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Impacts of Sanitation Practices on Human Development: A Decade-Long Analysis of the Malang District

Angga Dheta Shirajjudin Aji [a,1], Sapta Suhardono [b,2], I Wayan Koko Suryawan [c,3,*], Wisnu Prayogo [d,4]

[a] Department of Environmental Engineering, Faculty of Agricultural Technology, Universitas Brawijaya, Veteran Street, Malang, 65145 Indonesia
[b] Department of Environmental Sciences, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Ir. Sutami Street No.36, Surakarta, 57126 Indonesia
[c] Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Teuku Nyak Arief Street, Jakarta, 12220 Indonesia
[d] Department of Building Engineering Education, Faculty of Engineering, Universitas Negeri Medan, William Iskandar Street, Medan, 20221 Indonesia
[1]angga_glassis@ub.ac.id; [2]sapta.suhardono@staff.uns.ac.id; [3]i.suryawan@universitaspertamina.ac.id*;
[4]wisnuprayogo@unimed.ac.id
* Corresponding author

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ABSTRACT

This study explores the influence of various sanitation practices on the Human Development Index (HDI) in the Malang District from 2011 to 2020. Employing a multiple linear regression analysis, the research examines the relationship between the HDI and five critical sanitation practices: access to wastewater treatment plants, open defecation prevalence, septic tank usage, and direct waste disposal into water bodies and onto land. Secondary data was sourced from the Badan Pusat Statistika of Malang District, ensuring robust and authoritative information spanning over a decade. Preliminary diagnostics were performed to affirm the data's suitability for regression analysis. The results indicated a significant negative impact of direct disposal into water bodies on HDI, emphasizing the critical role of effective waste management practices in promoting human development. The study underscores the need for integrated policy approaches that address sanitation infrastructure improvements, environmental protection, and education on public health practices. This paper contributes to the literature by quantifying the effects of sanitation on human development over an extended period. It offers evidence-based recommendations for policymakers to support sustainable development goals in the region.

1. Introduction

The interplay between sanitation practices and human development encapsulates a vital concern within public health, urban planning, and economic development (Chakraborty et al., 2022; Donkor & Chitakira, 2022; Pereira & Marques, 2022). Establishing robust sanitation infrastructure is integral to fostering sustainable development, and the degree to which it influences the HDI is a question of pressing significance (Rizal et al., 2022), especially in developing regions like the Malang District. The HDI is a barometer for policy success, reflecting the population's health and longevity, educational attainment, and economic conditions. This study seeks to untangle the specific impacts of varied sanitation practices on the HDI within the Malang District over a critical ten-year period from 2011 to 2020. It is set against the backdrop of rapid urbanization and industrialization, which often strain existing sanitation facilities and underscore the urgency for systematic research into the efficacy of sanitation interventions (Pratama et al., 2018; Habanyama et al., 2024).

The research is conducted in Malang District to explore how diverse sanitation practices, including access to wastewater treatment, open defecation, septic tanks, and direct waste disposal, influence the Human Development Index (HDI). This region's ongoing economic development and varied sanitation landscape provide a valuable context for analyzing how these factors affect life expectancy, education, and income levels, which collectively constitute the HDI. By examining a decade's worth of data, the study seeks to clarify the reciprocal relationship between sanitation practices and HDI, with the hypothesis that improved sanitation correlates positively with higher HDI values, while poor sanitation may hinder human development. This analysis aims to offer insights that could inform both local and broader policy decisions, highlighting the importance of effective sanitation in driving health and socio-economic benefits (Erku et al., 2023).

The aim of this study extends beyond the mere identification of correlations. By elucidating the specific impacts and the strength of these relationships, the research intends to provide actionable insights for policymakers. These findings could inform targeted interventions in sanitation infrastructure to maximize the positive effects on human development. It is within the scope of this study to contribute to the literature by providing empirical evidence that supports the prioritization of sanitation in development agendas. The secondary data for this analysis, procured from the comprehensive records of Badan Pusat Statistika of Malang District, offers a longitudinal perspective on sanitation and HDI trends (Badan Pusat Statistika of Malang District, 2021). The decision to use data from 2011-2020 was based on the availability of comprehensive datasets and the historical context necessary to observe meaningful trends over time, allowing for an evaluation of the long-term effects of sanitation practices on human development. This decade-long range helps distinguish transient fluctuations from enduring trends and leverages a broad, district-wide scope that includes diverse environmental contexts and policy initiatives. If more recent data becomes available and can be integrated effectively, it would further enhance the study's relevance and accuracy.

This research provides an overview of a systematic approach to assess the relationship between various sanitation practices and the Human Development Index (HDI) by deploying a quantitative methodology, leveraging secondary data sources for a robust statistical examination. The secondary data, encompassing a decade, was retrieved from the authoritative repository of Badan Pusat Statistika of Malang District, ensuring the reliability and accuracy of the information. These data were comprehensive, capturing diverse aspects of sanitation practices such as the percentage of the population with access to wastewater

treatment plants, the prevalence of open defecation, the usage of septic tanks, and the rates of direct waste disposal into water bodies and onto land.

The chosen data sets represented a longitudinal cross-section of the district, allowing for an exploration of trends over time and a deepened understanding of the evolving interplay between sanitation and human development. This temporal dimension of the data enriched the analysis, permitting the capture of both short-term fluctuations and long-term trajectories in the variables of interest. The variables were meticulously defined and measured to ensure consistency across the dataset. As the dependent variable, the HDI was a composite measure reflecting the standard of living, comprising indices of life expectancy, education, and income. The independent variables encompassed discrete sanitation-related practices directly impacting public health and environmental quality. These included the percentage of treatment with wastewater treatment plants, the percentage of open defecation, the percentage of use of septic tanks, the percentage of direct disposal into various bodies of water, and the percentage of direct disposal onto land (see in Figure 1).

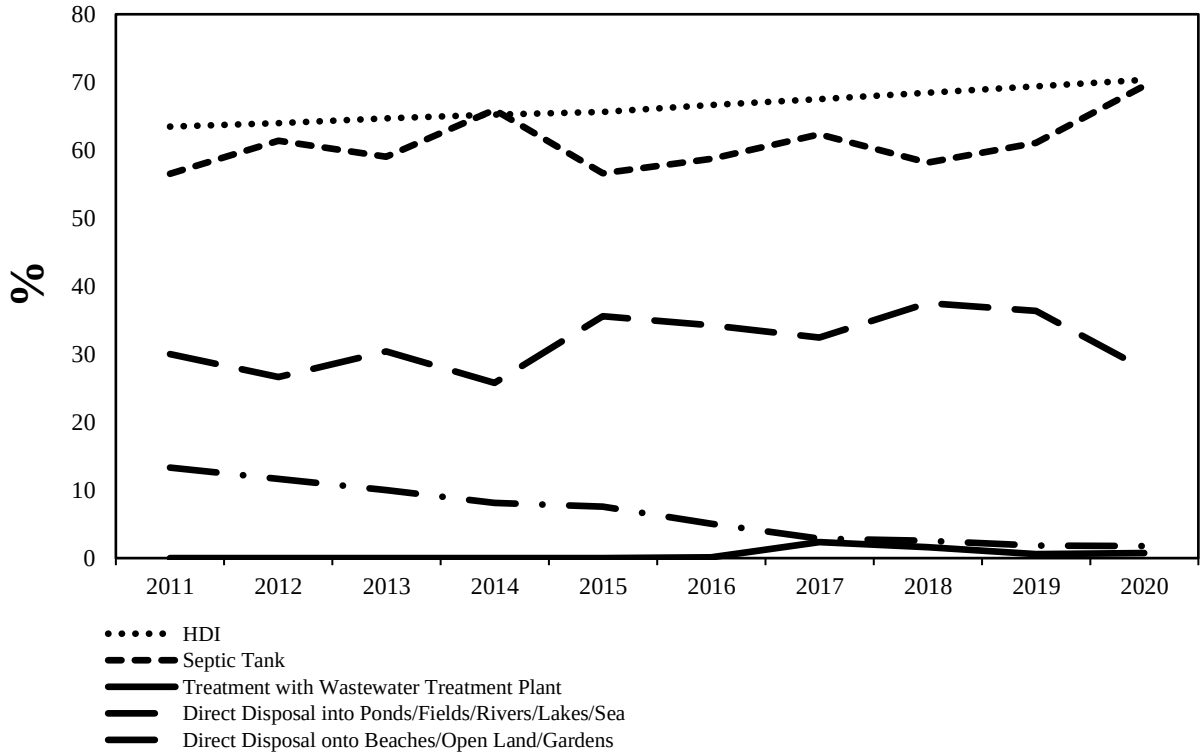

Figure 1. Trends in Sanitation Practices and HDI in Malang District from 2011 to 2020
Source: Badan Pusat Statistika of Malang District, 2021

2. Literature Review

Sanitation's influence on human development has been underscored in foundational works such as the World Health Organization's reports, which elucidate the direct effects of sanitation on health outcomes (Sumarsono, 2016; Francois et al., 2023). In particular, the focus has been on reducing open defecation, a practice linked with adverse health outcomes, especially in children (Abebe & Tucho, 2020; Rahman et al., 2020). The economic ramifications of such health impacts have been further analyzed by economists who argue that health improvements due to better sanitation contribute to labor productivity and educational attainment (Dhrifi et al., 2021; Gaies, 2022; Raghupathi & Raghupathi, 2020). Advancements

in sanitation technology, like the increased use of septic tanks in developing regions, have also received attention. Studies assessing their impact on local economies show that while they present an improvement over open defecation, they also come with challenges related to maintenance and environmental contamination (Abudulai et al., 2021; Willetts et al., 2020).

A significant contribution to the literature has been exploring wastewater treatment infrastructure's role in development. Scholarly work suggests that despite the upfront costs, the long-term benefits of such infrastructure are substantial (Nawaz et al., 2024; Suryawan et al., 2024; Suryawan & Lee, 2023). However, the effectiveness of this infrastructure in improving HDI has been contested by recent studies, which reveal that without comprehensive waste management systems, these facilities may not reach their full potential (Maket et al., 2024). The last decade has also witnessed a burgeoning interest in the environmental impacts of sanitation practices. The direct disposal of waste into water bodies, a common practice in many developing regions, has been linked with broader environmental degradation and negative impacts on economic activities such as fishing and tourism (Kumar et al., 2021; Mihai et al., 2022). This has expanded the discourse beyond the scope of public health to include environmental economics and sustainable development (Hussain et al., 2022; Khan et al., 2020).

Emerging research has started to address the complex feedback loop between sanitation, human development, and economic growth, with HDI serving as a proxy for the environmental effects of improved sanitation. The literature indicates a clear trend toward multidisciplinary approaches in assessing these effects, acknowledging the interplay between sanitation infrastructure and socio-economic outcomes (Rasmussen et al., 2021). However, gaps remain in the literature, particularly in longitudinal analyses that can capture the delayed effects of sanitation improvements on human development. Furthermore, studies that disaggregate the impact of different sanitation practices on the various components of HDI are still limited (Maket et al., 2024). This indicates a need for comprehensive models to separate and quantify these individual relationships. Considering these gaps, this literature review sets the stage for the current study, which employs a decade-long dataset and multiple linear regression analysis to quantify the relationships between sanitation practices and HDI in the Malang District. This approach adds to understanding how sanitation influences human development and provides a data-driven basis for policy recommendations to enhance the efficacy of sanitation interventions for economic and human development.

3. Research Method

Multiple linear regression analysis is the backbone of the study's methodology, providing a statistical framework to dissect the relationships between the independent variables of sanitation practices and the dependent variable of HDI. This analysis will include checks for assumptions pertinent to regression analysis linearity, homoscedasticity, absence of multicollinearity, and normal distribution of residuals. These diagnostics are crucial in affirming the reliability of the model and the validity of the conclusions drawn from it. The regression equation, formulated based on the analysis, aims to predict the HDI value from the independent sanitation variables. Each coefficient in this equation will quantify the change in HDI associated with each sanitation practice. Additionally, the study will review tolerance levels and VIF scores to address potential multicollinearity issues, ensuring that each independent variable uniquely contributes to the prediction of HDI without undue inter-variable influence (Pratama et al., 2018).

Beyond the quantitative measures, the study also contextualizes the findings within the broader theoretical frameworks of public health and economic theory. The literature on

economic development consistently points to the role of health infrastructure in fostering human capital. Improved sanitation is closely linked with reduced transmission of diseases, lower healthcare costs, and improved quality of life, which facilitate economic productivity and development. The implications of this study are manifold. For one, they provide a grounded understanding of how sanitation practices affect human development in the Malang District, which may mirror similar patterns in other developing regions. Furthermore, they offer evidence to support the integration of sanitation within broader development policies, advocating for investments that can yield comprehensive societal benefits.

Data analysis was conducted through multiple linear regression, a statistical technique that models the relationship between a scalar response (the dependent variable) and one or more explanatory variables (the independent variables). This method was particularly suited for the study due to its ability to discern the unique contribution of each sanitation practice to the variation in HDI while controlling for the influence of the other variables. Before the regression analysis, diagnostic tests were performed to verify the suitability of the data for linear regression. This included checking for linearity, homoscedasticity, multicollinearity, and normality of residuals. The presence of multicollinearity was assessed using Variance Inflation Factor (VIF) scores, while the Durbin-Watson statistic provided insight into the independence of the residuals. These preliminary diagnostics were critical to validate the assumptions underlying multiple linear regression and ensure the subsequent findings' reliability (Gravitiani & Juwita, 2020).

Upon confirmation of the data's adherence to regression assumptions, the regression model was specified: HDI was expressed as a function of the independent variables, with each variable weighted by a coefficient reflecting its estimated impact on HDI. An intercept term was included to capture the baseline level of HDI, independent of the explanatory variables. The unstandardized coefficients (B values) offered insights into the absolute change in HDI associated with a one-unit change in the respective sanitation practice. In contrast, the standardized coefficients (Beta values) facilitated a comparison of the relative strength of each practice's impact on HDI, irrespective of the units of measurement (Equation 1). The statistical significance of the regression coefficients was determined via t-tests, with the significance level (p-value) set to assess whether the observed relationships could be attributed to chance. The overall model fit was evaluated using the R-squared statistic, indicating the proportion of variability in HDI explained by the combined sanitation practices. The F-test further ascertained whether the regression model better fit the data than a model with no explanatory variables.

$$HDI = X1 - X2\beta_{\text{Treatment with Wastewater Treatment Plant}} - X3\beta_{\text{Open Defecation}} + X4\beta_{\text{Septic Tank}} - X5\beta_{\text{Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea}} - X6\beta_{\text{Direct Disposal onto Beaches/Open Land/Gardens}} \quad (1)$$

The equation (1) is constructed using multiple linear regression to quantify the impact of various sanitation practices on the Human Development Index (HDI). Here, X1 represents the intercept, or the baseline HDI when all sanitation variables are at zero. Each β β coefficient measures the extent of influence of specific sanitation practices—such as wastewater treatment, open defecation, septic tank use, and direct waste disposal methods—on HDI, which is composed of life expectancy, education, and income levels. The model differentiates between positive and negative impacts by assigning positive or negative signs to the coefficients, respectively. This method helps identify which sanitation practices are associated with improvements or declines in HDI (Mishra et al., 2021; Onyango, 2023).

4. Results and Discussion

This study examines the relationship between sanitation practices and human development in Malang District over a decade (2011-2020), emphasizing how diverse sanitation practices such as wastewater treatment, open defecation, and waste disposal impact the Human Development Index (HDI). By leveraging secondary data from the Badan Pusat Statistika of Malang District, the research aims to provide insights into how these practices affect life expectancy, education, and income levels, which together form the HDI. The decade-long data range allows for the analysis of long-term trends and distinctions between temporary fluctuations and enduring impacts, offering valuable information for policy interventions. The study highlights the importance of investing in effective sanitation infrastructure to drive improvements in human development and economic benefits, and it underscores the need for a multi-faceted approach to policy planning that integrates sanitation improvements with broader development goals.

Table 1 presents a comprehensive analysis of sanitation practices and human development in the Malang District from 2011 to 2020. It categorizes data into six distinct variables, each with its mean value and standard deviation, to indicate average performance and the degree of variance within the district. The HDI is the primary variable, with a mean of 66.530. This suggests that the Malang District has a moderate level of development. The standard deviation of 2.344 in HDI scores across the district indicates some uneven development outcomes among different areas, with some regions likely experiencing higher development levels than others. The second variable is the Treatment with Wastewater Treatment Plant (%), with a notably low mean of 0.540%. The high standard deviation of 0.824% in this variable suggests a considerable gap in the distribution and usage of wastewater treatment facilities. This could mean that while some areas may have access to such facilities, others do not, or it might indicate varying capacities of treatment plants across the district.

The percentage of Open Defecation at 6.592% with a standard deviation of 2.529% shows that, on average, open defecation is not extensively practiced. Still, there are areas within the district where it is more prevalent. This variance is a public health concern and highlights the need for targeted sanitation interventions. Septic Tank usage, with a high mean percentage of 60.923% and a standard deviation of 4.146%, is the district's most commonly used sanitation facility. However, the variation suggested by the standard deviation indicates disparities in septic tank adoption, possibly due to economic, cultural, or logistical reasons. The Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea at 6.462% mean and a standard deviation of 4.267% points to a significant pollution level in natural water bodies, which could have substantial environmental and health repercussions. The high variance indicates that this practice is not uniformly spread across the district. Lastly, the mean percentage for Direct Disposal onto Beaches/Open Land/Gardens is very low at 0.185%, with a standard deviation of 0.201%. This suggests that while the direct disposal of waste onto land is relatively rare, it is not entirely nonexistent and may represent a localized environmental issue.

Table 2 illustrates the Pearson correlation coefficients between various sanitation and human development variables in the Malang District over the period 2011-2020, laid out in a symmetric matrix format. The HDI is perfectly correlated with itself, as are all variables along the diagonal with a coefficient of 1.000. The HDI has a moderate positive correlation with the Treatment with Wastewater Treatment Plant (0.565), suggesting that as the HDI rises, so does the use of wastewater treatment facilities. A notable negative correlation between the HDI and Open Defecation (-0.736) indicates that higher human development is associated with lower instances of open defecation. Additionally, there's a positive correlation between the HDI and

the use of Septic Tanks (0.482), implying that improved human development coincides with increased use of septic systems.

Table 1. Descriptive Statistics of Sanitation Variables and HDI in Malang District

Variable	Mean	Std. Deviation
HDI	66.530	2.344
Treatment with Wastewater Treatment Plant (%)	0.540	0.824
Open Defecation (%)	6.592	2.529
Septic Tank (%)	60.923	4.146
Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea (%)	6.462	4.267
Direct Disposal onto Beaches/Open Land/Gardens (%)	0.185	0.201

Source: Badan Pusat Statistika of Malang District, 2021

A strong negative correlation exists between the HDI and Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea (-0.959), which points to a decrease in direct waste disposal into bodies of water as human development improves. Interestingly, an insignificant negative correlation exists between the HDI and Direct Disposal onto Beaches/Open Land/Gardens (-0.001), suggesting that human development has little to no direct relationship with this practice. The Treatment with Wastewater Treatment Plant negatively correlates with Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea (-0.665), implying that increased wastewater treatment will likely result in less waste being directly disposed of into water bodies. Open Defecation is strongly negatively correlated with Septic Tank usage (-0.778), indicating that the rates of open defecation are lower in areas where septic tanks are more prevalent. However, Open Defecation is moderately positively correlated with Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea (0.659), suggesting that where open defecation is more common, so is the practice of disposing waste directly into water bodies. Correlations involving Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea and Direct Disposal onto Beaches/Open Land/Gardens with other variables generally indicate less significant relationships, with coefficients close to zero, such as between Direct Disposal onto Beaches/Open Land/Gardens and Septic Tank usage (-0.072). This matrix of correlations provides a quantified glimpse into the relationships between different aspects of sanitation and development, which can be crucial for targeted interventions and policy-making.

Table 2. Pearson Correlation Coefficients Among Sanitation Practices and HDI in Malang District

Pearson Correlation	HDI	Treatment with Wastewater Treatment Plant	Open Defecation	Septic Tank	Direct Disposal into Ponds/Fields/ Rivers/Lakes /Sea	Direct Disposal onto Beaches/Open Land/Gardens
HDI	1.000	0.565	-0.736	0.482	-0.959	-0.001
Treatment with Wastewater Treatment Plant	0.565	1.000	-0.195	0.153	-0.665	-0.400
Open Defecation	-0.736	-0.195	1.000	-0.778	0.659	0.049
Septic Tank	0.482	0.153	-0.778	1.000	-0.396	-0.072
Direct Disposal into Ponds/Fields/Rivers/ Lakes/Sea	-0.959	-0.665	0.659	-0.396	1.000	-0.035
Direct Disposal onto Beaches/Open Land/Gardens	-0.001	-0.400	0.049	-0.072	-0.035	1.000

Table 3 delineates a regression analysis focused on the impact of various sanitation variables on the HDI for the Malang District from 2011-2020. The constant term, representing the HDI's starting value when all predictors are zero, stands at 68.491 with a statistically significant t-value, suggesting a reliable estimate within the model. For the sanitation variables, the Treatment with Wastewater Treatment Plant exhibits a negative coefficient of 0.521, yet it lacks statistical significance, indicating an uncertain relationship with HDI. Open

Defecation also presents a negative coefficient of -0.026; however, its high p-value denotes a non-significant link with HDI. Conversely, the Septic Tank variable shows a positive relationship with a coefficient of 0.039, although this, too, is statistically insignificant, pointing to a tenuous connection with HDI within this dataset.

Notably, Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea has a substantially negative coefficient of -0.570, which is significant at the 0.028 level, making it a meaningful predictor in the model and implying that increased disposal into water bodies may adversely affect HDI. In contrast, Direct Disposal onto Beaches/Open Land/Gardens has the highest negative coefficient of -1.220 but without statistical significance, implying that no definite conclusion can be drawn about its impact on HDI from this model. The model's summary metrics indicate a strong overall model fit with an R of 0.973 and an R Square of 0.946, signifying that approximately 94.6% of the variability in HDI can be explained by the combined effect of these sanitation practices. The Durbin-Watson statistic at 1.007 suggests no primary concern regarding autocorrelation in the model's residuals. The F Change significance of 0.012 indicates the model's predictors significantly explain the variation in HDI collectively, confirming the model's validity.

Table 3. Multiple Linear Regression Analysis of Sanitation Practices on HDI in Malang District

Variable	Unstandardized Coefficients	Std. Error	Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B		Beta			Tolerance	VIF
(Constant)	68.491	7.783		8.800	0.001		
Treatment with Wastewater Treatment Plant	-0.521	0.709	-0.183	-0.736	0.503	0.217	4.615
Open Defecation	-0.026	0.275	-0.028	-0.093	0.930	0.153	6.548
Septic Tank	0.039	0.115	0.070	0.344	0.748	0.327	3.054
Direct Disposal into Ponds/Fields/Rivers /Lakes/Sea	-0.570	0.169	-1.038	-3.369	0.028	0.142	7.063
Direct Disposal onto Beaches/Open Land/Gardens	-1.220	1.896	-0.104	-0.643	0.555	0.510	1.960
Model Summary							
R	0.973	R Square Change	0.946	Adjusted R Square	0.879	Sig. F Change	0.012
R Square	0.946	F Change	14.068	Std. Error of the Estimate	0.816	Durbin-Watson	1.007

Table 4 summarizes the ANOVA (Analysis of Variance) for the regression model, which assesses the overall significance of the model, as detailed in Table 3. The Regression row indicates the variance explained by the model, with a sum of squares of 46.785, degrees of freedom (df) at 5 (reflecting the number of predictors), and a mean square (an average of the squared deviations) of 9.357. The F-statistic of 14.068, with a significance level of 0.012, tells us that the model significantly predicts the outcome variable, which is likely the HDI. The Residual row reflects the variance not explained by the model, with a sum of squares of 2.660, df of 4, and a mean square of 0.665. The total sum of squares (49.445) is the total variance in the dependent variable. Using the information from Table 3, the regression equation for predicting HDI based on the given variables can be written as:

$$HDI = 68.491 - 0.521\ \beta_{\text{Treatment with Wastewater Treatment Plant}} - 0.026\ \beta_{\text{Open Defecation}} + 0.039\ \beta_{\text{Septic Tank}} - 0.570\ \beta_{\text{Direct Disposal into Ponds/Fields/Rivers/Lakes/Sea}} - 1.220\ \beta_{\text{Direct Disposal onto Beaches/Open Land/Gardens}} \quad \text{.....(2)}$$

This equation provides a linear model where the HDI score can be estimated based on the values of the sanitation practices included as independent variables. The negative coefficients suggest that as treatment practices with wastewater treatment plant, open defecation, and direct disposal into natural water bodies increase, the HDI decreases, with direct disposal into water bodies having the most substantial negative impact. Conversely, the positive coefficient for Septic Tank usage suggests a slight positive effect on HDI. However, it's essential to consider the statistical significance of each variable, as reported in Table 3, when interpreting their impact.

Table 4. ANOVA for Multiple Linear Regression Model Predicting HDI from Sanitation Practices in Malang District

Model	Sum of Squares	df.	Mean Square	F	Sig.
Regression	46.785	5	9.357	14.068	0.012
Residual	2.660	4	0.665		
Total	49.445	9			

The detailed regression analysis for the Malang District provides a nuanced understanding of how sanitation practices may influence economic development, as measured by the HDI. The HDI is a composite index reflecting three key dimensions of human development: life expectancy, education level, and economic income. These components are directly or indirectly influenced by sanitation practices, which, in turn, affect overall economic development. The treatment of wastewater is a critical component of urban infrastructure. The negative and statistically non-significant correlation between the Treatment with Wastewater Treatment Plant and HDI might seem counterintuitive, but several factors could explain this. It's possible that the existing wastewater treatment plants are inadequate to handle the current waste volume or are not evenly distributed across the district. There may also be delays in the socio-economic benefits of such infrastructure investments becoming apparent within the dataset's timeframe. In many emerging economies, expanding wastewater treatment infrastructure is initially outpaced by rapid urbanization, leading to perceived benefits lagging (Öberg et al., 2020; Onyango, 2023). Furthermore, if wastewater treatment facilities are not coupled with other forms of infrastructure, like solid waste management and water supply, the holistic benefits to public health and, subsequently, to economic productivity may not be fully realized.

The relationship between open defecation and economic development is well-documented. Open defecation is linked with poor health outcomes due to increased exposure to human waste, which can lead to the spread of diseases such as cholera, typhoid, and dysentery (Abudulai et al., 2021; Aminu & Udeze, 2023; Taufique et al., 2020). The resulting burden on public health can strain economic resources, decrease labor productivity, and reduce educational attainment when children miss school due to illness. The insignificance of this variable in the regression model may be due to improvements in sanitation being relatively recent and not yet fully reflected in the HDI data, or other unmeasured factors in the Malang District mitigate the effects of open defecation. Septic tank usage indicates individual household investment in sanitation. Even though statistically insignificant, the positive correlation may suggest that the widespread use of septic tanks could be a steppingstone to improved sanitation, which indirectly benefits economic development. Adequately maintained septic systems can protect the community from disease, thus maintaining a healthy workforce. A healthy workforce is a prerequisite for sustainable economic development, as it ensures consistent productivity and economic output (Jilcha, 2020; Umair et al., 2024).

Furthermore, installing septic tanks can increase property values, contributing to individual wealth and economic status, which feeds into the HDI. Direct disposal into ponds, fields, rivers, lakes, and seas showed a significant negative impact on HDI, and the implications for economic development are substantial. Pollution of water bodies can have dire consequences on local industries such as fishing, aquaculture, and agriculture, all of which depend on clean water. The economic impact of water pollution on these industries can be severe, leading to lost income, food insecurity, and increased vulnerability for populations that rely on these water bodies for their livelihoods (Mishra et al., 2021). Furthermore, water pollution can detract from tourism, a sector that constitutes a significant portion of economic activity in many regions (Rodríguez et al., 2020). Addressing this challenge can lead to recovery and enhancement of these economic sectors, thus contributing positively to the HDI.

Although the largest negative coefficient, the statistically insignificant correlation between direct disposal onto beaches/open land/gardens and HDI might indicate that other, unobserved variables may better explain the variation in HDI. Nevertheless, land pollution is a significant concern. Pollution can lead to loss of soil fertility, which compromises agricultural productivity. In economies where agriculture constitutes a substantial part of the economic base, such pollution can have far-reaching economic consequences. Land pollution also affects property values and can incur long-term costs due to the need for soil remediation (Drenning et al., 2023). The overall solid model fit indicated by an R Square value of 0.946 suggests that sanitation practices are closely linked to human development in the Malang District. The economic policy that targets improving sanitation infrastructure can thus be seen as a direct investment in human development. Such policy measures should prioritize expanding and improving wastewater treatment facilities, implementing public health campaigns to reduce open defecation, and promoting the proper use of septic tanks. Improving sanitation has long-term sustainability implications. Clean water and sanitation are fundamental to achieving several United Nations Sustainable Development Goals (SDGs), particularly SDG 6, which ensures the availability and sustainable management of water and sanitation for all. Achieving this goal is essential for environmental and economic sustainability, as it underpins a wide range of economic activities and contributes to the broader well-being that the HDI attempts to capture.

5. Conclusion

The analysis implies that economic development in the Malang District could be further optimized through strategic investments in sanitation infrastructure. This includes enhancing the capacity and reach of wastewater treatment facilities, reducing open defecation, and promoting proper waste disposal practices. The potential for such investments to contribute to economic development extends beyond immediate health benefits; it also includes long-term gains in labor productivity, property values, environmental sustainability, and overall quality of life. While the direct relationship between certain practices, like the use of septic tanks and wastewater treatment, and economic development may not be immediately evident in the statistical analysis, this does not negate the role of these sanitation solutions in contributing to economic and human development in a broader sense. It underscores the need for a multi-faceted approach to policy and infrastructure planning that considers the direct impacts and indirect pathways through which sanitation influences economic growth and development.

The findings advocate for policies focusing on comprehensive environmental health initiatives as essential components of economic development plans. This approach aligns with sustainable development goals, emphasizing the interconnections between sanitation, health,

education, and economic outcomes. For policymakers, the message is clear: investment in sanitation is an investment in human capital and economic resilience. As such, the pursuit of improved sanitation across the Malang District is a public health necessity and a strategic economic imperative. The implications of this study extend beyond the Malang District, suggesting that similar strategies could be relevant in other regions with comparable challenges. Addressing sanitation issues holistically can thus catalyze a virtuous development cycle, leading to enhanced human development indices and sustained economic growth. Future research should explore the impact of emerging sanitation technologies and practices, including recent innovations and updated data beyond 2020, to further refine strategies for enhancing human development and achieving sustainable development goals.

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