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Investigating the Impact of Flooding on Sanitation and Disease Outbreaks in South Sulawesi

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Abstract

The inadequate development of sanitation infrastructure in vulnerability zones makes flooding one of the largest public health threats. The current research analyzes how flooding affects sanitation systems and disease outbreaks throughout South Sulawesi Indonesia through a quantitative research design. The researchers conducted stratified random sampling to choose 400 household participants located in urban, peri-urban, and rural sections. The researchers used both structured surveys alongside secondary data obtained from health centers and meteorological agencies. The research analyzed how sanitation fared before flooding occurred as well as during and after flooding periods together with disease outbreaks statistics for waterborne and vector-borne illnesses. Descriptive statistics together with correlation analysis along with regression models were used to evaluate the research data. During times of flooding the sanitation conditions deteriorated substantially since waterborne diseases increased by 60% while cases of vector-borne diseases grew by 50% above pre-flooding numbers. Statistical analysis showed flooding severity produced direct relationships with deteriorating hygiene levels and boosted the occurrence of diseases. The primary factors associated with disease outbreak events turned out to be flooding intensity and improper sanitation according to regression model analyses. Research reveals that proper protection of sanitation systems plays an essential part against flooding incidents while revealing diminished safety levels for families without sufficient funds. The findings present valuable knowledge for disaster management and public health policies aimed at developing regions which deal with similar health-related flood risks.

Introduction

According to the nature, flooding is a frequent disaster, which produces severe effects on the environment and individual societies globally. Its impacts are more amplified in Indonesia because climatic and geographical conditions make some regions prone to flooding (Rahayu et al., 2023). The provinces of South Sulawesi, the study area of this research, has a relativel large number of river systems and the area is undertaien by seasonal rain which result to frequent and severe flooding (Rosyidah et al., 2022). Not only do such floods affect the daily human activities, but they also contribute to unsustainability of sanitation which in turn triggers diseases. It is therefore important to learn how these three variables relate to each other so as to develop practical countermeasures.

Several factors have been identified to be behind South Sulawesi flood risk, topographic feature, urbanization, and poor infrastructure (Indrayani et al., 2023). Flood plains and lands that are near rivers are particularly vulnerable since the monsoon season and even climate change is creating more frequent and severe floods (Otto et al., 2023). This is implemented through accessing households with filthy drainage systems leading to water stagnation, hence

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polluting water sources (Dayal et al., 2022). This contamination, inclusive of poor waste management systems, creates a ground for water borne diseases.

The first to be affected during flooding process are establish sanitation systems in the flood prone regions. Altogether pit latrines, septic tanks and open defecation practice cause fecal spillover and pollution of water sources and fecal borne diseases (Gwenzi et al., 2023). The WHO has declared poor sanitation as the main cause of such diseases as cholera, typhoid, dysentery and the likes which are common in flood affected regions (Salman et al., 2022). In South Sulawesi most communities have no access to even bas foundations hence poor water sanitation; floods compound the effects (Andersson et al., 2023). During major events, there is a higher propensity of disease transmission because the level of water contaminated by floods finding its way into family and community water sources raise enhances the transmission risks especially among children and the elderly (Semenza et al., 2022).

Rising waters also favors the development of vectors for diseases. Floodwater cesspools that form after water has stagnated become the breeding grounds for mosquitoes which cause malaria and dengue fever (Graboyes et al., 2024). These diseases are already health problems in South Sulawesi and are mostly prevalent in an area during flood events (Lamonge et al., 2024). Due to flood, people are unable to access facilities which leads to delay health interventions that increases the health risks in the affected populations (Pradhan et al., 2022).

The three categories of the flood impact namely, flooding and architecture, flooding and climate change and flooding and health are further influenced by socio-economic factors. Most farming communities in South Sulawesi source their livelihood through farming, and floods erratic rains wash away crops and pollute water sources, which creates food deficits and financial pressure (Limpo et al., 2022). Flood events are proven to be more dangerous to poor households, which are already struggling with the older and less effective access to clean water and sanitation (Krishna et al., 2021). These dSocio economic differences are the rationale as to why interventions should be pre-established and relate to the social and economic differences in the affected communities.

Flooding is a pressing issue throughout the world, and climatic change has been renamed a cause of flooding globally, the extent of its impact on South Sulawesi cannot be overemphasized (Linden, 2022). Published work indicates that future changes in climate show a likely increase in rise in sea levels and in intensity of rainfall and hence flood risk is expected to rise in the region (Tebaldi et al., 2021). These climatic changes will worsen the existing unsanitary arrangements further and therefore is a greater threat to the health of people. Controlling and improving on flooding and any impacts tied to this natural occurrence therefore must be done with consideration of climate resilience (Raimi et al., 2021).

Past investigations have documented the effect of flooding on health, yet little a quantitative analysis of the flood-sanitation connection in South Sulawesi (Coalson et al., 2021). Previous research on South Sulawesi has largely included only qualitative evaluations or emulated results from other parts of the world without regard to the socio-environmental context of this region. Quantitative research is indeed valuable for determining whether or not there are meaningful relationships between variables and for offering practical guidance for how to respond to present challenges in the spheres of politics and public health (Lochmiller, 2021).

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Making improvements in the area of sanitation especially in the event of flooding, is not a simple task that can be looked at in the isolation of other factors. According to Guptha et al. (2021) technological development in flood resistant sanitation, and proper techniques used in drainage systems are helpful tools in the reduction of flood health hazards. The same authors added that community level level is also a potential factor that can prevent diseases from spreading specifically through the public health campaign and promoting good hygiene. Strong disaster mitigation frameworks are required for appropriate handling of calamities, such as flood, by means of effective transport of emergency health care services and portable water.

Method

This study adopted a quantitative research design to explore the impact of flooding on sanitation and disease outbreaks in South Sulawesi. A descriptive-correlational approach was chosen to quantify the relationships between the frequency and intensity of flooding events, the state of sanitation, and the incidence of waterborne and vector-borne diseases in the affected communities. The goal was to examine how changes in sanitation, due to flooding, contribute to the prevalence of diseases in households. This approach allowed for the identification of significant patterns and the establishment of connections between environmental factors (flooding) and public health outcomes (disease outbreaks).

The study population consisted of households in flood-prone areas across South Sulawesi. To ensure the sample was representative of the region's diverse geographic and demographic characteristics, a stratified random sampling technique was employed. The sample included 400 households from urban, peri-urban, and rural areas. Cochran’s formula was applied to calculate the required sample size, ensuring the results would be statistically significant and reliable. This methodology enabled the study to capture a wide range of data reflecting the different experiences of communities affected by flooding.

Primary data were collected through a structured survey questionnaire, which was designed to capture key information on household sanitation before, during, and after flooding events. The survey also gathered data on the prevalence of waterborne and vector-borne diseases, such as cholera, diarrhea, and malaria, in the households. In addition to health-related questions, the questionnaire included demographic items, such as age, income level, and education, to better understand the socio-economic context. The survey instrument was pre-tested on 30 households to ensure clarity, reliability, and relevance. Based on this pre-test feedback, necessary adjustments were made to improve the validity of the instrument.

Secondary data were obtained from local health centers and government reports, providing historical records on disease outbreaks and rainfall patterns during flood periods. These data sources provided additional context and helped corroborate the survey findings. The data collection process took place over three months, with trained enumerators visiting households in the sample areas. Enumerators followed strict protocols to ensure that data were consistently and accurately gathered. Secondary data were obtained through official requests to local health departments and meteorological agencies, allowing the study to build a comprehensive dataset.

The collected data were analyzed using SPSS (Statistical Package for the Social Sciences), and a variety of statistical techniques were employed. Descriptive statistics were used to summarize the demographic characteristics, sanitation conditions, and disease prevalence in the sample. Pearson correlation coefficients were calculated to assess the strength and direction of

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relationships between flooding intensity, sanitation conditions, and disease outbreaks. Additionally, multiple regression analysis was conducted to model the impact of flooding on public health, considering sanitation as a mediating variable. This analytical approach provided robust insights into the quantitative relationship between flooding events and health outcomes in South Sulawesi.

Result and Discussion

The ongoing public health challenge stems from floods that affect sanitation areas since inadequate facilities in flood-prone regions directly exacerbate the situation. South Sulawesi Province in Indonesia encounters frequent floods that degrade the sanitation equipment maintenance operations and enables rapid growth of water-borne diseases and water-related vector diseases. The research conducted an analysis of flood effects through assessment of sanitation conditions against disease occurrences in areas prone to flooding. Before, during and after flooding the research conducted a detailed structured and qualitative sanitation assessment of households combined with Health facility record collection from surrounding health centers to determine evidence about flooding effects on public health risks. The upcoming section will demonstrate the research outcomes concerning local area flood severity and failed sanitation systems alongside disease patterns in this region.

Table 1. Demographic Characteristics of Survey Respondents

Demographic Variable	Frequency (n = 400)	Percentage (%)
Age Group		
18–30 years	80	20
31–45 years	120	30
46–60 years	100	25
61+ years	100	25
Income Level		
Low Income (< IDR 2,000,000)	150	37.5
Middle Income (IDR 2,000,000 – 5,000,000)	200	50
High Income (> IDR 5,000,000)	50	12.5
Education Level		
No Formal Education	40	10
Primary Education	100	25
Secondary Education	150	37.5
Higher Education	110	27.5

This table presents the demographic characteristics of the sample population, including age, income level, and education. The data shows a varied distribution, ensuring a comprehensive representation of the population across different socio-economic backgrounds. This information provides context for understanding the variability in sanitation and disease exposure across different groups.

Table 2. Flooding Events and Household Sanitation Conditions

Sanitation Condition	Before Flooding (%)	During Flooding (%)	After Flooding (%)
Access to Clean Water	90	40	70
Presence of Toilets	85	45	65
Proper Waste Disposal	80	30	60

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Water Storage Practices	75	25	50

This table displays the changes in sanitation conditions before, during, and after flooding. As flooding occurs, access to clean water, toilet availability, waste disposal, and water storage practices are negatively affected, which is reflected in the substantial drop during flooding. These changes in sanitation conditions are crucial for understanding the link to disease outbreaks.

Table 3. Disease Prevalence by Type Before, During, and After Flooding

Disease Type	Before Flooding (%)	During Flooding (%)	After Flooding (%)
Waterborne Diseases	15	60	40
Vector-borne Diseases	20	50	30
Respiratory Diseases	10	30	25
Skin Infections	5	15	10

This table summarizes the prevalence of different types of diseases before, during, and after flooding events. The data shows a significant increase in the prevalence of waterborne and vector-borne diseases during flooding. After flooding, while there is a decrease, these diseases remain a significant concern. The rise in disease prevalence during flooding is an important finding, linking inadequate sanitation to public health issues.

Table 4. Correlation Between Flood Intensity, Sanitation Conditions, and Disease Prevalence

Variable	Correlation Coefficient (r)	Significance (p-value)
Flood Intensity vs. Sanitation Conditions	-0.72	0.001
Flood Intensity vs. Waterborne Diseases	0.65	0.001
Sanitation Conditions vs. Waterborne Diseases	-0.80	0.0001
Sanitation Conditions vs. Vector-borne Diseases	-0.68	0.002

This table shows the correlation coefficients between flooding intensity, sanitation conditions, and disease prevalence. A negative correlation between sanitation conditions and disease prevalence indicates that poor sanitation leads to higher disease rates. Flood intensity was found to have a strong positive correlation with disease outbreaks, especially waterborne diseases. The significance values indicate that these relationships are statistically significant.

Table 5. Multiple Regression Analysis Predicting Disease Prevalence

Predictor Variables	Beta Coefficient	Standard Error	t-value	p-value
Flood Intensity	0.35	0.08	4.50	0.0001
Sanitation Conditions	-0.50	0.09	-5.56	0.0001
Income Level (Low vs. High)	0.12	0.05	2.40	0.02
Education Level (Low vs. High)	0.08	0.07	1.14	0.26

This table presents the results of the multiple regression analysis used to predict disease prevalence based on various predictor variables, including flood intensity, sanitation conditions, income level, and education level. Flood intensity and sanitation conditions were found to be the strongest predictors of disease prevalence, with flood intensity positively

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associated with higher disease rates and poor sanitation negatively affecting health outcomes. The analysis also showed that lower income levels were associated with higher disease prevalence, while education had a less significant effect.

This study findings can therefore be useful in understanding the effects of floods on sanitation and spread of diseases in South Sulawesi. Therefore, by adopting the descriptive-correlational design, this study has managed to establish the extent to which flooding impacts, sanitation standards, and waterborne and vector borne diseases are related. Hence, this study will contribute to the existing literature on the flooding effects on public health, especially in flood affected regions such as South Sulawesi where flood affected areas are struggling to overcome challenges in sanitation and health improvement.

One of the main conclusions of the present work is the negative impact of floods on sanitary conditions that have also been assessed by other authors as indicating that sanitation systems in flood zones are particularly ill-suited. Table 2 shows that factors such as availability of clean water, proper disposal of wastes and toilets were also affected during flood incidences. These disruptions in sanitation were observed especially during the flood situation where only 40% of the households were able to access to clean water from 90% before flooding. This corroborates the observation made by Rahaman et al. (2023) and others pointing to the fact that floods degrade water sources, put the water quality at risk for contamination and exacerbate sanitation crises with special reference to cities and peri-urbanization. Similarly, the findings of this study support these findings with additional calls for enhancement of the infrastructure to protect against challenges such as sanitation mishaps during and after flood disasters.

Sanitation deterioration due to flooding was found to be directly associated with increased disease incidence impacting water and vector borne diseases (Hyde et al., 2022). Table 3 shows a significant jump in incidence of water borne diseases (60% during flood as opposed to 15% prior flooding) which affirms with Noureen et al. (2022) who revealed that flood create instance source of water borne diseases such as colera and dysentery. These high findings of house hold prevalence of vector- borne diseases during flooding as compared to 20% prior to flooding is in line with trends observed in similar studies of malaria incidence following floods in tropical countries (Coalson et al., 2021). These diseases become rampant once the floods have taken their course, mainly because pool water breeding mosquito relatives is prevalent. This study has also cancelled the hypothesis which states that flooding causes the emergence of both, water borne and vector borne diseases, association which did not receive enough attention in the South Sulawesi regional researches.

Even more, the correlation analysis in table 4 depicted the presence of strong and highly significant relationship betwee; flooding intensity, sanitation conditions, and disease outbreaks. Preliminary assessment from the current hypothesis confirms that more severe flooding results in increased incidents of disease. This is in accordance with global approaches pointed out by Semenza et al. (2022) since they also highlighted how the severity of floods leads to enhanced spread of infectious diseases. The fact that the study reveals a negative relationship between sanitation conditions and disease incidences shows that poor sanitation greatly increases disease risks something that is important when there is need to address hygiene during flood periods. This result is in conformity with the works developed by Huda et al. (2022) who stressed that sanitation is perhaps a key factor for disease prevention in flood-affected areas.

Whereas existing research correlates floods, sanitary crises, and epidemics, this work further investigates these phenomena with respect to South Sulawesi where environmental conditions and demographics differ from the rest of the country. Previous research work has mainly targeted either the big cities or other regions in southeast Asia, where the fundamental conditions –like structures and flood protection levels are not necessarily similar to the

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conditions prevailing in the rural areas of the south Sulawesi province. Compared with the earlier studies that have only involved the urban residents only, this study has enabled a broader understanding of the effects of flooding on the urban, peri-urban and rural dwellers. From the evidence given earlier it is clear that disease susceptibility is closely linked with the local socio-economic factors as revealed by the higher number of diseases compared to lower income (Table 5). To the current debate on the effects of floods, this research contributes another viewpoint of public health in flood affected areas by incorporating the income level factor in post flood health impacts.

The analysis done using multiple regression equation as shown in Table 5 helped in the understanding of the various effects of various variables on the disease prevalence. Accordingly, the study concluded that flood intensity and sanitation conditions provided the highest values of the probability of disease outbreak. This finding is consistent with the prior study by Ahlers et al. (2022) who asserted that floods decrease the public health risk most significantly where sanitation conditions are already poor. The incorporation of income level as an indicator for disease prevalence indicates that flooding increases the health danger of poor families, a result that is consistent with the work of other scholars (Wang et al., 2023). Education level was not included as a variable that defines patient's eligibility for specialist treatment for chronic diseases and it is further explained that it could be due to the nature of the data or other contextual factor, public awareness programs or local health interventions.

Conclusion

This study also confirms the effects of flooding on the sanitation conditions and water-borne and water vehicle borne illnesses in South Sulawesi. Thus, the results stress the importance of focusing on the enhancement of infrastructure and health activities in the vulnerable flood areas, especially in low socio-economic populations. This study determines the levels of the relationships between HIV/AIDS prevalence, level of floods and sanitation standard and hence informs health officers and policy makers in identifying the prevention measures for hiv/aids and hard stand for increased standards of sanitation during flooding periods. The present findings provide insights that would be useful for designing further flood-related health intervention strategies in similar settings.

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