ORIGINAL ARTICLE

# The effect of sanitation risk on toddler stunting incident with geographically weighted regression approach in Malang Regency, Indonesia

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## ABSTRACT

Stunting is a fundamental problem in Indonesia's human development. The risk factors for stunting are very complex, including inadequate environmental sanitation. This study aims to analyze and map the influence of spatially correlated sanitation risk on the incidence of stunting toddlers in Malang Regency, Indonesia. Data collection was carried out by interviewing respondents using questionnaires, counting stunting toddlers, and observing environmental sanitation objects. Determination of respondents was done purposively with the following stages. First, at the village level, 75 sites were selected based on the following criteria: population density; poverty level; the presence of streams, drainage or irrigation canals; and flood vulnerability. Furthermore, in each village, 40 respondents were selected based on the following criteria: women aged between 18 to 65 years, came from poor families and had a child (or children). When the number of respondents who were willing to participate is less than 40 people in each village, they were replaced by other respondents based on recommendations from village officials. A total of 3000 respondents have participated in this study. The selected respondents include wives, dependent married women or widows. The spatial analysis approach was carried out using the Geographically Weighted Regression (GWR) method. Based on the results of the analysis of the spatial effect of the GWR model, the Sanitation Risk Factors that significantly affected the incidence of stunting in Malang Regency were; Environmental Drainage (greywater), Solid Waste, and Domestic Wastewater (black water). Clean and Healthy Lifestyles and Water Sources have less effect on sanitation risk. This study recommends government and public interventions to improve environmental sanitation including integrated waste management, improvement of drainage infrastructure, construction of standardized toilets, and carrying out health promotion efforts with education to increase public awareness.

**Key words:**
sanitation risk, toddler stunting, Geographically Weighted Regression

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# INTRODUCTION

Stunting is a condition of growth and development disorders experienced by children due to malnutrition, repeated infections, and inadequate psychosocial stimulation for several years [1]. Children are considered to experience stunting if their length/height is below −2 standard deviations from the World Health Organization (WHO) Child Growth Standards median for the same age and sex. Similarly, children are classified severely stunted if their length/height is below −3 standard deviations from the WHO Child Growth Standards median for the same age and sex [1,2]. The risk factors for stunting are complex, including maternal nutrition and infection, teenage motherhood and short birth intervals, fetal growth restriction and preterm birth, child nutrition and infection, and environmental factors (i.e., low quality of water and sanitation as well as the use of biomass fuels) [3,4]. Foodborne mycotoxins, a lack of adequate sanitation, dirt floors in the home, poor quality cooking fuels, and inadequate local waste disposal are among the pivotal environmental factors associated with an increased risk of stunting [5].

These factors are associated with each other, so stunting control requires concern for all of these factors. For example, fetal growth restriction and preterm birth may often associate with its origins, in part, in the fetal period, suggesting a need to intervene during an earlier life stage during pregnancy and even preconceptionally [6].

In general, the contribution of health factors to risk factors is a mere 30%, while non-health factors contribute 70%. The non-health factors involve various aspects such as food security, availability of sanitation, poverty alleviation, education, and social, economic and environmental components [4]. Data on the prevalence of stunting in toddlers collected by WHO shows that Southeast Asia is the region with the second highest prevalence of stunting (31.9%) in the world after Africa (33.1%). Indonesia is included as the sixth country in the South-East Asian region after Bhutan, Timor Leste, Maldives, Bangladesh, and India, with a high risk of stunting for toddlers of 36.4% [7].

Conversely, poor environmental sanitation may trigger digestive disorders, which lead to energy for growth diverted to the body's resistance to infection [8]. Poor environmental health may trigger infectious diseases, which in turn have an impact on children's nutritional intake and result in disorders [9]. Clinical infections may lead to growth delays in children [10], and those with a history of infectious diseases may have an increased risk of stunting [11]. Appropriate environmental sanitation management can reduce sanitation risk and hence protect children against stunting [12,13]. Therefore, concern about environmental factors in addition to nutritional factors is pivotal in controlling stunting[5].

Sanitation risk is the value of the risk to health from water sources, garbage, puddles, hygiene and sanitation behavior and domestic wastewater. Several developing countries use sanitation risk assessment parameters using indices, for example, the Water Integrity Risk Index which is applied in several countries in Eastern Europe, Africa, South America and Bangladesh 14; Water Supply, Sanitation and Hygiene Risk Index in India 15, water and sanitation risk index in Pakistan [16]. In Indonesia, the Ministry of Health compiles an assessment guideline expressed in the form of an index called the Sanitation Risk Index (SRI) [17,18]. The index measures the level of sanitation risk based on the results of the Environmental Health Risk Assessment (EHRA) analysis. There are five components of the SRI as follows: Environmental Drainage (greywater), Solid

Waste, Clean and Healthy Life Behavior, Domestic Wastewater (black water), and Water Resources [18].

Malang Regency, which is located in East Java, Indonesia is one of the 100 priority districts/cities for stunting national intervention. Geographically, the regency has areas of low, medium, and high topographies. The administrative area of Malang Regency is divided into 390 villages, with a total area of 3,534.86 $km^2$ and a projected population of 2,876,596 people in 2021. The diversity of socio-economic levels of society, and complex environmental and geographical conditions are challenges for local governments in controlling stunting cases based on risk factor characteristics in each village. The prevalence of stunting in Malang Regency reached 28.3% in 2019 and the results of weighing operations for toddlers obtained 18,466 new stunting cases in 2019 [19].

Previous research conducted in Malang Regency generally used secondary data [20], with general variables such as demography, health, and economy [21]. The difference in the number of cases of toddler stunting in each sub-district/village area in Malang Regency shows that there are specific and local risk factors, therefore it is necessary to research the existence of Sanitation Risk Factors that significantly affect the incidence of stunting in toddlers with a regional approach or spatial aspect using Geographically Weighted Regression (GWR). This study aims to analyze and map the local variation model of Sanitation Risk Factors that influence the incidence of toddler stunting in Malang Regency. The benefits obtained are information for regional-based target planning in the context of implementing prevention and control programs for toddler stunting in the Malang Regency.

## METHODS

This research was conducted in Malang Regency, East Java, Indonesia between January – March 2021. Malang Regency has 33 sub-districts, each consisting of 6 to 18 villages. Below the village, there are several non-formal neighborhood associations. On average, there are 36 neighborhood associations in each village. The population in this study were all housewives, married women or widows aged between 18 to 65 years and toddlers who took part in a weighing program in integrated health services.

In this study, data collection was carried out by interviewing respondents using questionnaires, counting stunting toddlers, and observing environmental sanitation objects. Determination of respondents is done purposively with the following stages. First, at the village level, 75 sites were selected based on the following criteria: population density; poverty level; the presence of streams, drainage, or irrigation canals; and flood vulnerability. Furthermore, in each village, 40 respondents were selected who met the following criteria: women aged between 18 to 65 years, came from poor families and had children. If the number of respondents who are willing to participate is less than 40 people, they are replaced by other respondents based on recommendations from village officials. Sanitation risk index variable data provided a total of 3000 respondents.

Interviews were conducted by the desired surveyor. Input data from the EHRA interview was collected using the Android-based Appsheet application (mWater Surveyor) which is connected to the google spreadsheet. Supervisors can monitor EHRA Study data via internet connecting phone/computer. Processing and analyzing data from the EHRA study interviews that have been entered and recapitulated from all respondents yields EHRA study information. Information on the results of the EHRA study is presented in the form of tables and graphs to make it easier to read and visualize the answers to a question in the EHRA study. The

processing and analysis of the EHRA data study were carried out using Microsoft Office Excel software and the SPSS application.

Data on stunting toddlers was obtained from the results of weighing the toddlers in 2021 in the respondent's area and verified according to the identity of the place of residence and history of the toddler. The data from observations of children under five are entered into the EHRA application in the form of Dos Box 0.74 and Epi Data 3.1, then the data is processed with SPSS to obtain various variations of information in the form of indexes, and tables and graphs related to sanitation in risk areas. The village sanitation risk index variables are presented in Table 1. These include environmental drainage (puddles), waste disposal services (main roads, frequency and transportation, sorting), clean and healthy living behavior, domestic wastewater (toilet and sewerage), and sources of water (drinking, washing, bathing, water scarcity). The behaviors studied were related to hygiene and sanitation, including washing hands with soap, defecating, and sorting waste.

The results of the sanitation risk index were then correlated with the number of stunted children under five in the observation area. The effect of spatial relationships was analyzed using the Geographically Weighted Regression (GWR) model. The GWR method is a development of linear regression where each parameter is calculated at each location point so that each geographic location point has a different regression parameter value with significant local variables for each observation location. The results are visualized in the form of thematic maps of sanitation risk areas using a Geographic Information System with ArcGIS 10.9 application. To find out the significant effect of sanitation risk on stunting in each area group, a partial test was conducted using t-test statistics on each parameter of the observation area (village). Testing the significance of the GWR model parameters using the following hypotheses:

H0: $\beta k\ (ui,vi) = 0$

H1: $\beta k(ui,vi) \neq \beta k$; $i=1,2,...,22$, $k=1,2,3$

**Table 1.** The Sanitation Risk Index variables

| Variables | Sanitation Risk Index | Type of data |
|---|---|---|
| Y | Number of stunting cases | Ratio |
| X1 | Environmental Drainage (greywater) | Ratio |
| X2 | Solid Waste | Ratio |
| X3 | Clean and Healthy Life Behavior | Ratio |
| X4 | Domestic Wastewater (black water) | Ratio |
| X5 | Water Resources | Ratio |

## RESULTS

A total of 3000 respondents who participated in this study consisted of wives (70.3%), dependent females (5.3%) and heads of household (24.4%). Most respondents were more than 45 years old (47.17%) and few of them were less than 20 years old (1.4 %). A total of 36,585 toddlers were involved in weighing operations, and about 7% of them were indicated to experience stunting. The detailed information about the respondents are shown in Table 2.

**Table 2.** Respondent's characteristics

| Characteristics | | Total | |
|---|---|---|---|
| | | N | % |
| Respondent's position | Wife | 2.109 | 70.3 |
| | Dependent female | 160 | 5.3 |
| | Head of household | 731 | 24.4 |
| Age (years old) | ≤ 20 | 42 | 1.4 |
| | 21 to 25 | 137 | 4.57 |
| | 26 to 30 | 239 | 7.97 |
| | 31 to 35 | 327 | 10.9 |
| | 36 to 40 | 435 | 14.5 |
| | 41 to 45 | 405 | 13.5 |
| | > 45 | 1.512 | 50.4 |
| House status | Owner | 2.794 | 91.1 |
| | Official house | 16 | 0.5 |
| | Share with another family | 24 | 0.8 |
| | Rent | 24 | 0.8 |
| | Kontrak | 15 | 0.5 |
| | Kin's house | 142 | 4.7 |
| Education | Non-formal school | 95 | 3.2 |
| | Elementary | 1.249 | 41.6 |
| | Junior High School | 776 | 25.9 |
| | Senior High School | 627 | 20.9 |
| | Vocational High School | 92 | 3.1 |
| | University/college | 161 | 5.4 |
| Certificate of incapacity holder | Yes | 408 | 13.6 |
| | No | 2.592 | 86.4 |
| Health insurance holder | Yes | 1.608 | 53.6 |
| | No | 1.392 | 46.4 |
| Having child | Yes | 2.624 | 87.5 |
| | No | 376 | 12.5 |

The pattern of sanitation risk distribution tends to disperse in east, south, and northwest remote areas (Figure 1). Generally, these areas have low accessibility to city centers or other public facilities. Some areas are even situated on the coast or in mountainous regions.

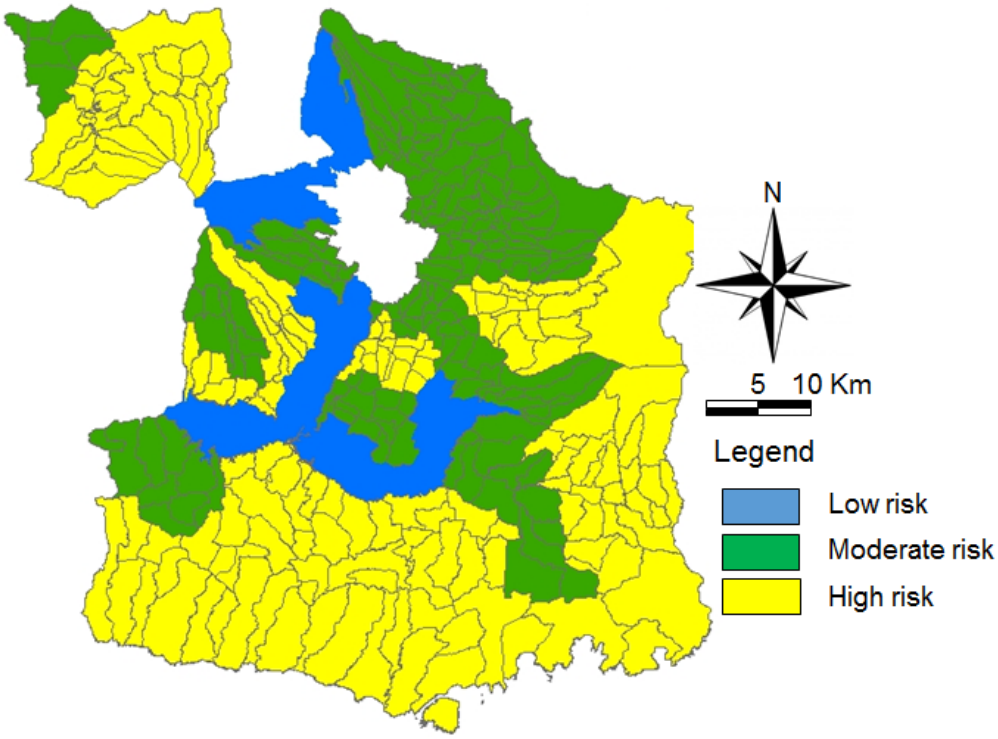


**Figure 1.** Sanitation risk index distribution in Malang Regency in 2021

The relationship between the influence of sanitation risk and the incidence of stunting in Malang Regency showed a positive correlation as shown in Figure 2. The scatter plot graph demonstrated a positive relationship between SRI and stunting prevalence, statistical tests indicated a fairly low correlation, ($R^2 = 0.41$). This meant that by increasing the value of the SRI, the incidence of stunting has the potential to increase.

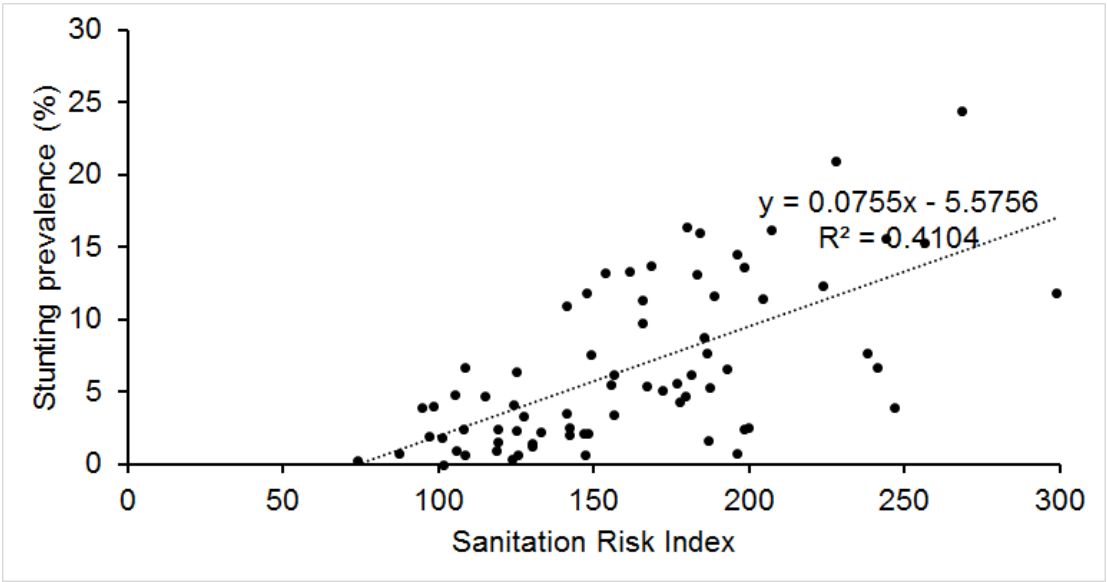


**Figure 2.** Relationship between sanitation risk index and toddler stunting prevalence (%)

Among the five SRI variables, wastewater shows the high index value (66.36), while household water source shows the lowest value (5.5). the high value of SRI indicates the low quality of handling of the SRI variable (Figure 3).

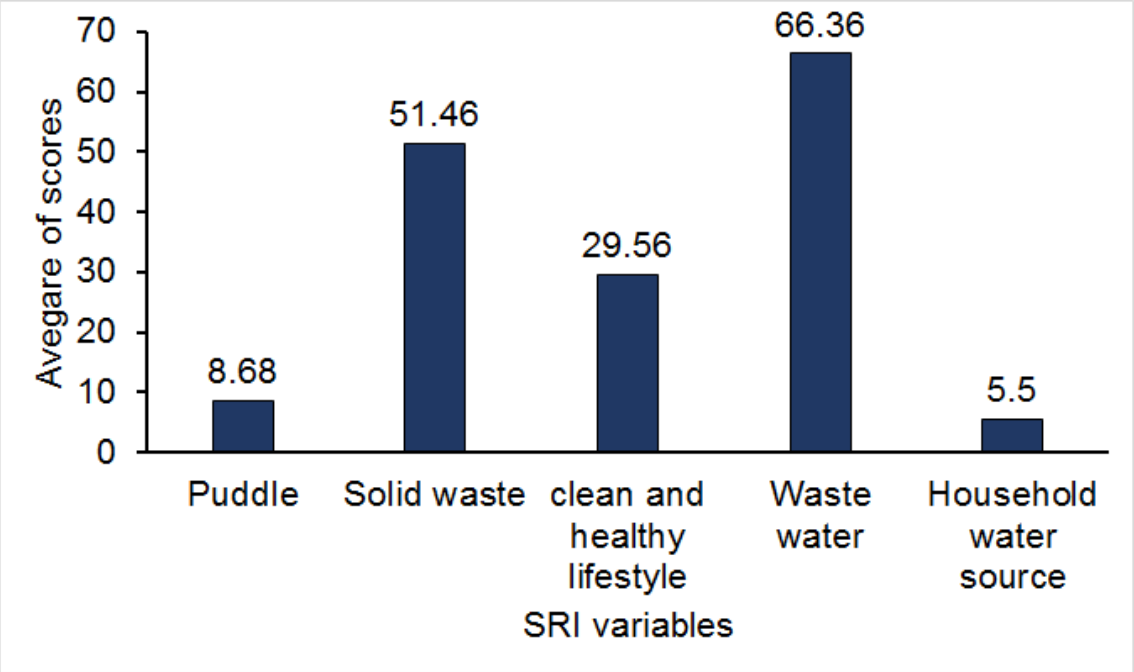


**Figure 3.** Value of sanitation risk index variables in Malang Regency in 2021

Analysis of the significant sanitation risk index with the incidence of stunting was conducted using the Geographically Weighted Regression (GWR) model. This model adopts fixed Gaussian Kernel weighting with an optimum bandwidth of 18872.56. This bandwidth value indicates that a sub-district/village influences each other within a radius of 18.87 kilometers. The goodness of a regression model can be seen from the resulting $R^2$ value. The value of $R^2$ which was greater than the comparison model, indicated that the model was better at explaining the effect of sanitation risk on stunting incidence in Malang Regency (Table 3).

**Table 3.** Model selection

| Model | $R^2$ | AIC |
|---|---|---|
| OLS | 0.33 | 471.59 |
| GWR | 0.52 | 463.44 |

By using the value criteria and AIC generated from the two models, the GWR model produced a better model than the linear regression (OLS) model. The $R^2$ value generated by the GWR model was greater (0.52) than that by the OLS (0.33). The $R^2$ explains the variability of the sanitation risk index that affects the incidence of toddler stunting in Malang Regency by 52.25% while the remaining 47.75% was explained by other factors outside the observed variables.

At the significance level (α) 5%, the value of t (0.05; 69) = 1.9. The results of the t-test of significant sanitation risk grouping on the incidence of stunting in Malang

Regency were visualized in Figure 4. Figure 4 showed that the sanitation risk of greywater and solid waste affected stunting in 43 observation villages; greywater, solid waste and domestic wastewater affected 17 observation villages, greywater and domestic wastewater affected 3 observation villages, while solid waste affected 13 observation villages. The risk factors for clean and healthy lifestyles as well as water sources have no effect in all observation villages.

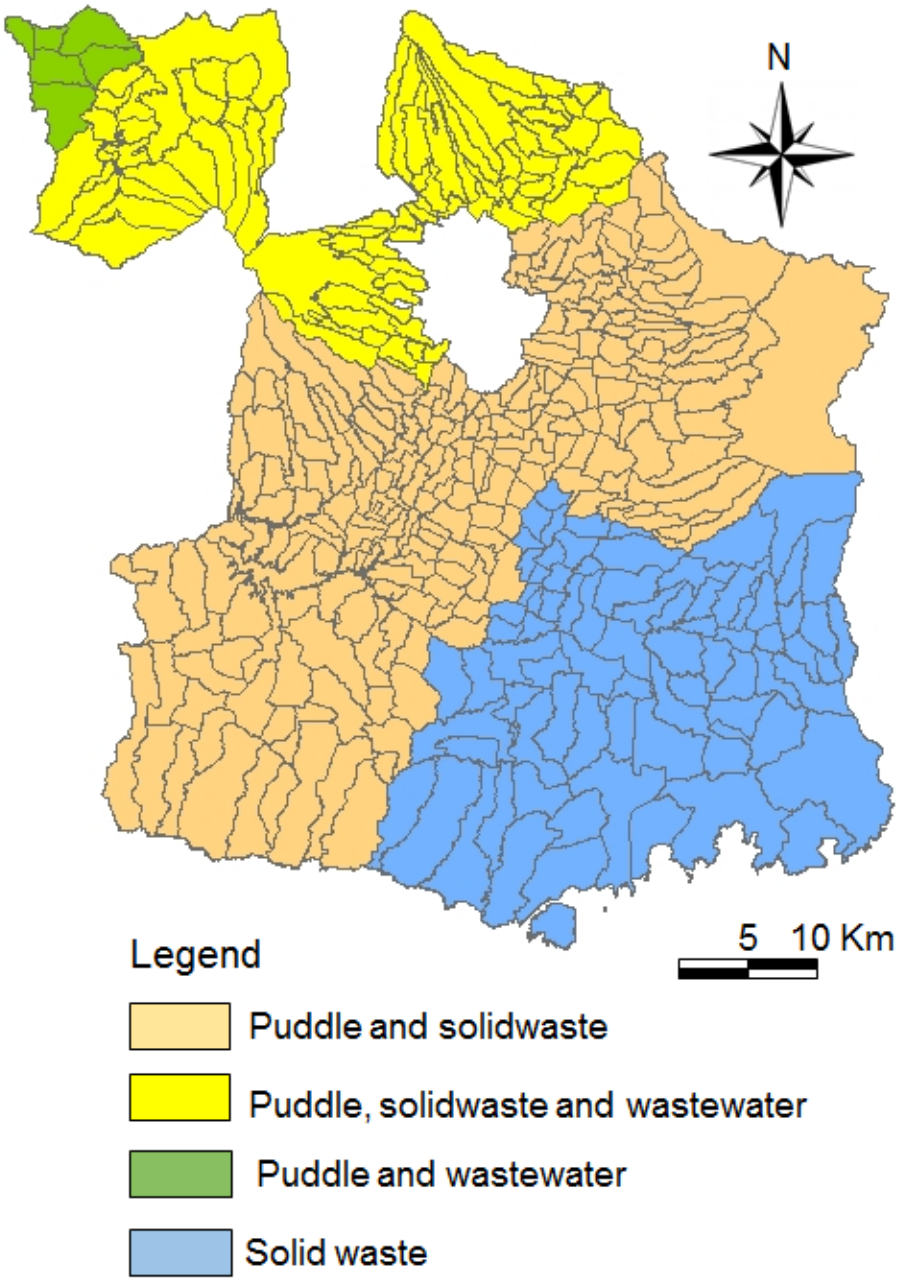


**Figure 4.** Significant variable sanitation risk index associated with the incidence of stunting in Malang Regency

***Environmental Drainage Risk Factors (Greywater)***

Based on the results of the survey, 49.37% of respondents had open Waste Water Treatments (WWTs), 30.17% had a closed WWT and 20.27% lacked WWT. Open wastewater treatment is one of the factors that may lead to environmental pollution due to seepage into the soil and increase the risk of infectious diseases, such as diarrhea and animal-borne diseases. Domestic waste comes from the bathroom, kitchen, washing water, and other household activities.

Etiologically unidentified gastrointestinal disease and giardiasis are the most common waterborne diseases found in groundwater or surface water systems. Based on the observations, most household wastes were not processed properly before being discharged into the environment, creating puddles of greywater around the house (13.4%). The distance of WWT to clean water sources is less than 10 meters and is sometimes invisible from observation. This may infiltrate into the ground and contaminate drinking water sources. Most of the WWT observed were dirty and consisted of blockages (33.23%), some of the final disposals (infiltration wells) were close to the dug wells and some were directly discharged into the river.

***Solid Waste Risk Factors***

Improper solid waste treatment affects the sanitary conditions in the residential environment. Household solid waste management factors influenced stunting in 13 villages. Based on observation, most respondents (98.47%) mixed the waste, while only 1.53% conducted waste sorting.

The frequency of garbage collection affects the generation of waste in the environment. The result showed that 15.88% of solid wastes were taken every day, 39.52% were picked up several times a week, 9.97% were collected several times a month, and 7.18% were collected only once a month (Figure 5).

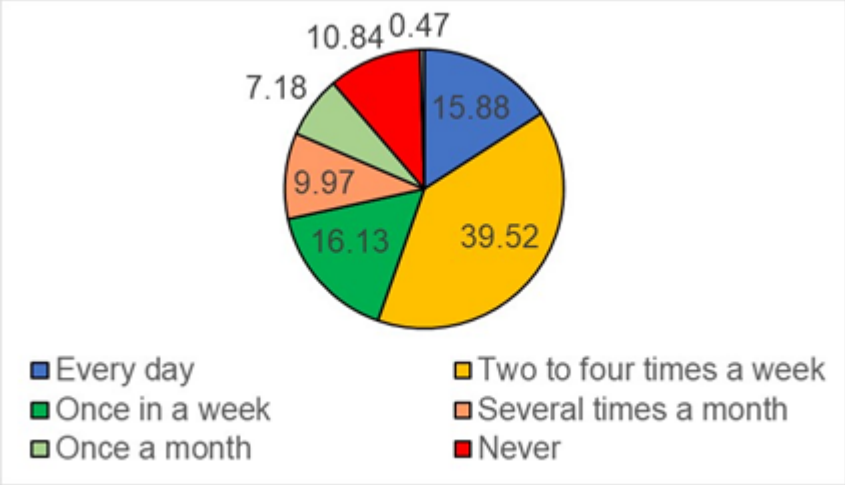


**Figure 5.** The solid waste-collecting intensity in Malang Regency (%)

The result showed that only 25.3% of the solid waste was collected and transferred to the intermediate processing site (before transport to the final processing site), while the rest were burned (51.5%) or went through other treatments (Table 4).

**Table 4.** Solid waste processing in the Malang Regency

| No. | Processing | Percentage (%) |
|---|---|---|
| 1 | Burning | 51.50 |
| 2 | Collecting and disposing of at Intermediate Processing Site | 25.30 |
| 3 | Collecting in a closed trash can | 10.87 |
| 4 | Throwing into an open hole | 4.27 |
| 5 | Throwing into vacant land | 2.53 |
| 6 | Other | 1.70 |
| 7 | Conducting the garbage sorting | 1.53 |
| 8 | Throwing into the river | 1.10 |
| 9 | Dumping into a hole and covered with soil | 0.60 |
| 10 | Collecting by informal collectors for the recycling process | 0.30 |
| 11 | Leaving it rotten | 0.27 |
| 12 | No idea | 0.03 |

***Domestic Wastewater Risk (black water) Factors***

Domestic Wastewater Risk (black water) arose from toilet and sewage sludge. Based on the survey, the problems of pollution from domestic waste in Malang Regency include; open defecation behavior in the field, improper facilities for storing and processing greywater, the close distance of the septic tank to drinking water sources, and the cleaning period of septic tank emptied. The means of defecation used showed that 96.1% of respondents stated that they used a private toilet, 1.8% used communal toilets and 1.3% defecated in the rivers or the field (Table 5). Among the respondent having personal toilets, most of them (52.7%) used goose-neck toilets with self-constructed septic tanks, 26.2% used goose-neck toilets with standardized fabricated septic tanks, while the rest used the unstandardized toilet.

**Table 5.** The use of toilets among the respondents

| No | Toilet types | N | % |
|---|---|---|---|
| 1 | Personal toilet | 2,884 | 96.1 |
| 2 | Communal toilet | 53 | 1.8 |
| 3 | River of field | 38 | 1.3 |

The majority of respondents (82.1%) have never emptied the septic tank for more than 10 years, while only a few respondents emptied their septic tank in less than 5 years (Figure 6). Regarding the safety from environmental pollution due to the construction of the septic tank, most of the respondents (73.83%) perceived that they had unsafe septic tanks, while only 26.17% of respondents believed that they had safe septic tanks.

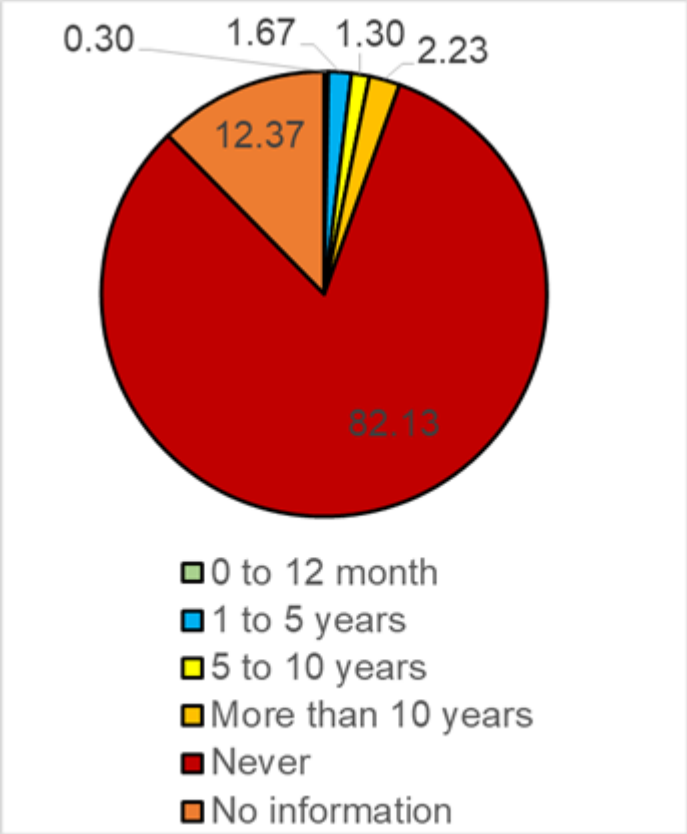


**Figure 6.** Septic tank emptying intensity (%)

## DISCUSSION

This study demonstrated that several sanitation risk factors i.e Environmental Drainage (greywater), Solid Waste, and Domestic Wastewater (black water) significantly affected the incidence of stunting in Malang Regency. Potential pollution from environmental drainage may increase due to wastewater infiltration into the ground, overflow of wastewater creating puddles around the house and clogged WWT becoming a breeding ground for disease vectors such as flies, rats, cockroaches and others. Children living in polluted environments due to inadequate sanitation have a 40% risk of experiencing stunting. The risk is significantly higher in rural and suburban areas (43% vs. 27%) compared to those living in urban areas (5%) [22].

The potential for pollution from the solid waste problem arose from burning, throwing into open holes, vacant land and the river. This condition may lead to an increase in the density of fly vectors in household waste piles around the residential area. Garbage generally contains micro-organisms that can cause various digestive infectious diseases in humans such as diarrhea, environmental enteric dysfunction, and intestinal worms. Microorganisms from dirty places are transferred by flies to food and drinks consumed by humans [23,24]. This condition may lead to growth disorders (stunting) in children[25–28]. Another study reported a relationship between stunting cases and household waste management, with all children experiencing stunting lacking in household waste management. Meanwhile, of the 88 respondents who used household waste security, 60% experienced stunting in the case group and 100% experienced stunting in the control group [29].

Potential pollution from environmental drainage is frequently associated with domestic wastewater

treatment. Most of the WWT observed were dirty and consisted of blockages (33.23%), some of the final disposals (infiltration wells) were closed to the dug wells and some were directly discharged into the river. Domestic wastewater in addition to the potential to cause contamination of water sources due to the content of pollutants both organic and inorganic also contains pathogenic microorganisms and parasites that may harmful to health [30]. The WWT with unproper maintenance has the potential to pollute the environment due to the hilly topography of the land. Other studies reported that unsafe drinking water sources and the distance of the water source from the disposal site were related to the incidence of stunting in toddlers [25,31]. Improper WWT and other pollution treatment facilites may occur in powerless communities with low income. A study in the Valley of Sinabung Volcano, North Sumatera, Indonesia indicated that daily income also plays a pivotal risk factor in the study population; therefore, it should alarm the government to provide incentives to the most vulnerable people in the regions [32].

Domestic wastewater that is at risk of contaminating the environment is the disposal of human wastewater and sewage sludge. The practice of defecating in inadequate facilities is the main factor for increasing public health risks, such as contaminating soil and water sources for daily purposes (i.e. eating and drinking) as well as increasing environmental-based disease transmission. This situation may increase the content of Coliform bacteria in groundwater due to the proximity of the septic tank and the position of the drainage canal close to the well. The location of several study sites in densely populated areas may increase the risk. The use of water containing Coliform bacteria for consumption has been reported to increase diarrhea cases [33]. Inadequate sanitation has an OR of 1.37 (95% CI, 1.33-1.41) and unsafe water has an OR of 1.09 (95% CI, 1.06- 1,12), indicating that water treatment and sanitation are improper, which has elevated the risk factors for stunting in children by 1.37 times [4]. Several strategies can be selected to cope with the liquid waste pollution problem. One effective strategy needs to involve participation at the community level. The use of piped water at dwellings may reduce the risk of diarrhea in young children [34].

A survey from 13 provinces of Indonesia found that households with good sanitation contributed positively to reducing the incidence of stunting intoddlers from 2007 to 2014. Most of the findings in rural areas of Indonesia related to sanitation using toilet facilities ranging from ownership, types, the use of septic tanks, hygiene, open defecation behavior and improper disposal of toddler feces were associated with an increase in stunting in toddlers in Indonesia [35-49].

A study in India has reported that the practice of open defecation is associated with the incidence of stunting. This behavior causes environmental pollution due to the spread of pathogenic bacteria from feces [50]. Intestinal infection conditions in the form of diarrhea and other environmental enteric dysfunction can affect the nutritional status of children by reducing appetite and interfering with nutrient absorption, which causes children to experience malnutrition and growth disorders [51]. The use of unstandardized toilet facilities, the practice of open defecation and improper disposal of toddler feces may create environmental pollution, hence facilitating the transmission of pathogens from feces and increasing the incidence of stunting in toddlers. Studies conducted in Peru have shown that unsafe disposal of toddler feces and inadequate use of toilet facilities by children, increase the prevalence of diarrhea, intestinal worms

and stunting in toddlers [52]. This study has limitations in terms of the studied area that includes administrative areas merely at the regency level. In addition, this study did not measure the nutritional intake of toddlers.

## CONCLUSION

Based on the results of the analysis of the spatial effect of the Geographically Weighted Regression (GWR) model, the Sanitation risk factors that significantly affected the incidence of stunting in Malang Regency were; Environmental Drainage (greywater), Solid Waste, and Domestic Wastewater (black water). Clean and Healthy Lifestyles and Water Sources have less effect on sanitation risk.

## RECOMMENDATION

This study recommends some efforts to prevent and break off the chain of environmental-based disease spread in reducing the incidence of stunting in toddlers. Efforts to reduce the incidence of stunting in toddlers in Malang Regency require sensitive interventions to improve environmental sanitation including integrated waste management, improvement of drainage infrastructure, construction of standardized toilets and carrying out health promotion efforts with education to increase public awareness.

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