Relationship Between Climate Variability, WASH and Diarrhea Cases in Indonesia

Puti S. Hidayangsih(✉), Ika Dharmayanti, Dwi H. Tjandrarini, and Noor E. W. Sukoco

Research Organization for Health, National Research and Innovation Agency, Jakarta, Indonesia
puti002@brin.go.id

Abstract. Climatic factors are suspected to encourage an increase in the incidence of diarrheal diseases in Indonesia, especially among children under five, as a vulnerable group and can lead to death. The problem of diarrhea for the last 3 years has almost stagnated, only slightly decreased. This study aims to determine the role of climatic factors and water conditions, sanitation and hygiene behavior on the incidence of diarrhea as a basis and evidence in planning programs. The data used is secondary data from various sources. Monthly diarrhea data for the period 2018–2020 was obtained from the Hepatitis and Gastrointestinal Infectious Disease Program Section, Directorate of Infectious Disease Prevention and Control, Ministry of Health. Data on WASH such as drinking water sources, latrine facilities, and the availability of hand washing facilities were obtained from the National Socio-Economic Survey (Susenas) year 2018–2020 from the Central Statistics Agency (BPS). As for weather data, obtained from the Meteorology, Climatology and Geophysics Agency (BMKG) for the same time period. Data includes monthly records of average maximum and minimum temperatures, total precipitation and humidity. The analysis using mean difference test. The results of the analysis showed that cases of diarrhea in children under five during 2018–2020 experienced a slight decrease from 3,186 cases (in 2018) to 2,196 cases (in 2020). There is a difference in the mean temperature (p-value = 0.000), rainfall (p-value = 0.000) and humidity (p-value = 0.000) for cases of diarrhea in children under five. Weather factors, namely temperature, rainfall and humidity have a relationship with the incidence of diarrhea in children under five years. Likewise, there was a decrease in diarrhea followed by a decrease in the problem of coverage of drinking water sources (14.6% in 2018 to 12.3% in 2020) and inadequate latrines (42.3% in 2018 to 36.6% in 2020) and unavailability of hand washing facilities (23.9% in 2019 to 23.5% in 2020). In conclusion, there is positively relationship between temperature, rainfall and humidity with diarrhea cases. The case of childhood diarrhea is inversely proportional to the unimproved of drinking water sources, latrines and the unavailability of hand washing facilities. Relevant public health intervention strategies that consider climate variability should be developed, including health education to improve public awareness for reducing risk of diarrhea.

Keywords: diarrhea · hand-washing · humidity · latrine · rain fall · temperature · water source

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1 Introduction

Climate change has been felt by the world for a long time and affects various aspects of life including in the field of health. It can be said that it starts from human behavior that accumulates changing weather elements, causing the phenomenon of global warming. One of the causes of the accelerated increase in air temperature is that carbon dioxide and methane emission gases from human activities are responsible for the temperature increase of about 1.10 C and it is estimated that the global temperature will reach 1.50 C or more over the next 20 years or so [1].

The impact of climate change is expected to increase the number of deaths significantly. Areas with a majority of poor people are more vulnerable to the adverse effects of rising temperatures, as their low incomes make them less able to adapt to hot weather [2]. Hotter temperatures also have a direct effect on health which causes exacerbations of respiratory diseases such as respiratory allergies and autoimmunity [3]. Not only exposure to heat, the impact of climate change on health to exposure to cold, air pollution, food safety risks, infectious diseases due to flooding, and disruption to access and functioning of health services [4]. The global mortality rate in 2080–2099 is expected to increase by 1.8% [95% CI 0.8–2.8%] under the scenario of RCP 4.5 or with lower emissions with the predicted increase in the global mortality rate by the end of the century being 1.1% [2].

Several studies have reported there are four diseases that are closely related to climate change and are of particular concern including acute respiratory infections (ARI), diarrhea, malnutrition, and malaria [5]. The increase in temperature as a result of climate change results in drought to the deposition of water and is positively correlated with diarrhea [6, 7], and an increase in temperature to 4 °C is projected to increase the relative risk of diarrhea by 8–11% [8].

The increased risk of diarrheal diseases related to climate change receives special attention, especially for toddlers, because they belong to the group that is prone to death from diarrhea. In Gaza, cases could rise by more than 10% below the global warming rate of 20 °C [9], while in Ethiopia the risk increases by up to 17% at any 10 °C temperature rise [10], and tends to decline in the rainy season [11]. However, there is an influence of non-climatic factors on diarrhea [12].

From several non-climatic factors that affect diarrhea, it is suspected that there is an influence of drinking water as a carrier of diarrhea pathogen bacteria [13]. And these bacteria can spread through water and can get worse when flood conditions are one of the effects of climate change. Therefore, management and improvement related to drinking water, sanitation and hygiene (WASH) are needed, especially in an environment where there are many children [14]. In addition, it is important to provide water and sanitation infrastructure in line with the provision of health education [15].

In Indonesia, climate change has also been felt as a result. Anthropogenic impacts have increased to 73% over the past ten years, where the combination of anthropogenic and climate change has a double impact on the ecosystem of Jakarta Bay [16]. Likewise, the impact of climate change is reported in South Sumatra which indicates a risk of sea level rise [17].

Based on the results of a health survey in households, there is an increase in the prevalence of diarrhea in Indonesia from 7% (in 2013) to 8% (in 2018) [18]. Diarrhea was found to have a significant relationship with defecation behavior, as well as the availability of proper drinking water and sanitation facilities [19]. Diarrhea is also thought to have a relationship with food processing practices [20], water sources and sanitation [21], water storage with an open container [22], and exclusive breastfeeding, low birth weight, overcrowding, smoking behavior, immunization, age, nutritional status, and socioeconomic status [23].

Climate change continues, and its impact on health would be worsen. In Indonesia, evidence-based adaptation and mitigation efforts related to climate variability, water, sanitation and hygiene (WASH) and diarrhea among children under five as a vulnerable group remains insufficient. Therefore, this study will describe the relationship between the short-term effects of climate, WASH and diarrhea as an early warning model to reduce the adverse health impacts.

2 Material and Methods

Guidelines for the identification of diarrheal diseases have been regulated in Minister of Health No. 35 of 2012 regarding the risk of water and food infections [24]. In this study, identify the risk of waterborne diseases due to climate change - in this case diarrhea -- by using 3-year trend data (2018–2020) for climate data such as rainfall, temperature and humidity as well as data on water sources, sanitation and handwashing facilities and also data on cases of diarrhea.

2.1 Study Site

This study was conducted in all regions of Indonesia (34 provinces) using secondary data. Based on the data, the average air temperature in the study area during the research period (2018–2020) in Indonesia is in the range of 18.81 °C – 32.71 °C. Meanwhile, the humidity ranges from 52% – 95%, and the rainfall range is quite wide, which is between 0–1034 mm.

2.2 Design Study

The study design is descriptive-analytic, to study the distribution of diarrheal disease and its determinants.

2.3 Source of Data

The data used in this study are secondary data from various sources. Diarrhea data was obtained from the Hepatitis and Infectious Diseases Program Section of the Gastrointestinal Tract, Directorate of Direct Infectious Disease Prevention and Control, Ministry of Health from 2018–2020. Diarrhea data is originally the number of diarrhea cases per month based on age groups reported by health care facilities in each district/city from 2018–2020. Data water, sanitation and hygiene (WASH) were obtained from the National

Socio-Economic Survey (Susenas) which was undertaken every year from the Central Statistics Agency (BPS). The data describes the condition of water sources, latrines and hand washing facilities in the form of proportions per household from observations and interviews during Susenas survey by BPS. As for climate-related data obtained from the Meteorology, Climatology and Geophysics Agency (BMKG) for the same period of time. Data includes monthly records of average minimum and maximum temperatures, rainfall and humidity. In order to be equal, the variables are made into averages per year and then combined to be analyzed to see the relationship between variables.

2.4 Variable of Analysis

Climate data are variables of monthly temperature, rainfall and humidity per year in each district in 34 provinces in Indonesia during 2018 to 2020 (3 years). While, data on water, sanitation facilities and handwashing in the form of a percentage of each district per province, which are distinguished in improved and unimproved. Facilities are categorized as improved if they are available and in good quality, and otherwise is categorized as unimproved. Diarrhea variable is the number of diarrhea cases per month recorded in health facilities in each district/city. The incidence rate of diarrhea was not used in this study because data on the total number of children under five in the population were not available, so the absolute number of children under five with diarrhea was used. This is one of the limitations in the study when using secondary data.

In order to be equal between variables, temperature, rainfall and humidity were categorized. For temperature, it is split up into three categories, as low temperature ($<= 19$ °C), moderate (20–25 °C) and high ($=> 26$ °C). For rainfall, it is separated into four categories, as low rainfall (<100 mm), moderate (100–300 mm), high (301–500 mm) and very high (>500 mm) and for humidity, it is categorized into two forms, such as normal humidity ($<= 65\%$) and high (>65%).

The WASH variable is the proportion of the condition of water source, latrines and hand washing facilities in households per year. Variables of water sources are categorized into improved or unimproved water sources, as well as latrine facilities. While, hand washing facilities are categorized as having facilities or no facilities. Then these variables were analyzed to see the relationship with the incidence of diarrhea in children under five.

The number of diarrhea cases per month was analyzed by calculating the average cases per year in each district/city, without being categorized.

2.5 Data Analysis

The data is analysis using comparative and relationship analysis. Comparative analysis aims to compare one or more variables for different samples, while relationship analysis is for finding association between one variable and another. This study uses two types of statistical analysis to see the relationship between variables. The first is an independent sample t-test to determine the difference between the two groups of variables, which is humidity in association with diarrhea. The second is analysis of variance (ANOVA) to compare the mean of more than two sample groups, which are temperature and rainfall in relation to diarrhea. These two types of tests were chosen because considering the size

of the data with an area coverage throughout Indonesia. By making categorization can simplify the process of statistical analysis. Data processing is undertaken using SPPS for Windows version 17.

3 Results

The distribution of diarrhea in each district in Indonesia shows that highest diarrheal cases was in Java, which is the island with the highest population in Indonesia, and also has high population density. The complexity of activities in densely populated areas will also affect the quality of the environment in the area. Apart from the number population, cases of diarrhea outside Java may show high numbers but not supported by available data, so that the picture seen in cases of diarrhea is very low in some areas (Fig. 1).

Cases of diarrhea in under five are described as tending to decrease during the period from January to December (Fig. 2). While climatic factors such as humidity, temperature and rainfall have their own patterns. Temperatures in Indonesia tend to be constant throughout the year, while rainfall fluctuates until it reaches a peak at the end of the year. A similar pattern occurs in humidity where the peak is in January-February and December. Humidity is lowest read in September, while rainfall reaches its lowest point in August (Fig. 3).

Figure 4 illustrates the relationship between drinking water sources and cases of childhood diarrhea. The proportion of unimproved drinking water sources decreased followed by a decrease in diarrhea cases in children under five. Poor sanitation conditions are indicated by the large proportion of unimproved latrines in accordance with the high cases of diarrhea (Fig. 5).

Regarding the availability of hand washing facilities, cases of diarrhea in children decreased along with the availability of hand washing facilities complete with soap and water (Fig. 6).

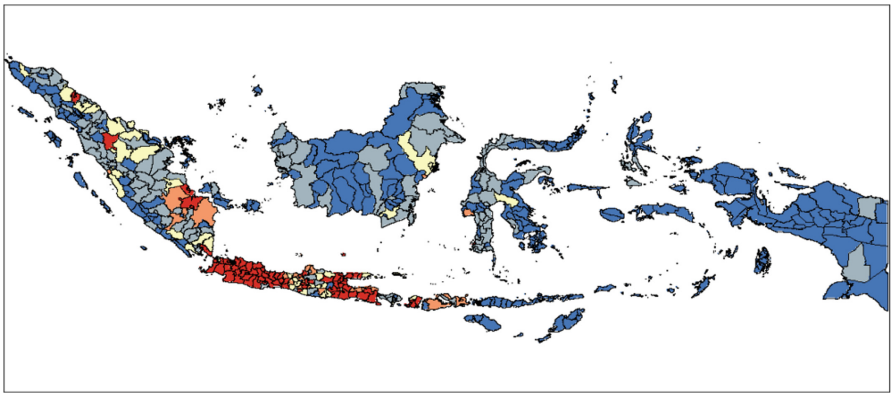

Fig. 1. The distribution of the number of diarrhea cases in under five in 2018–2020

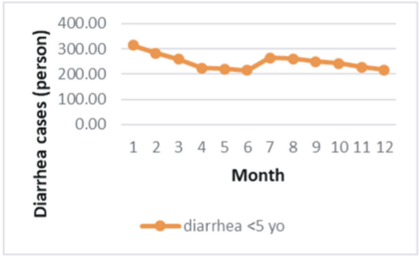

Fig. 2. Trends in under five's diarrhea cases January-December, 2018–2020

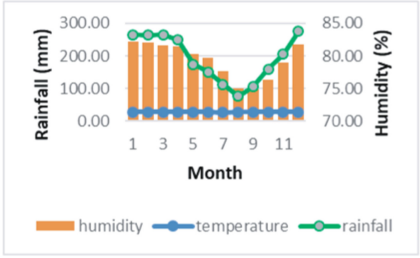

Fig. 3. Temperature, rainfall and humidity trends January-December, 2018–2020

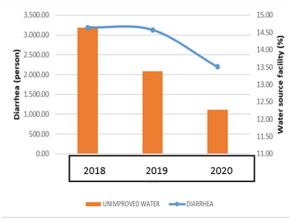

Fig. 4. The trend of children diarrhea towards unimproved drinking water sources in 2018–2020

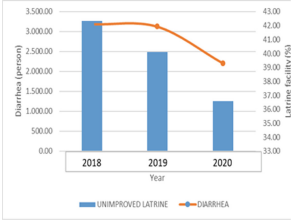

Fig. 5. The trend of children diarrhea towards unimproved latrines in 2018–2020

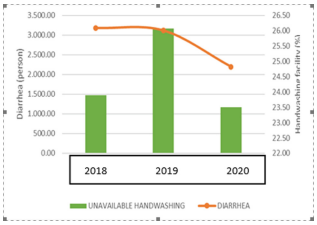

Fig. 6. The trend of children diarrhea to the availability of handwashing in 2018–2020

Furthermore, statistical testing of climate components and diarrheal diseases in children under five years was carried out, with the following results. The results of the analysis showed that there was a difference in the average number of diarrhea cases between normal and low temperatures, as well as low and high temperatures.

Statistically, rainfall has a relationship with the incidence of diarrhea in children under five years. It can be seen there are differences in the average cases of diarrhea between areas with low and moderate rainfall, and also between low and high rainfall.

The same pattern can also be seen in areas with normal humidity and high humidity (Tables 1 and 2).

In general, it was found there were differences in the number of cases of diarrhea in children under five years based on climate variability and conditions of water, sanitation and hygiene in Indonesia. Diarrhea cases tend to decrease, followed by a decrease in the coverage of unimproved drinking water sources, unimproved latrines and the availability of hand washing facilities. There is a positive relationship between cases of childhood diarrhea and climate variations, as well as a similar pattern to WASH conditions in the household.

Table 1. Anova test results in the average case of children diarrhea according to air temperature and rainfall

Climate variables	Category	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Temperature						
Low	Normal	−169.612*	30.087	.000	−241.65	−97.58
	High	−184.662*	28.718	.000	−253.42	−115.91
Normal	Low	169.612*	30.087	.000	97.58	241.65
	High	−15.050	10.206	.421	−39.48	9.38
Rainfall						
Low	Moderate	95.527*	7.339	.000	76.16	114.89
	High	93.591*	9.321	.000	69.00	118.19
	Very high	9.075	16.437	1.000	−34.29	52.45
Moderate	High	−1.936	8.916	1.000	−25.46	21.59
	Very high	−86.452*	16.211	.000	−129.22	−43.68
High	Very high	−84.516*	17.199	.000	−129.90	−39.13

*. The mean difference is significant at the 0.05 level.

Table 2. The results of the t-test differed in the average cases of children diarrhea according to relative humidity

	Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	321.080	.000	19.514	17141	.000	329.468	16.884	296.373	362.562
Equal variances not assumed			11.764	648.076	.000	329.468	28.007	274.473	384.462

4 Discussion

This study is one of the few epidemiological studies conducted in Indonesia uses the national disease surveillance dataset and the household WASH facility survey to measure the association between childhood diarrhea, climate variability and water, sanitation and hygiene (WASH) conditions. Our research findings show that distribution of diarrhea in

children under five years of age in Indonesia is related to climate variability and WASH conditions.

We assume that increases in temperature and rainfall are likely to increase the burden of childhood diarrhea in Indonesia. While the decline in the quality of water sources, latrines and hand washing facilities are followed by the increase of childhood diarrhea as well.

From the results of statistical analysis, it is known that temperature changes are related to cases of diarrhea. Several plausible explanations have been put forward to explain the underlying mechanism influencing the relationship between increased temperature and diarrhea transmission. Studies by Levy and Konkel describe that diarrheal pathogenic bacteria such as Shigella, spp. Has reported to express a virulent gene encoding a toxin in inflammation intestinal lining resulting in fluid loss in response to increased temperature from 30 °C to 37 °C [25].

These findings are in line with studies in Nepal that reported a correlation between the incidence of diarrhea cases and temperature [12]. Likewise, in Botswana, Africa, rising temperatures and rainfall are thought to be positively correlated with the incidence of diarrhea [11]. A significant increased risk of diarrheal disease in Gaza - Palestine is related to temperatures where diarrhea cases increase by more than 10% below the global warming level of 20 °C [9]. The incidence of the highest cases of diarrhea in the dry season shows an average increase of 20% in a year [7, 10]. This increase in temperature also results in deposition in water sources which ultimately worsens vulnerability and decreases the resilience of people in low-income countries. This will greatly affect access to safe, reliable drinking water, and basic sanitation. Therefore, a combined approach to human and environmental systems and engineering is needed to increase the resilience of communities in developing countries [6]. Mellor's findings were supported later by Bressler who stated that there is a need for income-based adaptation because with increased income, the community is able to reduce the adverse effects of climate change [2].

The rainfall pattern in Indonesia tends to be high in December and reaches its lowest point in August. While the most cases of diarrhea occur in January. Statistical analysis shows a link between rainfall and the incidence of diarrhea in children. This may be explained by the fact that in Dhaka, Nepal, it has been reported experienced several diarrheal epidemics during flood episodes caused by excessive rainfall. Floods can cause contamination of water sources with pathogenic bacteria, causing higher incidence of diarrhea during heavy rain events [25]. The content phenomenon is in line with the results of a study in Botswana that found that the incidence of diarrhea cases appeared with a bimodal cycle pattern with peaks in March and October in the rainy and dry seasons respectively [11]. On the contrary, the findings of Hajat conveyed an increase in diarrhea cases when there was a decrease in rainfall [9]. Kraay's study presented the results of a systematic review indicating that the effect of rainfall on diarrhea depends on conditions before extreme rain. If precipitation falls after a dry period, it can flush pathogenic bacteria into surface water, thereby increasing the incidence of diarrhea, while rainfall that occurs after a wet period can dilute the concentration of pathogens in surface water, thereby reducing the incidence of diarrhea. The study found that the influence of precipitation depends on previous conditions. Their study also found that

diarrhea caused by bacteria will increase in the rainy season, but on the contrary diarrhea caused by rotavirus actually decreases in the rainy season [26]. Patterns of heavy rainfall that increase the incidence of diarrhea were also recorded through study reports in Ecuador, which occur in dense urban areas. Projected increased variability of heavy rainfall could increase the burden of diarrhea in urban areas, which are growing rapidly globally [27]. In the future studies are needed that use clear exposure standards and variables to strengthen understanding of the relationship between rainfall and diarrheal diseases.

Some studies suggest the consistency of association between low relative humidity and diarrhea cases. There is a strong negative correlation of humidity with diarrhea incidence. Sumi in Wang's paper found that humidity had an inverse linear relationship with the number of cases of rotavirus diarrhea. A laboratory study showed that humidity of less than 50% was favorable for rotavirus survival, whereas increasing relative humidity to 80% resulted in rapid loss of rotavirus infectivity [28]. Humidity in Indonesia is highest in January-February, where there are also the most cases of diarrhea. The results of the statistical test also showed a relationship with cases of childhood diarrhea. This fact is similar to a study in South Africa [29]. Similarly, studies in Bangladesh report that higher humidity correlates with higher numbers of malaria and diarrhea cases [30].

The results of the analysis of this study showed that the decrease in the incidence of diarrhea in under five was in line with a decrease in the quality of unimproved drinking water sources. This is in line with other studies that report that at the household level, piped water is significantly associated with the prevalence of diarrhea, although it has no direct effect at the community level [21]. Sources of drinking water contaminated with bacteria or viruses can cause diarrheal diseases [26]. Therefore, the availability of a decent source of drinking water is very important in reducing the risk of diarrhea [19]. The World Health Organization (WHO) together with UNICEF has created a joint monitoring program for water, sanitation and hygienic facilities, where for a decent source of drinking water is a source of water which has the potential to provide safe water. To meet the criteria for safely managed drinking water services, households must use better sources that are accessible on-site, available when needed, and free from contamination [31]. Therefore, improving safe drinking water source facilities is the basis for improving people's living standards [32].

The results of the analysis showed that the incidence of childhood diarrhea decreased along with a decrease in the proportion of unimproved latrines. Studies that support this fact are from Komarulzaman et al. which describes an increase in sanitary coverage associated with a lower prevalence of diarrhea in the community [21]. An improved latrine facilities affect the incidence of diarrhea in children. For this reason, the provision of proper defecation facilities is important to be considered [33]. In Indonesia, the Community-Based Total Sanitation (STBM) program has long been implemented in an effort to provide adequate drinking water and sanitation facilities through increasing public awareness so that they are more concerned about the environment. One of the pillars of STBM is to achieve public awareness not to defecate indiscriminately, which can pollute the environment [34].

The trend of diarrhea for children under five tends to decrease in the last 2 years (2019–2020) along with a decrease in the unavailability of handwashing facilities. This is in line with the results of a Western Ethiopian study that reported that the availability of handwashing facilities around latrines and handwashing practices had an influence on the occurrence of diarrhea [35]. This is slightly different from a study in Laos that found no influence on the availability of handwashing facilities with diarrhea, but instead found that the incidence of diarrhea was related to washing hands only with water without soap [36]. Therefore, it is important to provide education about personal hygiene and proper hand washing with flowing water and soap, in addition to providing proper the facilities. By the STBM approach, the community is expected to be more aware of the importance of sanitation and hygiene and become a daily habit.

The limitation of this study is it cannot distinguish cases of diarrhea with a diagnosis based on laboratory results or only symptoms. Nor can diarrhea be experienced repeatedly in the same person. In addition, there is no information about the cause of diarrhea (bacteria or rotavirus). There is also no more specific description of the time period for climate variables. Likewise, for water, sanitation and hand washing based on existing data without direct observation in the field to get more accurate results.

5 Conclusion

In conclusion, climatic factors such as temperature, rainfall and humidity have a relationship with the incidence of diarrhea in children under 5 years. Diarrhea cases tend to decrease, followed by a decrease in the coverage of inadequate drinking water sources, inadequate latrines and the unavailability of hand washing facilities. As climate change continues, relevant public health intervention strategies that consider climate variability should be developed, such as, an early warning system based on accurate and real-time weather forecasts, adequately provision of drinking water, latrines and hand washing facilities, public health education to increase public awareness of seasonal epidemiological patterns and appropriately hygienic behavior, will be effective in enabling communities to better prepared for health risks related to climate change as well as maintain the availability of WASH facilities to reduce diarrhea cases.

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