Association between Climate, Socio-Economic, and Environmental Factors to Diarrhea in West Nusa Tenggara, Indonesia

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Abstract. Diarrhea is a significant health problem in Indonesia, particularly in developing regions where the disease is endemic. A substantial number of its cases arise from the contamination of food and water sources. The study focused on West Nusa Tenggara Province, which had a high prevalence rate of diarrhea. It aimed to examine the influence of climate, environmental factors, and regional attributes on diarrhea.The study results can be used to develop region-specific strategies to reduce outbreaks. An ecological method was adopted and data from 10 districts/cities were analyzed. Negative binomial regression was used to evaluate the relationship between monthly diarrhea cases from 2017 to 2020 and climate variables, access to water-sanitation-hygiene (WASH), population density, and well-being indices over the same period. The results showed that rising temperatures increased the number of cases (IRR: 1.095; 95%CI: 1.043-1.149), while relative humidity served as a protective variable. Limited access to drinking water and sanitation increased the risk of diarrhea (IRR: 1,082; 95% IC: 1,056-1,110). Higher temperatures often led to drought, complicating access to safe water sources. Therefore, there was an urgent need for enhanced development of accessible WASH infrastructure, particularly for underserved communities.

1 Introduction

In 2017, approximately 1.6 million people worldwide died from diarrheal, with one-third of the incidents occurring in toddlers and the elderly [1]. According to the Ministry of Health's Basic Health Research, the prevalence of the disease in Indonesia was 7% in 2013 and slightly increased to 8% in 2018 [2]. Diarrhea is an endemic disease prevalent in developing countries, where it can progress into an outbreak that often leads to death [3].

Diarrhea is attributed to dehydration due to excessive fluid and electrolyte loss, and without timely treatment, it can lead to fatal outcomes. Children with malnutrition or weakened immunity are particularly susceptible to the disease [4].

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In cases of prolonged or recurrent diarrhea, damage to intestinal tissue may occur, impairing nutrient absorption and inhibiting growth. The primary sources of the disease are bacterial, viral, or parasitic infections, often transmitted through contaminated water and feces, often due to inadequate access to clean water. Globally, millions of people die each year from conditions related to unsafe water, sanitation, and hygiene (WASH). It is important to acknowledge that approximately 300,000 children under five succumb to diarrhea caused by a lack of WASH services [5].

Water demand outpaces population growth, with half of the global population facing severe scarcity for a minimum of 1 month each year. The situation is expected to worsen as global temperatures rise due to climate change [6]. This includes long-term changes in temperature and weather patterns, which are natural processes significantly accelerated by human activities, specifically the burning of fossil fuels.

Some of the impacts of climate change include rising sea levels, air temperatures, and more frequent extreme weather events such as floods and droughts. These changes can directly or indirectly affect human life, disrupt economic development, threaten water availability, alter disease patterns, reduce air quality, and harm health [7-8].

Hydrometeorological disasters, which are natural events related to weather, can decrease water quality and food security, leading to an increase in infectious diseases such as diarrhea. Several studies showed a varying relationship between climate variables and the incidence of diarrhea [9-11]. However, investigations focused on factors related to WASH present that during periods of rising temperatures and increased rainfall, households relying on unsafe water or sanitation facilities are at higher risk of developing the disease [12].

West Nusa Tenggara (NTB) Province has a higher prevalence rate of diarrhea than the national average of 8.6% [2]. The province comprises 10 districts and cities across two large and several small islands. Furthermore, the stunning natural beauty makes it a popular tourist destination. As a tropical climate, the rainy season often lasts from November to April, while the dry season occurs from May to October. However, the problem of diarrhea remains a threat, as observed from the high number of cases, especially among toddlers in 2013. The prevalence of the disease was recorded at 11.0, which then increased to 13.4 in 2018 [2].

This study aims to explore the correlation between climate patterns and the incidence of diarrhea as well as identify the causative factors in the province. The results are expected to provide insight through practical recommendations in NTB.

2 Materials and Methods

Climate data of this study were obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG) covering 2017 to 2020. The number of monthly diarrhea cases was sourced from the Ministry of Health. Furthermore, WASH data and economic status were obtained from the National Socio-Economic Survey conducted by the Central Statistics Agency (BPS). Population density data for the same period were also included and in total, 480 records (N) were analyzed.

This study used an ecological design, concentrating on the characteristics of population groups. The analysis unit consists of 10 districts/cities in NTB. The dependent variable was the incidence of diarrhea, specifically the number of monthly cases for 4 years from 2017 and 2020. Meanwhile, the independent

variable in this study included climate factors, represented by 3 key parameters:

1. Air temperature (average daily temperature fluctuations in the atmosphere each month)
2. Monthly relative humidity (ratio of water vapor content in the air to the maximum amount of holdable water vapor)
3. Monthly rainfall (amount of rainfall per month)

Another independent variable was WASH, comprising access to safe drinking water, sanitation facilities, and sanitation conditions, by the standards set by World Health Organization (WHO), Joint Monitoring Program (JMP), and the United Nations Children's Fund (UNICEF) [13]. Additional independent variables included population density and well-being index.

Access to WASH was evaluated by assessing the level of service for each component. Access to drinking water was determined by the availability of water sources (location in the house or yard, travel time is no more than 30 minutes to fetch water), ensuring physical quality standards were met. Sanitation was analyzed by considering factors such as the type of toilet, ownership, and utilization of latrine facilities. Hygiene was assessed based on the availability of handwashing facilities, water supply, and soap or antiseptic liquid. Furthermore, the negative binomial regression method, which is a non-linear regression model based on a Poisson-gamma mixed distribution was used to analyze data.

3 Result

The number of diarrhea cases in NTB was high nationally. The results of the study show that the disease fluctuates and tends to decrease, as shown in Table 1.

Table 1. Description of diarrhea cases per year in NTB in 2017-2020

Diarrhea cases	**2017**	**2018**	**2019**	**2020**
Mean	1461,34	1114,83	1157,24	977,19
SD	1380,58	861,04	913,93	1219,25
Min-Max	0 - 8972	164 - 3879	137 - 4235	0 - 9961
Entire	175361	133779	138869	117263

NTB experiences a rainy season from December to March and a longer dry season from April to November. During the observation period, there is a minimum of 1 month without rainfall, as evidenced by a minimum monthly rainfall of 0 mm. In terms of the welfare index, approximately one-third of the total districts and cities were in the poor category. Furthermore, the percentage of people with limited access to safe drinking water and sanitation was highest in 2017 but declined in subsequent years. This trend reflected positive progress in improving water and sanitation facilities, providing more individuals with access to essential services.

Table 2. Description of climate, socio-economy, and WASH in NTB in 2017-2020

	2017	**2018**	**2019**	**2020**
Temperature (°C)				
Mean	27,76	28,02	27,95	28,25
SD	0,89	1,03	1,22	0,88
Min-Max	25,41- 29,14	25,32 - 29,79	24,89 - 30,23	25,72 - 29,63
Relative humidity (%)				
Mean	78,03	75,6	74,41	77,13
SD	5,13	5,9	6,70	4,84

	2017	2018	2019	2020
Temperature (°C)				
Min-Max	67,0 - 87,0	67,0 - 89,0	62,0 - 92,0	67,0 - 87,0
Rainfall (mm)				
Mean	153,07	113,21	118,06	133,93
SD	132,12	126,05	140,83	102,43
Min-Max	0 - 567,80	0 - 448,30	0 - 447,50	0 - 327,70
Population density (/km^2)				
Mean	1121,88	1141,09	1160,65	1188,39
SD	2202,89	2245,55	2289,57	2329,98
Min-Max	67,68 -7642,89	68,30-7789,17	68,89 - 7939,89	76,72-8086,15
Well-being index (WI-1)*				
Mean	33,77	33,77	34,14	30,79
SD	3,65	3,65	3,28	13,80
Min-Max	28,0 - 41,0	28,0- 41,0	30,9 - 40,6	5,7- 54,0
Limited water sanitation** (%)				
Mean	10,06	5,85	8,22	7,29
SD	3,92	2,58	3,10	2,01
Min-Max	4,3 - 17,2	0,1- 9,3	1,9 - 13,3	3,8 - 10,3
Limited hygiene (%)				
Mean	31,86	30,88	31,53	30,38
SD	10,0	12,62	13,61	12,48
Min-Max	16,6 - 49,6	15,3 - 52,7	17,9 - 65,5	15,7 - 50,5

* *Level 1/poor*
***Unsafe drinking water and limited sanitation*

Statistical tests showed that several variables, such as temperature and relative humidity, were significantly correlated to diarrhea cases. Humidity had a negative relationship, as shown in Table 3. Limited access to water and sanitation, as well as limited hygiene and overcrowding, also showed a positive correlation with cases of diarrhea. Meanwhile, economic status did not show a significant correlation during the period.

Due to the acceleration of climate change, including rising temperatures, more frequent heavy rainfall and floods, as well as deterioration in air quality caused by widespread drought, airborne, and foodborne diseases were expected to increase [14]. Tropical diarrhea often peaks during the rainy season, with floods and droughts linked to higher risk factors for the disease, despite the temporary nature of many of these events. Heavy rain can easily introduce contaminants into the water supply, while during the dry season, the scarcity of clean water increases the risk of hygiene-related diseases [15].

Table 3. Correlation between diarrhea cases and climate variables, WASH, and economic status

Variable	**Spear r**	***P value***
Temperature (°C)	0.304	0.000
Relative humidity (%)	-0.186	0.000
Rainfall (mm)	0.148	0.001

Variable	**Spear r**	***P value***
Limited water sanitation (%)	0.353	0.000
Limited hygiene (%)	0.468	0.000
Well-being index	0.016	0.723
Population density (/km^2)	0.258	0.000

The results from multivariate analysis using negative binomial regression showed that monthly mean temperature, rainfall, access to WASH, and economic status were statistically significant factors related to diarrhea cases, as presented in Table 4. There was a significant positive association between temperature (IRR: 1,054; 95%CI: 1,043-1,149) and the incidence of diarrhea, as well as between limited access to safe drinking water and sanitation and reported cases (IRR: 1,082; 95%CI: 1,056-1,110). However, a significant inverse relationship was observed in terms of relative humidity (IRR: 0.966; 95% CI: 0.953-0.979).

Table 4. Analysis of negative binomial regression between climate, WASH, socio-economy
and the incidence of diarrhea in NTB in 2017-2020

Variable	**IRR (95% CI)**	**Adjusted IRR (95%CI)**
Temperature	1.054 (1.028-1.082)* *	1.095 (1.043-1.149) * *
Relative humidity	0.971 (0.958-0.983)* *	0.966 (0.953-0.979) * *
Rainfall	1.00 (0.999-1.001)	1.001 (1.00-1.002) * *
Limited water sanitation	1.121 (1.094-1.149)* *	1.082 (1.056-1.110) * *
Limited hygiene	1.034 (1.027-1.041)* *	1.017 (1.008-1.026) * *
Well-being index	1.006 (0.993-1.019)	1.024 (1.014-1.033) * *
Population density	0.999 (0.999-1.00)	0.999 (0.999-0.999) * *

*P < *0.001*

The results of this study are in line with an investigation conducted in sub-Saharan Africa where an increase in average temperature of 1°C led to a rise in the incidence ratio (IRR) of diarrhea by 6.7% at the household level (IRR = 1,067, p<0.001). Similarly, a 1 mm increase in rainfall was associated with a 0.6% rise in IRR (IRR = 1.006, p<0.001). It was important to acknowledge that environmental variables mediate the effects of climate variation on cases. Low- and middle-status households had IRR for diarrhea that was 1.21 times greater than high-status households (IRR = 1.21 and IRR = 1.12, p< 0.001) [12].

An analysis of 28 studies conducted in 15 countries between 1974 and 2010 showed that for every 1°C average monthly temperature increase, the incidence of E. induced diarrhea would increase by 8%. High temperatures can accelerate the replication of bacteria and increase their ability to survive in the environment, leading to genetic changes in E. strains [16].

The results are not in line with a study conducted in Singapore, where a 10% rise in relative humidity was related to a higher incidence of diarrhea [9]. Conversely, a study in India showed that low humidity levels elevated the risk of diarrhea caused by rotavirus [17]. Low humidity has been correlated with an increasing risk of the disease in northern and central Surabaya [18].

In developing countries, the absence of clean drinking water and adequate sanitation facilities was associated with an increased risk of diarrhea, specifically among children. Higher maternal mortality rates were observed in households with poor water and

sanitation conditions. In the long term, diarrhea can lead to malnutrition in young children, negatively impacting growth and cognitive development. The microbiological quality of drinking water is very important and is associated with the incidence of diarrhea and trachoma [19]. There is no guarantee that a safe water source is a free-form fecal contaminant, presenting the importance of regular microbiological quality testing.

According to a study, as temperatures and rainfall increase, households consuming unsafe drinking water or engaged in inadequate sanitation are at higher risk of diarrhea [20]. Household sanitation conditions are closely related to the risk of enteric infections, as they often reflect the sanitary environment in the surrounding area [21].

Some recommendations that were proposed include increasing the provision of drinking water by the government to ensure accessibility to safe water for consumption. In addition, sanitation facilities should be constructed to fit local communities' needs, utilizing sustainable technology and ensuring the integration of sanitation improvements with adequate water supply systems. Public awareness of the importance of safe use of drinking water, maintaining hygienic latrines and ensuring the availability of adequate handwashing facilities, accompanied by washing hands with soap and running water need to be emphasized.

4 Conclusion

In conclusion, climate factors, access to WASH, economic, and population density were associated with diarrhea in NTB. Therefore, providing safe WASH facilities, specifically in areas with low rainfall and limited water resources, as well as enhancing public awareness, helped control the disease.

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