Analysis of diarrhea cases based on weather elements in Yogyakarta City 2017-2021

Inas Tri Ramadhanti[1]*, Hari Kusnanto[2], Aditya Lia Ramadona[3]

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[1]Environmental Health Program, Faculty of Public Health, Sriwijaya University, South Sumatra, Indonesia / Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia

[2]Department of Family, Community Medicine and Bioethics, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia

[3]Department of Health Behavior, Environmental, and Social Medicine, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia

***Correspondence:**
inas_tri_ramadhanti@fkm.unsri.ac.id

Abstract

Purpose: The objective of this study is to determine the relationship between weather elements (such as rainfall, temperature, humidity, and sunshine duration) with cases of diarrhea, as well as to map the areas vulnerable to diarrhea in Yogyakarta City using data from 2017 to 2021. **Methods:** This study used an ecological study design with Graphical/Time Trend Analysis, correlations, non-linear analysis using the Generalized Additive Model (GAM), and spatial analysis. **Results:** Statistically, temperature lag of 0 - 3 months has a negative correlation (p-value < 0.05; rlag1= -0.672), and humidity lag of 0 - 3 months has a positive correlation (p-value < 0.05; rlag1= 0.414) with diarrhea. Severe cases of diarrhea, even during the COVID-19 pandemic, are still being brought to health services, suggesting a serious underlying cause, such as rotavirus infection. Further multivariate analysis showed that the most dominant weather element related to diarrhea was temperature lag for 3 months, with an R-squared value of 0.516. Diarrhea is distributed across sub-districts in Yogyakarta City, but there are six sub-districts with high vulnerability to diarrhea: Danurejan, Pakualaman, Jetis, Kotagede, Gedongtengen, and Gondomanan. **Conclusions:** The most dominant weather element related to diarrhea in Yogyakarta city is the temperature from the previous three months (lag 3). Danurejan, Pakualaman, Jetis, Kotagede, Gedongtengen, and Gondomanan sub-districts have high vulnerability to diarrhea.

Keywords: diarrhea; spatial; weather

INTRODUCTION

Diarrhea remains a major health issue across all age groups and is a leading cause of death globally. In 2017, diarrhea resulted in 1.6 million deaths [1]. In developing countries like Indonesia, diarrhea is an endemic disease that has the potential to cause outbreaks and remains a significant unresolved problem due to its high mortality and morbidity rates [2]. The prevalence of diarrhea in Indonesia in 2018 was 8.0% [3]. In 2020, diarrhea was the leading cause of death in Indonesia, accounting for 14.5% of all deaths [2].

Many factors can cause diarrhea, and weather is one of the significant factors influencing its transmission [4]. Weather elements such as temperature, environmental humidity, indoor humidity, prolonged dry seasons, and rainfall affect microbial and parasitic species' growth and distribution and population variables [5]. The impact of climate change on weather is expected to increase the risk of diarrhea spread. According to WHO, between 2030 and 2050, climate change is projected to cause approximately 250,000 additional deaths annually, one of which is due to diarrhea. The risk of diarrhea is expected to increase by up to 10% in some regions due to climate change [6]. Epidemiological studies have demonstrated a link between climate change and the increased reporting of diarrheal disease [7–9].

Yogyakarta City faces health issues related to diarrhea. Data from the Yogyakarta City Health Office shows that diarrhea is among the top ten most common diseases. Of the five regencies/cities in the Special Region of Yogyakarta, Yogyakarta City had the highest diarrhea incidence rate in 2021, with 9.57 cases per 1000 population [10]. According to Yogyakarta City Health Office data, diarrhea cases fluctuate annually. The number of diarrhea cases in 2018 was 8,439, which increased to 8,503 in 2019 and decreased to 5,437 in 2020. This indicates that diarrhea remains an unresolved health issue in Yogyakarta City.

Yogyakarta City, the capital of the Special Region of Yogyakarta, is an urban area with high human activity. The city's area is 32.50 km², with a population density of 11,579 people per km² in 2021 [11]. This population density exceeds the balanced population density threshold set by WHO, 9,600 people per km² [12]. High population density affects the rising temperature in Yogyakarta City, caused by human activities and changes in urban land cover [13]. High population density areas also lead to poor environmental sanitation conditions, increasing the likelihood of diarrheal disease [14].

As part of environment-based disease management, spatial analysis involves analyzing and describing disease data geographically concerning population, distribution, environment, behavior, socioeconomic status, disease incidence, and the relationship between these variables [15]. Therefore, spatial analysis research is needed to understand the distribution of diarrhea in Yogyakarta City. Additionally, analyzing factors related to diarrhea cases is essential to prevent the negative impacts of diarrhea in Yogyakarta City.

Despite existing studies on the relationship between weather and diarrhea, there is a notable gap in research specifically examining the impact of climate change on diarrhea incidence in densely populated urban areas like Yogyakarta City. Most studies focus solely on correlating weather variables with diarrhea cases without explaining the vulnerable regions' underlying mechanisms or spatial distribution, limiting the effectiveness of public health interventions.

Additionally, spatial analysis remains limited in its application to understanding the dynamics of diarrhea in Indonesia. This study addresses this gap by analyzing how weather elements such as rainfall, temperature, humidity, and sunshine duration affect diarrhea cases and mapping areas vulnerable to diarrhea in Yogyakarta City.

METHODS

This study employs a quantitative research approach with an ecological study design conducted in Yogyakarta City, Special Region of Yogyakarta Province. The independent variables are weather elements (rainfall, temperature, humidity, and sunshine duration). The dependent variable is the incidence of diarrhea cases.

The study population consists of the administrative regions of Yogyakarta City, with the sample comprising the total number of cases over five years, from 2017 to 2021, totaling 60 months. Case data were collected from records of the Yogyakarta City Health Office, sourced from 18 community health centers across 14 districts. Data were gathered based on the total number of monthly cases without differentiating by cause, resulting in 840 observations (14 districts x 60 months). Weather elements data were obtained from the Yogyakarta Climatology Station.

The analysis included univariate analysis to describe the distribution and frequency of each variable. Bivariate analysis was conducted using the Spearman-rho correlation test to determine the relationship between independent and dependent variables, using 0 to 3 months lags. In addition to correlation tests, the relationship patterns between weather elements and diarrhea cases were examined graphically per month using time-trend analysis.

Multivariate analysis was conducted to evaluate the simultaneous influence of several independent variables on the dependent variable, identifying the most significant predictors. This study employed non-linear analysis using the Generalized Additive Model (GAM), implemented through the R package "mgcv."

To map the distribution of diarrhea based on regional vulnerability in Yogyakarta City, spatial analysis was performed using the Standardized Morbidity Ratio (SMR). The SMR values were then visualized to display the spatial distribution of diarrhea across each sub-district in Yogyakarta City. Regions with an SMR value greater than 1 at any given time were assigned a score of 1. These scores were then summed over five years (2017-2021), and the total final score was used to identify regions vulnerable to diarrhea.

RESULTS

The average number of diarrhea cases per month over the five years (2017-2021) was 566. The highest number occurred in January 2020, with 1,330 cases, while the lowest occurred in August 2021, with 179 cases. During these five years, diarrhea cases increased from 2017 to 2019 and then decreased in the following years. The highest number of cases was recorded in 2019, with 8,509, then significantly decreased in 2020 and 2021 to 5,437 cases and 3,788 cases, respectively.

The average monthly rainfall, temperature, humidity, and sunshine duration from 2017 to 2021 was 230 mm, 26.8 ℃, 79.26%, and 65.41%. The highest rainfall occurred in November 2017, reaching 875 mm, while the lowest amount was 0 mm, occurring in the middle months of the five years. The highest average temperature was recorded in May 2021 at 28.7 ℃, while the lowest average temperature occurred in July 2019 at 24.5 ℃. The highest average humidity was recorded in November 2017 at 88%, while the lowest was in October 2018 at 71%. The highest sunshine duration was recorded in June 2017 at 96%, while the lowest was in November 2017 at 27.6%. Over the five years, it was observed that the average temperature increased by 1.8℃, from 26℃ in 2017 to 27.8℃ in 2021. Humidity decreased by 7.4%, from an average of 83.7% in 2017 to 76.3% in 2021. Meanwhile, rainfall and sunshine duration fluctuate each year.

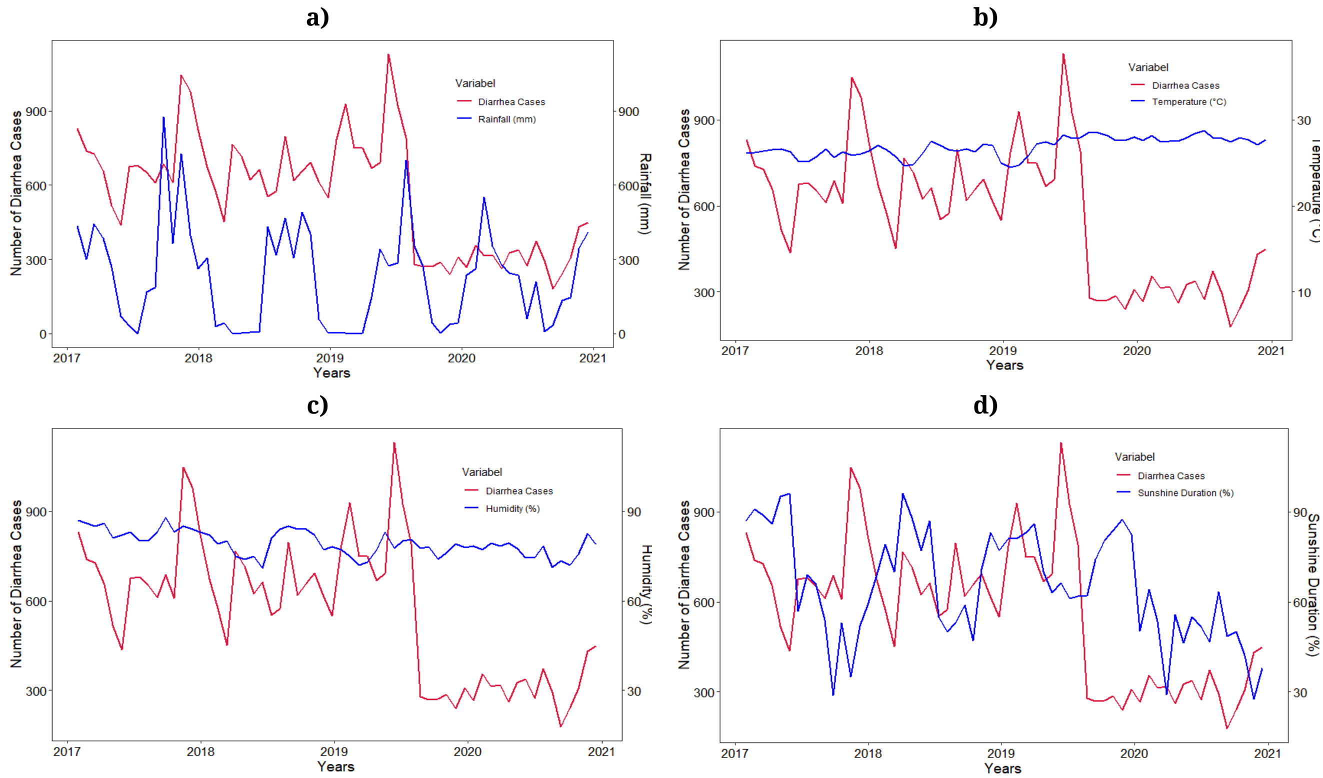

Figure 1. Graphics of a) Rainfall, b) Temperature, c) Humidity, and d) Sunshine duration with diarrhea cases by month in Yogyakarta

Graphical/Time Trend Analysis (Figure 1) shows that the monthly pattern of diarrhea cases over the 5 years (2017-2021) is in the same direction as the rainfall, humidity, and sunshine duration patterns. Meanwhile, temperature has a pattern that is not in the same direction as cases of diarrhea, meaning that as cases of diarrhea increase, the temperature in the same month decreases.

During the five years (2017-2021), there was a significant decrease in diarrhea cases, particularly from 2020 to 2021. This decrease was noticeable in March 2020 and is likely related to the COVID-19 pandemic. Therefore, a correlation analysis between weather factors and diarrhea cases was conducted in three time periods: the entire five-year period (2017-2021), the period before the COVID-19 pandemic (2017-2019), and the period during the COVID-19 pandemic (2020-2021). This analysis aimed to identify differences in the overall model.

Table 1. Correlation analysis of weather elements with diarrhea cases in Yogyakarta City

Diarrhea	Lag 0		Lag 1		Lag 2		Lag 3	
	p-value	r	p-value	r	p-value	r	p-value	r
Period 2017-2021								
Rainfall	0.251	0.150	0.688	0.052	0.711	0.048	0.878	-0.020
Temperature	$1.41e^{-06}$*	-0.576	$3.86e^{-09}$*	-0.672	$1.14e^{-08}$*	-0.657	$9.47e^{-07}$*	-0.584
Humidity	0.003*	0.374	0.001*	0.414	0.008*	0.338	0.024*	0.289
Sunshine Duration	0.08	0.227	0.491	0.09	0.531	0.082	0.363	0.119
Period 2017-2019								
Rainfall	0.688	0.067	0.552	-0.099	0.850	-0.031	0.052	0.317
Temperature	0.533	-0.104	0.085	-0.283	0.500	-0.113	0.021*	0.372
Humidity	0.765	0.049	0.529	0.105	0.922	0.016	0.922	-0.121
Sunshine Duration	0,778	-0.047	0.082	-0.285	0.116	-0.259	0.449	-0.126
Period 2020-2021								
Rainfall	0.011*	0.528	0.127	0.334	0.889	0.031	0.853	-0.041
Temperature	0.741	0.074	0.698	-0.087	0.871	0.036	0.001*	-0.560
Humidity	0.074	0.388	0.045*	0.430	0.384	-0.194	0.937	0.017
Sunshine Duration	0,118	-0.342	0.066	-0.397	0.488	-0.155	0.309	-0.227

*Significant (p-value < 0.05)

Based on the results of Spearman's rho correlation test between weather elements and diarrhea cases (Table 1), it was found that from 2017 to 2021, temperature and humidity from lag 0 to lag three were significantly associated with diarrhea cases. Temperature was negatively correlated with moderate to strong levels of association, while humidity was positively correlated with a weak level of association. In the pre-COVID-19 period (2017-2019), only temperature at lag 3 showed a significant positive correlation with diarrhea cases, with a weak level association levelwhile, during the COVID-19 period (2020-2021), significant correlations were observed between rainfall at lag 0, temperature at lag 3, and humidity at lag 1 with diarrhea cases. Rainfall and humidity were positively correlated with moderate and very weak levels of association, while temperature was negatively correlated with a moderate association level.

Table 2. Final model of multivariate analysis of weather factors with diarrhea cases in Yogyakarta City

Diarrhea	p-value	r^2
Temperature lag 3	$2.58e^{-07}$***	0.516
Humidity lag 3	0.313	

***significant (p-value < 0.001)

The nonlinear analysis using the Generalized Additive Model (GAM) indicates that the most dominant weather factor related to diarrhea cases is the temperature from three months prior (lag 3), with the explanatory power of the independent variable accounting for 51.6% of the variance in the dependent variable (Table 2).

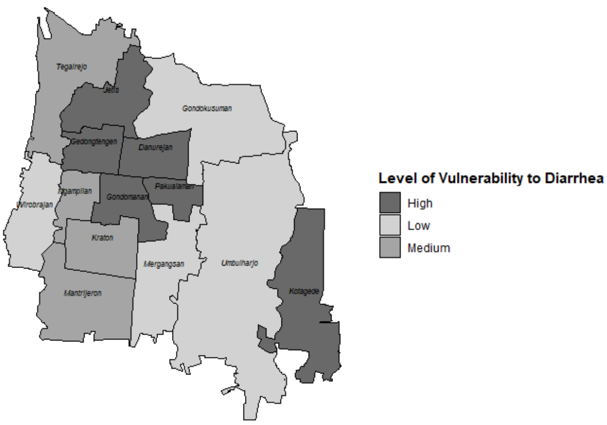

Figure 2. Map of diarrhea vulnerability levels in Yogyakarta City

Figure 3. The map of diarrhea distribution in Yogyakarta City over 5 years from 2017-2021 based on standardized morbidity ratio (SMR)

In Figure 2, six sub-districts are classified as highly vulnerable to diarrhea: Danurejan, Kotagede, Pakualaman, Jetis, Gedongtengen, and Gondomanan. Four sub-districts are classified as having medium vulnerability to diarrhea: Tegalrejo, Mantrijeron, Ngampilan, and Kraton. Four sub-districts are classified as having low vulnerability to diarrhea: Gondokusuman, Mergangsan, Umbulharjo, and Wirobrajan.

Figure 3 visualizes the distribution of diarrhea across sub-districts in Yogyakarta City based on SMR values. Regions with an SMR value greater than 1 at any given time were assigned a score of 1. These scores were then summed over a five-year period (2017-2021). The total final score was used to identify regions vulnerable to diarrhea.

DISCUSSION

Decreased temperatures are associated with increased rotavirus-induced diarrhea [16–19]. Lower temperatures accelerate the onset and intensity of rotavirus diarrhea outbreaks [20]. Rotavirus can survive outside the human body for several hours to months, depending on the environment, with low temperatures (4℃-20℃) providing ideal conditions for its replication and survival [21,22]. Research in Taiwan shows that low temperatures are associated with diarrhea risk within 8 weeks [21], while other studies find a risk within 0 months [22].

The negative correlation between temperature and diarrhea cases in 2020-2021 supports the suspicion of rotavirus infection. The decrease in diarrhea cases during this period may be due to reduced visits to healthcare services and activity restrictions during the COVID-19 pandemic. Recorded diarrhea cases likely represent severe cases requiring treatment and reporting to healthcare services. Severe diarrhea is often caused by rotavirus infection, which can lead to rapid dehydration [2]. Severe rotavirus infections leading to acute diarrhea almost always occur in children under 2 years old [23].

A positive correlation between temperature and diarrhea cases was found for 2017-2019. This may be because, before the COVID-19 pandemic, individuals with mild to severe symptoms were more likely to seek healthcare services. This suggests that various infections caused diarrhea during this period. Previous studies have shown that high temperatures are associated with increased diarrhea caused by bacteria such as Shigella, Vibrio cholera, and Salmonella [21,24].

Changes in environmental temperature and the frequency of extreme weather events can alter the distribution, survival, and virulence of diarrhea pathogens and host exposure patterns. Diarrhea transmission is complex and multifactorial, involving host and environmental factors, so the impact of temperature on diarrhea can vary across different pathogens, host populations, and environments [25].

Research in Bandung shows that high humidity is associated with an increased risk of rotavirus infection [19]. High relative humidity can increase diarrhea cases by creating conditions that support the growth of pathogens and vectors like flies, which contribute to the spread of diarrhea [26]. Humidity also affects vector populations' reproduction, development, and dynamics, indirectly influencing the spread of infectious diseases and allergies [27].

Increasing humidity by 1% can raise the incidence of diarrhea by 0.06997% [28]. Relative humidity is significantly associated with the risk of diarrhea after a 2-month lag, with a 2.3 times higher risk [22]. Research in Singapore shows a positive relationship between relative humidity one week prior and the incidence of diarrhea [29], while research in Taiwan found a significant relationship between relative humidity in the same month up to 2 months prior and the incidence of diarrhea [24].

Spatial analysis over 5 years reveals that Danurejan, Pakualaman, Jetis, Kotagede, Gedongtengen, and Gondomanan are the sub-districts most vulnerable to diarrhea. These high-risk areas are concentrated in the central part of Yogyakarta City, except Kotagede, located on the city's edge. Danurejan, Pakualaman, Jetis, Gedongtengen, and Gondomanan are lowland areas in the city center traversed by the Code River, which is likely contaminated, contributing to the high incidence of diarrhea.

The Code River has higher pollution levels than other rivers in Yogyakarta City, primarily due to its passage through urban areas and contamination from domestic waste [30]. Research along the Code River in the sub-districts of Gondomanan, Jetis, and Danurejan has shown that E. coli bacteria in the river contaminate residents' wells, leading to poor water quality with high E. coli levels. This pollution is attributed to poor conditions around the wells, such as seepage from contaminated river water and domestic waste, which can lead to diarrhea and dysentery [30,31].

The high vulnerability to diarrhea in Danurejan and Gondomanan may be due to the high risk of flood disasters. Flooding occurs due to river overflow from heavy rainfall, affecting densely populated areas around the river [13,32]. Additionally, slum settlements around the river also exacerbate environmental health issues. Kotagede is one of the largest slum areas in Yogyakarta City, covering 12.29 hectares [33]. Research along the Code River shows minimal sanitation management, poor waste disposal, low well water quality, and inadequate sewage systems [34]. Studies in slum areas in Nepal, India, and Kenya have shown a higher prevalence of diarrhea due to poor sanitation and hygiene [35–37]. Factors such as unhealthy toilet use behavior, lack of access to clean water, minimal hygiene facilities, and poor environmental conditions are significantly associated with diarrhea [38]. Low sanitation and extreme weather conditions, such as temperature drops and increased humidity, can increase diarrhea cases. Poor environmental conditions and lack of food hygiene during climate change can accelerate the development of parasites, viruses, and vectors of diarrhea-related diseases [39].

This research highlights the significant impact of diarrhea on public health, particularly among children under the age of 5 with low sanitation. Based on data, it is estimated that 525,000 deaths per year in Indonesia are caused by diarrhea [40]. The high mortality rate of infants due to diarrhea underscores the importance of public health interventions. Education on good sanitation practices and the importance of handwashing with soap, especially in areas with high population density and poor sanitation, can reduce the risk of diarrhea transmission.

Additionally, diarrhea represents a significant risk factor for childhood stunting, as it impairs nutrient absorption, which is crucial for growth and development [40]. Recurrent diarrheal episodes can lead to compromised physical and cognitive development, potentially resulting in diminished academic performance and reduced productivity in adulthood [41]. Consequently, this phenomenon may adversely affect the overall quality of Indonesia's human capital, potentially limiting its capacity to contribute effectively to the nation's economic and social advancement.

The long-term ramifications of stunting attributable to diarrhea extend beyond individual health outcomes, encompassing increased healthcare expenditures and economic burden. Children with stunted growth exhibit heightened susceptibility to various illnesses, elevating healthcare costs. Moreover, the reduced productivity associated with stunting can impede economic growth and hinder poverty alleviation initiatives. Therefore, addressing the interrelated challenges of diarrhea and stunting is paramount for enhancing quality of life and fostering sustainable development in Indonesia.

Furthermore, changes in temperature and extreme weather conditions due to climate change can worsen the situation, especially in communities with limited access to resources. Changes in diarrhea-related disease patterns indicate the need for an adaptive approach in public health strategies considering climate change's impact. Increasing community awareness about adapting to these changes, such as managing water sources during the rainy season or mitigating the risk of infection during low temperatures, is essential in reducing the social burden of diarrhea diseases.

CONCLUSION

The weather element most closely related to diarrhea cases is the temperature from three months prior. Severe cases of diarrhea, even during the COVID-19 pandemic, were likely brought to healthcare facilities due to serious causes such as rotavirus. The sub-districts with high vulnerability to diarrhea are Danurejan, Kotagede, Pakualaman, Jetis, Gedongtengen, and Gondomanan.

Environmental interventions are needed to improve access to and availability of safe drinking water, safe sanitation, and basic hygiene facilities in areas vulnerable to diarrhea. An early warning system should be implemented using weather data from three months prior to strengthen monitoring and evaluation efforts to reduce diarrhea cases. Additionally, research on rotavirus-induced diarrhea is necessary to confirm the hypotheses in this study.

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