRACT Diarrhea remains a significant public health challenge in Bulurejo Village, Gresik, Indonesia, with a notable increase in cases reported in 2022, particularly linked to inadequate basic sanitation. This study investigates the relationship between household sanitation conditions and diarrhea prevalence, employing a Geographic Information System (GIS) approach to enhance spatial analysis and intervention strategies. The research aims to assess how clean water, toilet, wastewater disposal (SPAL), and waste disposal facilities correlate with diarrhea incidence and to map their distribution for targeted public health interventions. A descriptive-analytical case-control design was utilized, involving 300 households in Bulurejo Village, with data collected through direct observations and GPS coordinates. Bivariate and univariate analyses, using the chi-square test, evaluated the association between sanitation variables and diarrhea prevalence, while Q-GIS software facilitated spatial mapping. Results revealed a significant correlation between poor household sanitation and increased diarrhea prevalence (p=0.044). Specifically, clean water facilities (p=0.014), SPAL (p=0.009), and waste disposal facilities (p=0.029) showed significant associations with diarrhea, while toilet facilities (p=0.347) did not. Odds ratio analyses indicated that deficient clean water facilities posed a 2.251 times higher risk of diarrhea. Spatial mapping highlighted Nyanyat Hamlet as a high-risk area due to inadequate sanitation infrastructure. The study concludes that improving household sanitation, particularly clean water, wastewater, and waste disposal systems, is critical for reducing diarrhea prevalence. GIS-based mapping offers a valuable tool for identifying high-risk areas and optimizing community health interventions, emphasizing the need for enhanced sanitation infrastructure and public health education in Bulurejo Village.

INDEX TERMS Diarrhea prevalence, basic sanitation, Geographic Information System (GIS), Bulurejo Village, chi-square analysis.

I. INTRODUCTION

Diarrhea remains a pressing global public health challenge, particularly in low- and middle-income countries where inadequate sanitation infrastructure exacerbates disease transmission. In Bulurejo Village, Gresik, Indonesia, a significant surge in diarrhea cases was reported in 2022, with 958 cases recorded, marking it as a high-incidence area within the Benjeng Community Health Center region [1]. Poor household sanitation, including contaminated water sources, substandard latrine facilities, open wastewater disposal systems (SPAL), and inadequate waste management, significantly contributes to the fecal-oral transmission of diarrheal pathogens, such as *Escherichia coli* [2], [3]. These environmental factors underscore the urgent need to investigate the relationship between household sanitation and diarrhea prevalence to inform evidence-based public health interventions.

Recent advancements in public health research have leveraged spatial analysis tools, notably Geographic Information Systems (GIS), to map disease distribution and identify environmental risk factors [4]–[6]. GIS facilitates the visualization of spatial patterns, enabling precise identification of high-risk areas and supporting targeted interventions [7], [8]. Studies have also explored Community-Based Total Sanitation (CBTS) programs to improve sanitation access and reduce diarrhea incidence [9], [10]. However, many existing studies focus on general sanitation factors without integrating spatial analysis, limiting their ability to provide geographically targeted solutions [11]-[13]. Furthermore, research specific to rural settings like

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Bulurejo Village is scarce, and few studies combine comprehensive sanitation assessments with GIS to address diarrhea prevalence, revealing a critical research gap.

This study aims to assess the correlation between household sanitation facilities specifically clean water, latrines, SPAL, and waste disposal and diarrhea prevalence in Bulurejo Village, employing a GIS-based approach to map disease distribution and sanitation conditions. By addressing this gap, the research seeks to provide actionable insights for public health strategies. The contributions of this study are threefold:

1. It advances the application of GIS in public health by mapping sanitation-related risk factors, enabling precise identification of high-risk areas for diarrhea control.
2. It provides empirical evidence on the association between specific sanitation components and diarrhea prevalence, guiding infrastructure improvements.
3. It supports community health centers in designing data-driven diarrhea prevention programs, enhancing local health outcomes.

These contributions strengthen the evidence base for environmental health interventions and promote sustainable sanitation practices. The article is structured as follows: Section II details the methodology, including the case-control design, data collection methods, and GIS application. Section III presents the results, encompassing chi-square analyses and spatial mapping of sanitation variables. Section IV discusses the findings in the context of global public health literature, highlighting implications for policy and practice. Section V concludes with recommendations for sanitation enhancements and future research directions. By integrating GIS with detailed sanitation assessments, this study offers a novel approach to addressing diarrhea in Bulurejo Village, contributing to the broader discourse on environmental health and disease prevention in resource-constrained settings.

II. METHODOLOGY

This study utilized a descriptive-analytical case-control design to examine the correlation between household sanitation facilities and diarrhea prevalence in Bulurejo Village, Gresik, Indonesia, incorporating a Geographic Information System (GIS) approach for spatial analysis. Conducted from January to November 2022, the research focused on observational data collection and statistical analysis to ensure replicability. The methodology targeted households within the Benjeng Community Health Center area, assessing the impact of sanitation infrastructure on diarrhea incidence. The procedures outlined below provide a clear framework for replication in similar settings.

A. STUDY POPULATION AND SAMPLING

The study population included all 300 households in Bulurejo Village with reported diarrhea cases in 2022, as recorded by the Benjeng Community Health Center. A case-control design was employed, with cases defined as households with at least one confirmed diarrhea case (n=150) and controls as households without diarrhea cases (n=150). Simple random sampling was used to select participants, ensuring an unbiased sample. Cases were identified based on health center records confirming diarrhea diagnoses between January and November 2022. Controls were selected from the same village, with no reported diarrhea cases during the study period. Households with incomplete sanitation data or unwilling to participate were excluded. The sample size was determined using a power of 80% and a significance level of 0.05, informed by prior sanitation and diarrhea studies [14].

B. DATA COLLECTION

Primary data were collected through direct household observations using a standardized checklist adapted from international sanitation assessment protocols [14]. The checklist evaluated four sanitation variables: clean water facilities (e.g., source type, distance from pollution sources), toilet facilities (e.g., ventilation, septic tank presence), wastewater disposal facilities (SPAL; e.g., open or closed system), and waste disposal facilities (e.g., bin construction, cover presence). Each variable was classified as "good" or "poor" based on established health standards [15]. Physical water quality (color, odor) was assessed visually and through resident reports, while sanitation infrastructure was evaluated against structural criteria [16]. Trained enumerators conducted observations to ensure consistency, with data collected during daytime visits for optimal visibility. Geographic coordinates of each household were recorded using a Global Positioning System (GPS) device (Garmin GPSMAP 64s, accuracy ±3 meters) to support spatial mapping. Secondary data, including diarrhea case records, were obtained from the Benjeng Community Health Center to verify case and control group assignments. Data collection followed a systematic protocol to minimize observer bias and ensure data integrity [17].

C. STUDY DESIGN AND VARIABLES

This retrospective case-control study analyzed existing diarrhea cases and compared them to controls to identify sanitation-related risk factors. The independent variables were the four sanitation components: clean water, toilet, SPAL, and waste disposal facilities. The dependent variable was diarrhea prevalence, defined as the presence of at least one diarrhea case per household in 2022. Potential confounders, such as household size and socioeconomic status, were controlled through randomized sampling [18]. The study design allowed for the assessment of associations between sanitation conditions and diarrhea incidence.

D. DATA ANALYSIS

Data analysis included univariate and bivariate approaches. Univariate analysis summarized the frequency and distribution of sanitation conditions and diarrhea cases. Bivariate analysis used the chi-square test to evaluate associations between each sanitation variable and diarrhea prevalence, with a significance threshold of $p<0.05$. Odds ratios (OR) with 95% confidence intervals (CI) were calculated to determine the strength of associations [19]. Statistical analyses were performed using SPSS version 26. Spatial analysis was conducted using QGIS version 3.22 to

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map diarrhea prevalence and sanitation conditions. Household GPS coordinates were imported into QGIS, and thematic maps were generated to visualize the distribution of diarrhea cases across sanitation variables, categorized as good or poor. Diarrhea cases were represented by red squares and non-diarrhea cases by green squares, facilitating identification of high-risk areas [20]. An overlay technique integrated sanitation and diarrhea data to analyze spatial correlations [21].

E. ETHICAL CONSIDERATIONS

Ethical approval was obtained from the Poltekkes Kemenkes Surabaya Ethics Committee. Informed consent was secured from all participating households, ensuring voluntary participation and confidentiality. Data were anonymized to protect participant privacy, adhering to ethical guidelines for public health research [22].

F. REPLICABILITY

This study is replicable in similar rural settings by following these steps: select a case-control sample using health center records, employ standardized sanitation checklists, collect GPS coordinates for spatial mapping, and apply chi-square and GIS analyses. The methodology can be expanded to include behavioral factors or additional sanitation variables [23].

III. RESULT

The results of the observational assessment of basic house sanitation in Bulurejo Village were included in the poor category, and the results of the analysis using chi-square stated that there was a relationship between basic house sanitation and the prevalence of diarrheal disease.

TABLE 1
Results of Diarrheal Disease Prevalence Analysis (Case-Control Study of Basic Sanitation of Houses in Bulurejo Village

No	Variable	Case	Control	*p-value*
		N=75	N=75	
1.	**Basic Home Sanitation**			0.044
	Good	15 (10%)	26 (17.3%)	
	Not enough	60 (40%)	49 (32.7%)	
2.	**Clean Water Facilities**			0.014
	Good	29 (19.3%)	44 (29.3%)	
	Not enough	46 (30.7%)	31 (20.7%)	
3.	**Toilet Facilities**			0.347
	Good	71 (47.3%)	68 (45.3%)	
	Not enough	4 (2.7%)	7 (4.7%)	
4.	**Waste Water Disposal Facilities (SPAL)**			0.009
	Good	9 (6%)	1 (0.7%)	
	Not enough	66 (44%)	74 (49.3%)	
5.	**Waste Disposal Facilities**			
	Good	7 (4.7%)	1 (0.7%)	0.029
	Not enough	68 (45.3%)	74 (49.3%)	

Based on TABLE 1, it is known that the basic sanitation of houses in which diarrhea sufferers live is in the deficient category in 60 houses, whereas in the houses of non-diarrhea sufferers, it is in the deficient category in 49 houses. From the results of the chi-square test, it can be interpreted that there is a significant relationship between basic household sanitation and the prevalence of diarrheal disease, with a p-value of 0.044 ($P < 0.05$). An increase in the prevalence of diarrheal disease due to poor basic sanitation at home, such as not having complete basic sanitation facilities at home and not meeting health requirements, can facilitate the occurrence of diarrheal disease. The lack of basic sanitation facilities at home in Bulurejo Village puts people at risk of diarrheal disease incidents if environmental factors are unhealthy human behavior, namely food and drink (Ministry of Health of the Republic of Indonesia, 2019). This is further supported by the odds ratio analysis presented in TABLE 2.

TABLE 2
Results of Diarrheal Disease Prevalence Analysis

No	Variable	OR	95 % CI	
			Lower	Upper
1.	**Basic Home Sanitation**	2,122	1,014	4,445
2.	**Clean Water Facilities**	2,251	1,171	4,328
3.	**Toilet Facilities**	0.547	0.153	1,954
4.	**Waste Water Disposal Facilities (SPAL)**	0.099	0.012	0.803
5.	**Waste Disposal Facilities**	0.131	0.016	1,095

A. MAP OF THE PREVALENCE OF DIARRHEA BASED ON BASIC HOME SANITATION

Bulurejo Village is a sub-district consisting of four hamlets, namely Bulurejo Hamlet, Nyanyat Hamlet, Balowangon Hamlet, and Rayung Hamlet. The population of Bulurejo Village is 4,367, with 2,184 men and 2,183 women. There are four maps of the prevalence of diarrhea disease based on basic household sanitation in Bulurejo Village, Benjeng Health Center Working Area, namely maps of clean water facilities, latrine facilities, SPAL, and waste disposal facilities. The following are the results of the basic sanitation mapping of the house, which has been processed using Q-

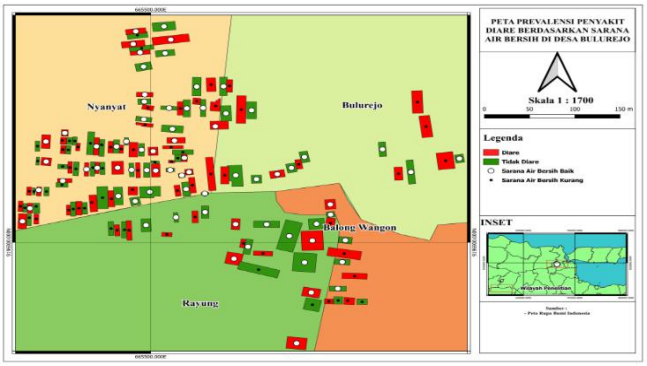

FIGURE 1. **Map of Clean Water Facilities on The Prevalence of Diarrheal Diseases**

GIS.

Based on FIGURE 1, the distribution pattern of diarrhea based on clean water facilities is divided into two categories: good and poor. In this picture, symbols representing diarrhea cases are depicted with red squares, while non-diarrhea cases are depicted with green squares. This helps visualize and understand how the distribution of diarrhea cases correlates with the quality of clean water facilities, with a specific focus on areas categorized as either good or poor. The image

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provides a visual insight into the relationship between water sanitation and the occurrence of diarrhea in various village or district areas.

The distribution pattern of diarrhea based on toilet facilities is divided into two categories: good and poor. In this picture, symbols representing individuals with diarrhea are depicted with red squares, while those without diarrhea are depicted with green squares. This helps visualize and understand how the distribution of diarrhea cases correlates with the quality of toilet facilities, with a specific focus on areas categorized as either good or poor. This spatial

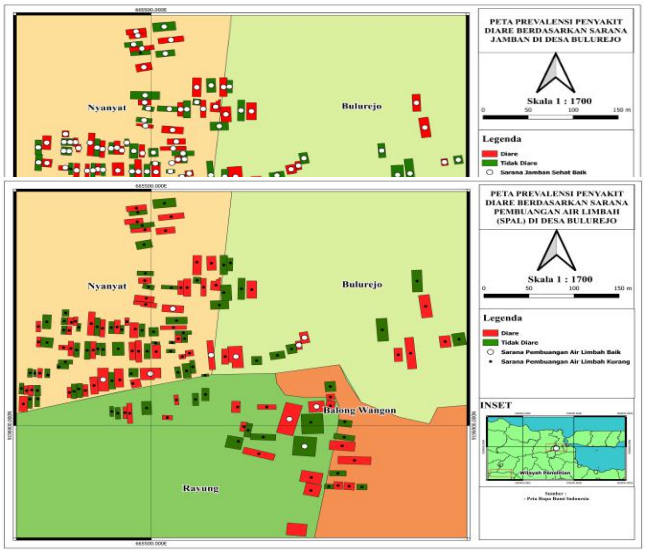

FIGURE 3. Map of SPAL facilities on the prevalence of diarrheal diseases

relationship is clearly illustrated in the village map, highlighting toilet facility access and diarrhea incidence patterns FIGURE 2.

Based on FIGURE 3, the distribution pattern of diarrhea based on wastewater disposal facilities is divided into two categories: good and poor. In this picture, symbols representing individuals with diarrhea are depicted with red squares, while those without diarrhea are depicted with green squares. This helps visualize and understand how the distribution of diarrhea cases correlates with the quality of wastewater disposal facilities, with a specific focus on areas categorized as either good or poor.

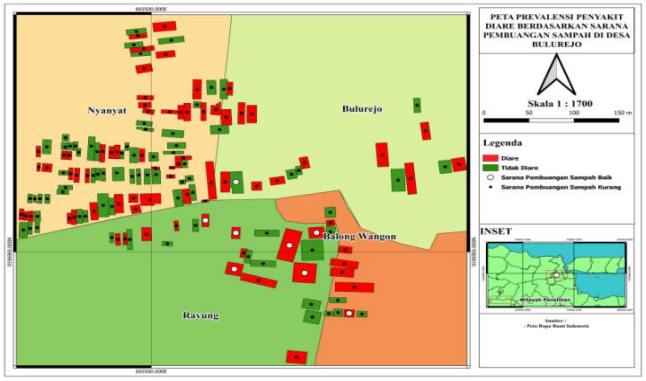

FIGURE 4. Map of waste disposal facilities on the prevalence of diarrheal diseases

Based on FIGURE 4, the distribution pattern of diarrhea based on waste disposal facilities is divided into two categories: good and poor. In this picture, symbols representing individuals with diarrhea are depicted with red squares, while those without diarrhea are depicted with green squares. This helps visualize and understand how the distribution of diarrhea cases correlates with the quality of waste disposal facilities, with a specific focus on areas categorized as either good or poor.

IV. DISCUSSION

This study investigated the correlation between household sanitation facilities and diarrhea prevalence in Bulurejo Village, Gresik, Indonesia, employing a Geographic Information System (GIS) approach for spatial analysis. The findings offer valuable insights into environmental determinants of diarrhea and highlight the utility of GIS in targeting public health interventions. This discussion is organized into three sub-chapters: interpretation of results, comparison with existing literature, and limitations and implications of the findings.

The results reveal a significant association between poor household sanitation and increased diarrhea prevalence in Bulurejo Village, with an overall p-value of 0.044 ($p<0.05$). Specifically, clean water facilities ($p=0.014$), wastewater disposal facilities (SPAL, $p=0.009$), and waste disposal facilities ($p=0.029$) demonstrated statistically significant correlations with diarrhea incidence, while toilet facilities ($p=0.347$) did not. Odds ratio (OR) analysis indicated that households with deficient clean water facilities faced a 2.251 times higher risk of diarrhea (95% CI: 1.171–4.328), and those with poor overall sanitation had a 2.122 times higher risk (95% CI: 1.014–4.445). These findings suggest that contaminated water sources and inadequate waste management facilitate fecal-oral transmission of pathogens, such as *Escherichia coli* [24]. The lack of association with toilet facilities may be due to high compliance with health standards in latrine construction, including adequate ventilation and septic tank presence, observed across both case and control households. Spatial analysis using QGIS identified Nyanyat Hamlet as a high-risk area, with a concentration of deficient clean water, SPAL, and waste disposal facilities correlating with elevated diarrhea prevalence. GIS mapping showed that uncovered dug wells, often located near pollution sources, likely contributed to water contamination in Nyanyat Hamlet [25]. Similarly, open SPAL systems and uncovered waste bins attracted vectors like flies, exacerbating disease transmission [26]. These results underscore the critical role of sanitation infrastructure in diarrhea prevention and demonstrate GIS's capacity to identify geographic clusters for targeted interventions [27]. The visualization of red (diarrhea cases) and green (non-diarrhea cases) squares on thematic maps provided a clear representation of high-risk areas, facilitating data-driven public health strategies.

The findings align with international studies linking poor sanitation to diarrhea. A systematic review by Brown et al. found that inadequate water and sanitation infrastructure increases diarrhea risk by 20–30% in low-income settings, supporting the significant associations observed for clean

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water, SPAL, and waste disposal facilities [24]. A case-control study in rural Tanzania reported that unprotected water sources were associated with a 2.5 times higher diarrhea risk (95% CI: 1.7–3.6), consistent with the current study's findings on clean water facilities [28]. However, the non-significant association with toilet facilities contrasts with research from Uganda, where unimproved latrines were linked to a 2.9 times higher diarrhea risk ($p<0.01$), likely due to lower latrine compliance compared to Bulurejo Village [29]. The significant associations with SPAL and waste disposal facilities are consistent with a study in Nepal, which found that open wastewater systems increased diarrhea incidence by fostering vector breeding ($p=0.015$) [30]. In contrast, a study in urban Philippines reported no significant link between waste disposal and diarrhea ($p=0.42$), attributed to community waste management practices despite poor infrastructure [31]. The integration of GIS in this study distinguishes it from traditional sanitation research. A study in Vietnam used GIS to map waterborne diseases, similarly identifying high-risk areas linked to poor sanitation, reinforcing the value of spatial tools in public health [32]. The current study's GIS approach enhances intervention precision, offering a model for other rural settings.

This study has several limitations. First, the retrospective case-control design relies on health center records, which may introduce recall bias or incomplete documentation, potentially affecting data accuracy [33]. Second, water quality assessments were limited to visual and sensory evaluations (color, odor), lacking microbiological testing to confirm pathogen presence [34]. Third, behavioral factors, such as handwashing or food hygiene, were not included, which may confound the relationship between sanitation and diarrhea [24]. Fourth, the study's focus on Bulurejo Village limits generalizability to regions with different environmental or socioeconomic conditions. Finally, the GPS device used (±3 meters accuracy) may introduce minor spatial errors in GIS mapping, potentially affecting the precision of high-risk area identification [32]. The findings have significant implications for public health policy and practice. The strong associations between poor clean water, SPAL, and waste disposal facilities and diarrhea prevalence highlight the need for targeted infrastructure improvements in Bulurejo Village, particularly in Nyanyat Hamlet. Interventions should prioritize providing covered wells, closed SPAL systems, and robust waste bins to reduce contamination and vector proliferation [30]. The GIS-based mapping approach offers a scalable tool for community health centers to identify high-risk areas and allocate resources efficiently, enhancing diarrhea control programs [32]. For example, prioritizing sanitation upgrades in Nyanyat Hamlet could significantly reduce diarrhea incidence. The study underscores the value of integrating spatial analysis into public health research. GIS can enhance evidence-based decision-making by visualizing disease patterns and guiding localized interventions, as demonstrated in similar studies [27]. Community health centers should leverage these findings to advocate for sanitation improvements and implement education campaigns on proper waste and wastewater management [31]. Future research should incorporate behavioral factors to provide a comprehensive understanding of diarrhea risk [24]. Additionally, including microbiological water testing and longitudinal designs could strengthen causal inferences and improve generalizability [34]. Expanding GIS applications to other rural settings could further refine public health strategies for diarrhea prevention, contributing to global efforts to reduce environmental health burdens. This study provides robust evidence linking poor household sanitation to diarrhea prevalence, with GIS offering a powerful tool for spatial analysis. Addressing the identified sanitation deficiencies through infrastructure improvements and community education can reduce diarrhea incidence in Bulurejo Village. The findings advocate for a multifaceted approach combining enhanced sanitation systems, spatial analysis, and public health education to improve environmental health outcomes in resource-constrained settings.

V. CONCLUSION

This study aimed to evaluate the correlation between household sanitation facilities clean water, toilet, wastewater disposal (SPAL), and waste disposal and diarrhea prevalence in Bulurejo Village, Gresik, Indonesia, using a Geographic Information System (GIS) approach to map disease distribution and inform targeted interventions. The findings confirmed a significant association between poor household sanitation and increased diarrhea prevalence, with an overall p-value of 0.044 ($p<0.05$). Specifically, clean water facilities ($p=0.014$), SPAL ($p=0.009$), and waste disposal facilities ($p=0.029$) showed significant correlations with diarrhea incidence, while toilet facilities ($p=0.347$) did not. Odds ratio analyses revealed that households with deficient clean water facilities faced a 2.251 times higher risk of diarrhea (95% CI: 1.171–4.328), and those with poor overall sanitation had a 2.122 times higher risk (95% CI: 1.014–4.445). GIS mapping identified Nyanyat Hamlet as a high-risk area, with 60% of households exhibiting poor sanitation conditions, particularly in clean water and waste management, correlating with elevated diarrhea cases. These results underscore the critical role of improved sanitation infrastructure in reducing diarrhea prevalence and highlight GIS as a valuable tool for pinpointing high-risk areas. The spatial insights obtained through GIS also facilitate more strategic planning, enabling local authorities to respond more efficiently to environmental health threats. Future research should incorporate behavioral factors, such as hygiene practices, food safety, and water storage behavior, to provide a more comprehensive understanding of diarrhea risk. Additionally, longitudinal studies with microbiological water testing could strengthen causal inferences and enhance generalizability. Expanding GIS applications to other rural settings and integrating real-time data could further refine public health strategies. Community health centers should leverage these findings to prioritize infrastructure upgrades, such as covered wells and closed SPAL systems, and implement education programs on sanitation practices to mitigate diarrhea incidence in Bulurejo Village and similar settings.

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DATA AVAILABILITY

No datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTION

Silvia Retna Ning Tyias was responsible for the conceptualization, methodology, data curation, original draft writing, and visualization. Narwati handled conceptualization, methodology, supervision, project administration, and review and editing, also serving as the corresponding author. Suprijandani contributed to the methodology, formal analysis, resources, and software. Demes Nurmayanti managed the investigation, data curation, and validation. Lastly, Leila Florento assisted with review and editing, validation, and resources.

DECLARATIONS

ETHICAL APPROVAL

Ethical approval is not available.

CONSENT FOR PUBLICATION PARTICIPANTS.

Consent for publication was given by all participants

COMPETING INTERESTS

The authors declare no competing interests.

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