
Household Organic Waste Management, Healthy Behavior, and Disease Symptoms: Greenhouse Gas Implications

R. Azizah^{1,2,*}, Agus Bintara Birawida³, Yuanita Windusari⁴, M. Ariiq Setiawan⁵, Zaneta Aaqilah Salsabila^{6,8}, Zafira Nuha Naura^{6,8}, Mifaidah Kusumawati^{7,8}, Fariha Zahra Aghnia⁵, Edza Aria Wikurendra^{1,9}

¹Department of Environmental Health, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia.

²Research Group of Environmental Health and Climate, Universitas Airlangga, Surabaya, Indonesia.

³Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia

⁴Department of Environmental Health, Faculty of Public Health, Universitas Sriwijaya, Indralaya, South Sumatra, Indonesia

⁵Master's Program in Environmental Health, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia

⁶Undergraduate Study Program, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia.

⁷Alumnus of the Undergraduate Program, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia

⁸Enviro Earth Non-Governmental Organization (NGO), Surabaya, Indonesia

⁹Department of Health Sciences, Faculty of Humanities and Health Science, Curtin University Malaysia

*Corresponding Author: R. Azizah

*Email: azizah@fkm.unair.ac.id

Abstract. Household organic waste is a major contributor to national waste generation in Indonesia, yet household-level management remains limited, potentially increasing environmental disease risks and greenhouse gas (GHG) emissions. This study analyzed relationships between individual characteristics, healthy behavior, household organic waste management, and symptoms of malaria, cholera, dengue fever, pneumonia, stunting, diarrhea, and leptospirosis. A quantitative cross-sectional study involved 100 respondents in Kelurahan Larangan, Kecamatan Candi, Kabupaten Sidoarjo, across RW 1–9, selected using proportional stratified random sampling. Data were analyzed descriptively; differences in organic waste weight between RWs were tested using the Kruskal–Wallis test, and relationships among variables were examined using Structural Equation Modeling-Partial Least Squares (SEM-PLS) at $\alpha = 10\%$. Organic waste management remained limited: 38% of respondents owned a biopore and 48% managed their organic waste, mainly through composting. Organic waste weight did not differ significantly between RWs ($p = 0.169$). SEM-PLS showed valid and reliable indicators and seven significant relationships. Healthy behavior negatively affected dengue fever, diarrhea, and malaria symptoms; organic waste management negatively affected cholera and stunting but positively affected pneumonia, contrary to the hypothesized direction; education positively affected organic waste management. The highest R^2 was for dengue fever (19.4%). Overall, healthy behavior and household organic waste management may reduce several waste-related disease risks and GHG emissions through controlled composting. Strengthening household education and waste-management

facilities is needed to support disease prevention and climate-change mitigation. These findings highlight integrated environmental health approaches for sustainable community waste management.

Keywords: organic waste, healthy behavior, waste-related disease, household, SEM-PLS

INTRODUCTION

Indonesia is one of the largest waste producers in the world, with most of its waste generated by households. Data from the SIPSN of the Ministry of Environment and Forestry show that household waste contributed more than half of the national waste composition in 2024, with food scraps and organic material as the dominant components (1). This condition confirms that households are a crucial point for organic waste management at the source, in accordance with Government Regulation No. 81 of 2012 (2).

Various methods of household organic waste management have been developed biopores, composters, Takakura, biogas, animal feed, and maggot/black soldier fly (BSF) cultivation yet their application in the community remains low. Wibowo and Widodo (3) found that biopores effectively increase water absorption and reduce organic waste, although their success depends on residents' awareness in maintaining them. Amalia et al. (4) found that the public did not yet adequately understand how to manage organic waste. Badu et al. (5) confirmed that integrating biopores can improve soil infiltration, but this remains dependent on household consistency, while Rahmawati and Setiawan (6) highlighted barriers in the form of limited education and mentoring.

Low organic waste management practices have implications for an increased risk of environmental-based diseases. Widjaja and Gunawan (7) reported that poorly managed waste becomes a breeding ground for disease vectors, while Karim et al. (8) found a significant relationship between waste management and the health status of infectious disease. Other studies have also linked waste management and sanitation with specific diseases: Putra et al. (9) with diarrhea; Febrianti et al. (10) and Juliska et al. (11) with dengue hemorrhagic fever; and Junanda et al. (12) and Kuewa et al. (13) with stunting in toddlers. Maryani and Mandagi (14), through a systematic review, further confirmed sanitation and water quality as important determinants of stunting.

These findings indicate that the relationship between organic waste management behavior and disease symptoms is multidimensional, involving individual characteristics, healthy behavior, waste management practices, and various disease symptoms. The SEM-PLS approach is considered appropriate for uncovering such complex relationship patterns simultaneously, as applied by Cerlyawati et al. (15), who examined environmental sanitation and diarrhea in stunted toddlers, and has proven more comprehensive than conventional bivariate approaches.

Although various studies have examined partial relationships between waste management, sanitation, and specific diseases, research that simultaneously analyzes the influence of individual characteristics, healthy behavior, and household organic waste management on various symptoms of waste-related diseases (malaria, cholera, dengue fever, pneumonia, stunting, diarrhea, and leptospirosis) within a single structural model remains limited. Therefore, this study analyzes these relationships using SEM-PLS among 100 households in RW 1–9 of the study area.

METHODS

This quantitative cross-sectional study was conducted in Kelurahan Larangan, Kecamatan Candi, Sidoarjo, East Java, Indonesia, across RW 1–9. Using the Lemeshow formula, 100 respondents were selected through proportional stratified random sampling, with each RW as a stratum. The allocation was RW 1–9: 8, 17, 12, 13, 8, 7, 9, 13, and 13 respondents, respectively. Data were collected using

questionnaires covering individual characteristics (age, education, occupation), healthy behavior, organic waste management practices, disease symptom perception (dengue, diarrhea, cholera, leptospirosis, malaria, pneumonia, and stunting), and organic waste weight (<1, 1–2, and >2 kg).

Data were analyzed using PLS-SEM. The outer model assessed convergent validity, discriminant validity, and construct reliability using outer loadings, AVE, Fornell–Larcker criteria, and Composite Reliability. The inner model evaluated R^2 , path coefficients, and significance through bootstrapping at $\alpha = 0.10$ ($p < 0.10$). Each disease was analyzed separately as a dependent variable because symptom indicators did not form a single construct. The Kruskal–Wallis test assessed differences in ordinal waste-weight categories across RWs, with $p < 0.05$ indicating significance.

The study followed human research ethics and received approval from the Health Research Ethics Committee, Faculty of Public Health, Universitas Airlangga (No. 249/EA/KEPK/2026).

RESULT

1. *Respondent characteristics, organic waste management, and greenhouse gases from organic waste*

Descriptive analysis was conducted to describe the distribution of respondents' answers for each research variable. The number of respondents in this study was 100. The presentation of the descriptive analysis was based on the latent variables and their indicators (manifest variables) that formed each construct. The results are presented in the form of frequency distributions and percentages, providing an overview of respondents' condition for each research indicator. The Individual Characteristics variable describes respondents' identity related to age, education, and occupation.

2. *Variables of healthy behavior, organic waste management, and disease symptoms*

The Healthy Behavior variable reflects biopore ownership in the yard and the routine of filling biopores with organic waste and utilizing the resulting compost. The descriptive analysis showed that biopore and organic waste management practices among respondents remained relatively limited. For the biopore ownership indicator (PS.1), the mean value was 1.38, which mathematically indicates that 38% of respondents owned a biopore, while 62% did not.

The Organic Waste Management variable describes general organic waste management practices and processing methods. In organic waste management, the most frequently practiced method was composting (KSO.2), with a mean of 2.35, followed by general organic waste management practices (KSO.1) at 2.29. The use of the Takakura method (KSO.3) had a mean of 1.74, utilization of organic waste as animal feed (KSO.5) was 1.70, processing into biogas (KSO.4) was 1.42, and use of the maggot/BSF technique (KSO.6) was 1.30. Composting was therefore the most frequently practiced organic waste processing method, while processing using maggot/BSF was the least frequently practiced. Descriptive analysis described the source, weight, and management of organic waste among 100 respondents from RW 1–9. The largest proportion was from RW 2 (17.0%), while the smallest was from RW 6 (7.0%). RW 4, RW 8, and RW 9 each contributed 13.0%; RW 3, 12.0%; RW 7, 9.0%; and RW 1 and RW 5, 8.0% each.

All respondents (100%) reported that their organic waste originated from their own households. Most generated less than 1 kg (89.0%), followed by 1–2 kg (9.0%) and more than 2 kg (2.0%). Regarding waste management, 48.0% had managed their organic waste, while 52.0% had not. The most common practice was combined composting and eco-enzyme production (26.0%), followed by composting alone (14.0%) and eco-enzyme production alone (8.0%). Thus, although all organic waste originated from households, more than half of respondents had not yet managed it.

The Disease Symptoms variable consisted of symptoms of malaria, cholera, dengue fever, pneumonia, stunting, diarrhea, and leptospirosis. Based on the disease symptom analysis, the mean values showed variation in respondents' level of recognition/experience of the disease symptoms asked. Cholera had the highest mean value (1.97), followed by dengue fever (1.90). Meanwhile, pneumonia had a mean of 1.51 and malaria 1.46. Lower values were found for stunting (1.31), diarrhea (1.34), leptospirosis (1.19), typhoid fever (1.08), and the lowest was plague (1.03). On a scale of 1 = never to 5 = always, this pattern indicates that the frequency of respondents reporting having experienced or recognized the symptoms asked was generally low, with variation between diseases.

3. Results of the partial least squares (PLS) analysis

The relationships between variables were analyzed using SEM-PLS because it is capable of simultaneously analyzing complex relationships between latent variables and their indicators, testing causal relationships, and accommodating models with multiple constructs. This method is variance-based and does not require strict multivariate normality, making it suitable for health and social science research.

The analysis stages included the outer model (testing construct validity and reliability through convergent validity, discriminant validity, and composite reliability) and the inner model (testing relationships between latent variables through path coefficients, R^2 , f^2 , Q^2 , Goodness of Fit, and hypothesis testing via bootstrapping with t-statistics and p-values). The results were used to answer the research objectives and test the hypotheses.

4. Outer model evaluation

Evaluation of the measurement model was conducted to assess construct validity and reliability, consisting of construct validity evaluation and construct reliability evaluation, described as follows (Figure 1):

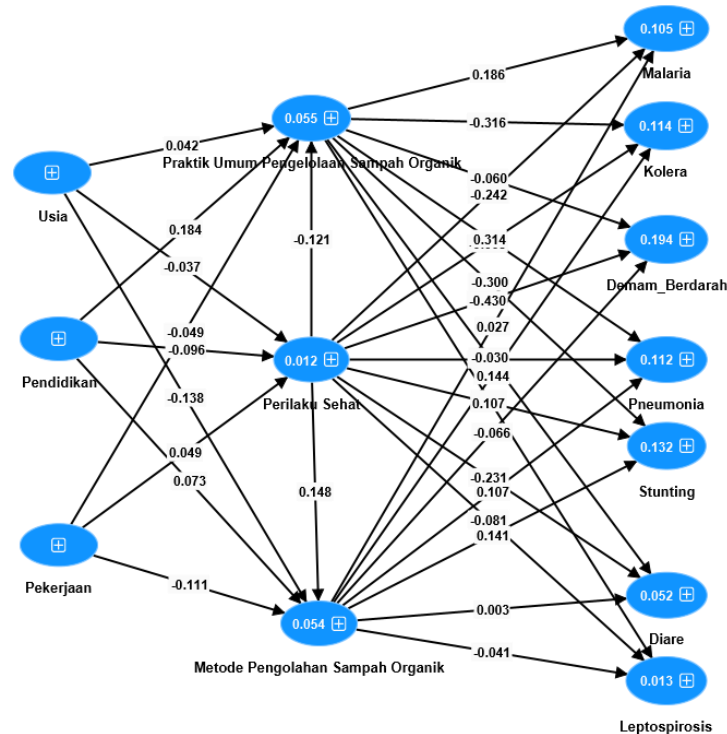


Figure 1. Outer model construct

5. Convergent and discriminant validity tests and construct reliability

Construct validity was assessed using convergent and discriminant validity. Convergent validity was confirmed when loading factors and Average Variance Extracted (AVE) exceeded 0.5. All indicators met the loading factor criterion and were therefore considered valid.

Discriminant validity was assessed using the Fornell–Larcker criterion, requiring each construct's $\sqrt{\text{AVE}}$ to exceed its correlations with other constructs. All constructs met this criterion, indicating adequate discriminant validity.

HTMT was additionally used as a more stringent test. Among 78 construct pairs, 77 had HTMT values below 0.90 (range 0.001–0.592). One exception was Healthy Behavior–Dengue Fever (HTMT = 1.076). The complete HTMT matrix is provided in Supplementary Table S1, and this exception is discussed in the Study Limitations.

Construct reliability was assessed using Composite Reliability (CR), with values ≥ 0.70 generally considered acceptable, although 0.60–0.70 may be acceptable for exploratory research. Organic Waste Processing Method showed good reliability ($\rho_C = 0.890$), while Healthy Behavior was acceptable for exploratory research ($\rho_C = 0.689$).

Model fit was assessed using SRMR, d_{ULS} , and d_{G} . The saturated model showed acceptable fit (SRMR = 0.068; < 0.08), whereas the estimated model exceeded the threshold (SRMR = 0.110), indicating that the hypothesized structural paths did not fully reproduce the observed correlation structure. This issue is addressed in the Study Limitations.

6. Inner model evaluation

After the measurement model (outer model) met the validity and reliability criteria, the next step was to evaluate the structural model (inner model). The inner model evaluation aimed to assess the model's ability to explain the relationships between constructs and to test the formulated hypotheses. In PLS-SEM analysis, structural model evaluation can be conducted through several criteria, including the coefficient of determination (R^2), path coefficients, and their significance. The results of this evaluation were used to determine the extent to which exogenous constructs could explain endogenous constructs and to determine empirical support for the hypothesized relationships in the research model.

7. Coefficient of determination (R^2) and hypothesis testing

The Coefficient of Determination (R^2) was used to determine the extent to which the endogenous variables could explain the variation in the exogenous variables, or in other words, the extent of the contribution of the exogenous variables to the endogenous variables. The R^2 results are shown in Table 1.

Table 1. Results of the coefficient of determination (R^2)

Dependent Variable	R Square	R Square Adjusted
Dengue fever	0.194	0.169
Diarrhea	0.052	0.022
Cholera	0.114	0.086
Leptospirosis	0.013	−0.017
Malaria	0.105	0.077
Organic Waste Processing Method	0.054	0.014
Healthy Behavior	0.012	−0.019
Pneumonia	0.112	0.084
General Organic Waste Management Practice	0.055	0.016
Stunting	0.132	0.105

Based on the analysis, the highest R^2 was found for dengue fever (0.194), meaning that 19.4% of its variation was explained by Healthy Behavior, General Practice, and the Organic Waste Processing Method, with the remaining 80.6% explained by factors outside the model. Stunting had an R^2 of 0.132 (13.2%), followed by cholera at 0.114, pneumonia at 0.112, and malaria at 0.105 all in the range of 10-13%. Diarrhea had an R^2 of 0.052 (5.2%), while leptospirosis had the lowest R^2 at 0.013 (1.3%). For the waste management and behavior constructs, the values were also low: the Organic Waste Processing Method ($R^2 = 0.054$) and General Practice ($R^2 = 0.055$) were each explained by about 5.4-5.5% by healthy behavior and individual characteristics, while Healthy Behavior itself was only 1.2%. Overall, the model's ability to explain variation in the dependent variables remained limited, as disease symptoms are influenced by many other factors environment, vectors, sanitation, socioeconomic status, household, access to health services, and individual factors that were not fully captured in the model.

Hypotheses were tested using PLS-SEM with bootstrapping at $\alpha = 10\%$, with relationships considered significant when $t \geq 1.645$ or $p < 0.10$. Seven relationships were statistically significant (Figure 2).

None of the paths to leptospirosis were significant: Organic Waste Processing Method ($\beta = -0.041$, $t = 0.340$, $p = 0.734$, $f^2 = 0.002$), Healthy Behavior ($\beta = -0.081$, $t = 0.761$, $p = 0.447$, $f^2 = 0.006$), and General Organic Waste Management Practice ($\beta = 0.055$, $t = 0.541$, $p = 0.588$, $f^2 = 0.003$). This was consistent with the low R^2 (1.3%) and negligible effect sizes.

Predictive relevance was additionally assessed using blindfolding (omission distance = 7) on a re-specified model retaining significant constructs and paths. The model included Healthy Behavior, General Organic Waste Management Practice, and Education as predictors of Dengue Fever, Diarrhea, Malaria, Cholera, Pneumonia, and Stunting.

8. *Effect of healthy behavior on dengue fever, diarrhea, and malaria*

Healthy behavior had a significant negative effect on dengue fever symptoms ($\beta = -0.430$; $t = 4.689$; $p < 0.001$), significant at $\alpha = 1\%$, indicating that the more frequently healthy behavior was practiced, the lower the dengue fever symptoms. Healthy behavior had a negative effect on diarrhea symptoms ($\beta = -0.231$; $t = 1.814$; $p = 0.070$), significant at $\alpha = 10\%$ but not yet at $\alpha = 5\%$, indicating that better healthy behavior tended to reduce diarrhea symptoms. Healthy behavior had a negative effect on malaria symptoms ($\beta = -0.242$; $t = 1.884$; $p = 0.060$), significant at $\alpha = 10\%$, indicating that the more frequently healthy behavior was practiced, the lower the malaria symptoms.

9. *Effect of general organic waste management practices on cholera, pneumonia, and stunting*

General organic waste management practices had a significant negative effect on cholera symptoms ($\beta = -0.316$; $t = 3.638$; $p < 0.001$), significant at $\alpha = 1\%$, indicating that better organic waste management was associated with lower cholera symptoms. General organic waste management practices were positively associated with pneumonia symptoms ($\beta = 0.314$; $t = 3.739$; $p < 0.001$), significant at $\alpha = 1\%$. However, this relationship does not mean that waste management causes pneumonia and may be influenced by other factors not explained in the model. General organic waste management practices had a significant negative effect on stunting symptoms ($\beta = -0.300$; $t = 2.947$; $p = 0.003$), significant at $\alpha = 1\%$, indicating that better waste management tended to be associated with lower stunting symptoms.

10. *Effect of education on general organic waste management practices*

Education had a positive effect on general organic waste management practices ($\beta = 0.184$; $t = 1.899$; $p = 0.058$), significant at $\alpha = 10\%$ but not yet at $\alpha = 5\%$, indicating that the higher the

education level, the greater the tendency of the community to practice organic waste management.

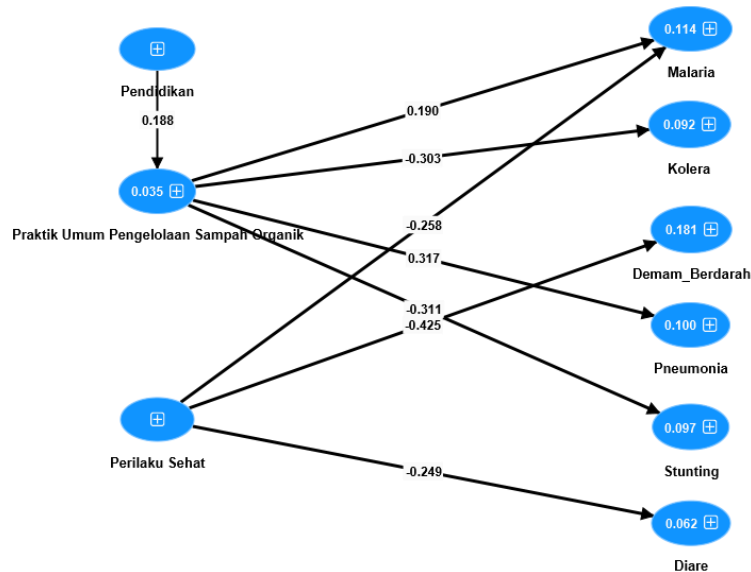


Figure 2. Final model

DISCUSSION

1. Respondent characteristics, organic waste management, and greenhouse gases from organic waste

Most respondents were elderly (72%) and had low education (57%), characteristics that may influence waste-management practices through knowledge, motivation, social norms, and facility access. Consistent with Celestino et al. (16) and Kunszabó et al. (17), waste behavior is multidimensional and shaped by psychosocial and sociodemographic factors. Nguyen et al. (18) further showed that households differ in waste reduction and sorting behaviors, indicating that uniform interventions may be less effective. Age had no significant effect on waste processing ($\beta = -0.138$; $p = 0.369$) or healthy behavior ($\beta = -0.037$; $p = 0.759$). Therefore, interventions should be tailored to community characteristics using simple, practical, visual, and demonstration-based approaches rather than relying solely on facility provision.

2. Low utilization of Takakura, biogas, animal feed, and maggot/BSF

Limited adoption of Takakura, biogas, animal feed, and maggot/BSF reflects barriers in knowledge, skills, space, cost, and perceived benefits. Kunszabó et al. (17) reported only 31% simultaneous food–garden waste composting, constrained by space, knowledge, and pest concerns. Thus, effective waste management requires a technology–behavior fit approach aligned with community characteristics, waste volume, space, technical capacity, and perceived economic or ecological benefits.

3. No difference in organic waste weight between RWs

The Kruskal–Wallis test showed no significant difference in organic waste weight across RWs ($H = 11.617$, $df = 8$, $p = 0.169$), with most respondents generating <1 kg. Thus, management programs can be implemented across RWs rather than targeting specific areas. However, similar waste quantities do not imply similar management behaviors; knowledge, attitudes, social norms, facilities, and institutional support may differ. Celestino et al. (16) highlighted the importance of integrating psychosocial and sociodemographic factors into organic waste management strategies.

4. *Greenhouse gases from organic waste*

All organic waste came from households, with 89% generating <1 kg/day. However, 52% had not managed their waste, while 48% had, mainly through compost and eco-enzyme (26%). This indicates strong potential for simple source-based technologies such as composting, Takakura, and biopores. Composting had the highest mean (2.35), likely due to its simplicity and useful output. Ferdinan (19), Zhou et al. (20), and Xu et al. (21) emphasized household waste management, composting feasibility, and organic waste recovery within a circular economy.

Organic waste decomposition can generate GHGs, particularly CH₄, CO₂, and N₂O, under anaerobic conditions, making source-based processing such as composting important for climate mitigation (22,23). Controlled composting regulates aeration, moisture, temperature, and C/N ratio to promote aerobic decomposition and reduce GHG emissions (20,24). Adequate aeration and moisture, balanced C/N ratios, and mixing wet nitrogen-rich waste with dry carbon-rich materials help suppress CH₄ formation (24–26). Although emissions vary with materials and operating conditions, composting converts organic waste into useful soil conditioner while reducing landfill methane and supporting circular economy and sustainable waste management (23,24).

5. *Interpretation of the PLS-SEM model*

Outer model results showed all loading factors >0.50, confirming convergent validity. Composite reliability was 0.890 for organic waste processing and 0.689 for healthy behavior, acceptable for exploratory research. However, future studies should use multiple validated indicators for complex constructs.

The model explained limited disease variation, with R² ranging from 0.013 for leptospirosis to 0.194 for dengue, followed by stunting (0.132), cholera (0.114), pneumonia (0.112), malaria (0.105), and diarrhea (0.052). These findings indicate that waste management and healthy behavior represent only part of multifactorial disease determinants, including climate, vectors, WASH, nutrition, socioeconomic conditions, and healthcare access. Thus, waste–health relationships should be interpreted within a multidimensional environmental health framework.

6. *Effect of healthy behavior and education on general organic waste management practices*

Education had a positive effect on general organic waste management practices ($\beta = 0.184$; t-statistic = 1.899; p-value = 0.058). The relationship was significant at $\alpha = 10\%$ but not yet at $\alpha = 5\%$, indicating that the higher the level of education, the more frequently the community tended to manage organic waste.

7. *Healthy behavior and biopore management practices*

Biopore ownership was low (38%), with only 1.80 mean utilization for organic waste filling and compost use, indicating a gap between potential and actual practice. As a source-based technology integrating waste reduction, water infiltration, and organic reuse, biopore adoption requires more than facility provision. Sewak et al. (27) and Ma and Jiang (28) highlight the importance of community-based behavior change and addressing the gap between environmental awareness and practice. Therefore, interventions should combine education with demonstration, mentoring, monitoring, and feedback to strengthen sustained biopore use.

8. *Education as a determinant of waste management practice*

Education was the only individual characteristic significantly associated with organic waste management at $\alpha = 10\%$ ($\beta = 0.184$; $p = 0.058$), indicating that higher education tended to support better practices. However, the weak association shows that formal education alone does not ensure proper waste management. Consistent with Celestino et al. (16) and Nisa et al. (29),

knowledge and positive attitudes may not translate into practice due to individual, social, and structural barriers. Therefore, education should be strengthened through environmental health literacy to promote informed and consistent waste management behavior.

9. *Effect of healthy behavior on dengue fever, diarrhea, and malaria*

Healthy behavior significantly reduced dengue symptoms ($\beta = -0.430$; $p < 0.001$) and showed negative effects on diarrhea ($\beta = -0.231$; $p = 0.070$) and malaria ($\beta = -0.242$; $p = 0.060$), significant at $\alpha = 10\%$. These findings support healthy behavior and household environmental management as components of disease prevention, consistent with studies linking waste management to dengue, diarrhea, and malaria (30–33).

Organic waste management significantly reduced cholera ($\beta = -0.316$; $p < 0.001$) and stunting symptoms ($\beta = -0.300$; $p = 0.003$), supporting its role in environmental disease prevention. Conversely, it was positively associated with pneumonia symptoms ($\beta = 0.314$; $p < 0.001$), contrary to expectations; this should not be interpreted causally and may reflect confounding, reporting, or unmeasured factors. Overall, the findings support an integrated environmental health approach linking waste management, WASH, hygiene, infection prevention, and nutrition to reduce disease risks (8,34).

CONCLUSION

Household organic waste management in RW 1–9 remains low, with 52% not managing waste despite 89% generating <1 kg/day and only 38% owning biopores. Most respondents were elderly (72%) and had low education (57%); education showed a positive effect on waste management ($\beta = 0.184$; $p = 0.058$), while age had no significant effect. Waste volume did not differ significantly between RWs ($p = 0.169$).

SEM-PLS identified seven significant relationships: healthy behavior reduced dengue, diarrhea, and malaria symptoms, while organic waste management reduced cholera and stunting but increased pneumonia symptoms, possibly due to unmeasured confounding. Dengue had the highest R^2 (19.4%), indicating limited explanatory power.

Low waste management may increase GHG emissions, particularly CH_4 under anaerobic conditions. Although composting offers climate-mitigation benefits, limited adoption of other methods indicates untapped potential. Therefore, integrated waste–health interventions should strengthen education and facilities using simple, practical, visual, and demonstration-based approaches tailored to community characteristics.

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