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Climate Variability and Its Impact on Acute Respiratory Infections: A Case Study from Semarang, Indonesia

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Abstract
This study aims to analyze the relationship between climate variability and acute respiratory infection (ARI) cases in Semarang City over the period 2015-2023. This issue is becoming increasingly relevant as climate change continues to influence weather patterns and environmental conditions, potentially affecting public health outcomes, particularly respiratory health. Method: The research method used is descriptive observational with an ecological study approach according to time which aims to see climate variability with ARI cases. Analyses were conducted to test the correlation between ARI cases and various climatic parameters, so as to obtain a comprehensive understanding of climatic factors that can affect the incidence of ARI. Results: The results of univariate analysis showed that during the period 2015 - 2023 the average ARI cases amounted to 9,815 cases / month, the average temperature was 28.31˚C, the average humidity was 73.49%, the average rainfall was 12.52 mm / month, the average length of sunshine was 7.42 hours, and the average wind speed was 2.55 km / hour. The correlation test results show that, maximum temperature (p = 0.002), average temperature (p = 0.003), average humidity (p = 0.008), wind direction with maximum speed (p = 0.000) have a significant relationship with ARI cases in Semarang City. While the average rainfall parameter (p = 0.681) and the length of sunshine parameter (p = 0.752) have no relationship with ARI cases in Semarang City in 2015 – 2023. Conclusion: Maximum temperature parameter, average temperature parameter, average humidity parameter, and wind direction parameter at maximum speed have a significant relationship with ARI cases. Promotive and preventive efforts need to be made to reduce the risk of ARI transmission, especially at the turn of the season and the density of activities carried out in the community.

Keywords: climate, acute respiratory infections, environment, respiratory health

INTRODUCTION

ARI or acute respiratory infection is a series of symptoms such as cough, runny nose, sore throat, dizziness, and sometimes fever. ARI can occur in mild to severe conditions. In worse conditions, a person can develop bronchitis and pneumonia (inflammation of the lungs). ARI is a priority public health problem because it is potentially the leading cause of infectious disease morbidity and mortality worldwide with 18.8 billion cases and 4 million deaths each year[1,2] . Globally ARI contributes significantly to mortality with an estimated 2.18 million deaths occurring in 2021[3] . The disease can be

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found in all regions of the world, from developed to developing countries. In the United States, it is estimated that 12% of deaths in 2020 were caused by ARI and it is the fourth leading cause of death in all age groups[4].

In the Southeast Asian region, Indonesia is one of the countries with the highest cases and number of deaths due to ARI besides the Philippines, Myanmar, Vietnam, Laos, and Cambodia. For vulnerable groups such as children, acute respiratory infections (ARI) account for 6% of the total burden of disease which is higher than diarrhea, cancer, HIV, heart disease or malaria. Each year more than 12 million children under 5 years suffer from ARI[5] , and 70% of ARI-related deaths occur in Africa and Southeast Asia[6] . Environmental, familial, socio-economic factors, air pollution levels, macro-micro nutrition, cultural issues and access to basic health services may explain the incidence and prevalence of ARI in developing countries[7] .

Based on Basic Health Research (Riskesdas) 2018, the prevalence of ARI according to the diagnosis of health workers (doctors, midwives or nurses) and symptoms experienced was 9.3 percent. This disease is an acute respiratory infection with symptoms of fever, cough for less than 2 weeks, runny nose / nasal congestion and / or sore throat. According to the Ministry of Health (MoH) in 2018, the 10 provinces with the highest ARI sufferers in Indonesia are East Nusa Tenggara (NTT) at 15.4 percent, Papua at 13.1%, West Papua 12.3%, Banten 11.9%, Bengkulu 11.8%, West Nusa Tenggara (NTB) 11.7%, West Java 11.2%, Bali 9.7%, Gorontalo 9.7%, and East Java 9.5%. Meanwhile, the least ARI sufferers are in Jambi at 5.5% [8]

Data from the Semarang City Health Profile shows that ARI cases in the last 5 years have experienced an increasing trend and are always included in the top 10 ranking of diseases from Puskesmas services. In 2023, ARI cases in Semarang City ranked first in the morbidity data of diseases from all Puskesmas services totaling 1,564,308 cases [9].

Many factors contribute to the incidence of ARI disease. The environment is one of the determinants of disease occurrence[6]. In recent decades, there has been significant climate change. These changes will also affect the likelihood of ARI disease occurrence[10].

Based on the above background, researchers are interested in conducting research with the aim of knowing the relationship between climate variability and ARI disease cases in Semarang City.

METHOD

The research method used is descriptive observational with a time-based ecological study approach that aims to look at climate variability with ARI cases. ARI case data came from the morbidity report of the Semarang City Management Information System of Public Health Center (SIMPUS) daily from 2015 - 2023, and climate data came from the Ahmad Yani station of the Meteorology Climatology Geophysics Agency (BMKG) through the dataonline.bmkg.go.id page. The climate parameters studied include minimum temperature (°C) which is the lowest temperature recorded in a day, maximum temperature (°C) which is the highest temperature recorded in a day, average temperature (°C) which

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is the average of the minimum and maximum temperatures recorded in a day, average humidity (%) which is the percentage of average air humidity recorded in a day, average Rainfall (mm): the average amount of rainfall recorded in a day, length of sunshine (hours) the number of hours of sunshine recorded in a day, maximum wind speed (km/h) the highest speed of wind recorded in a day, wind direction at Maximum Speed (degrees): The direction from which the wind is blowing when it reaches its maximum speed, average wind speed (km/h) is the average speed of the wind recorded in a day.

Univariate, bivariate, and multivariate analyses were implemented during data analysis. Univariate analysis was conducted to determine the description of each variable. Bivariate and multivariate analysis used the backward regression test method. The backward regression method is used to build a regression model to determine the climate variables that have the most influence on ARI cases. This method starts by including all predictor variables into the regression model and then removing statistically insignificant variables one by one. This process continues until statistically significant variables remain in the model. The result of this method is to assess whether there is a relationship between two variables. If $p<0.05$, there is a significant relationship between two variables and test the correlation, if the value is 1, the correlation relationship is strong and the relationship is unidirectional if the correlation coefficient is positive or the relationship is opposite if the correlation coefficient is negative[8]. The test model was used to determine whether climate variability jointly affects ARI cases in Semarang City.

RESULT & DISCUSSION

The data indicated that the mean monthly ARI cases from 2015 to 2023 totaled 88,332, with the highest cumulative incidence occurring in March at 108,917 cases. A substantial surge of 26,021 instances occurred in November 2022. The minimum number of ARI cases was recorded in October 2020, totaling 2,808 cases.

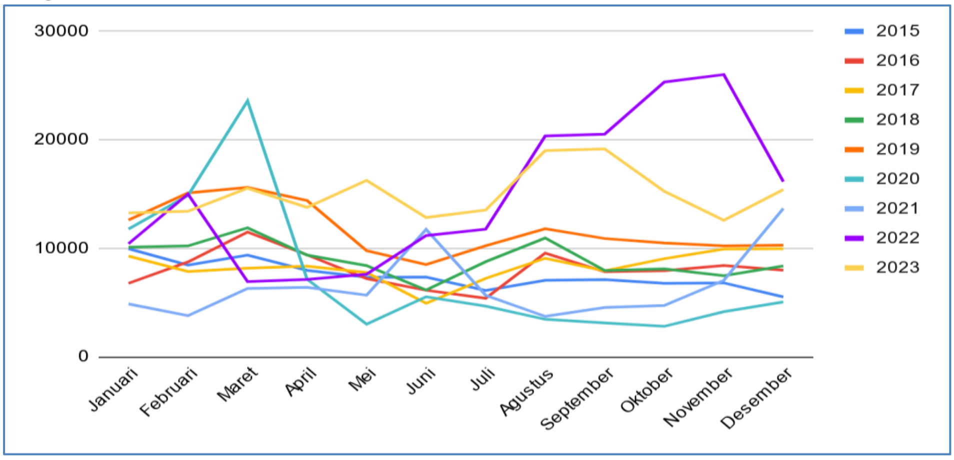

Figure 1. ARI cases in 2015-2023

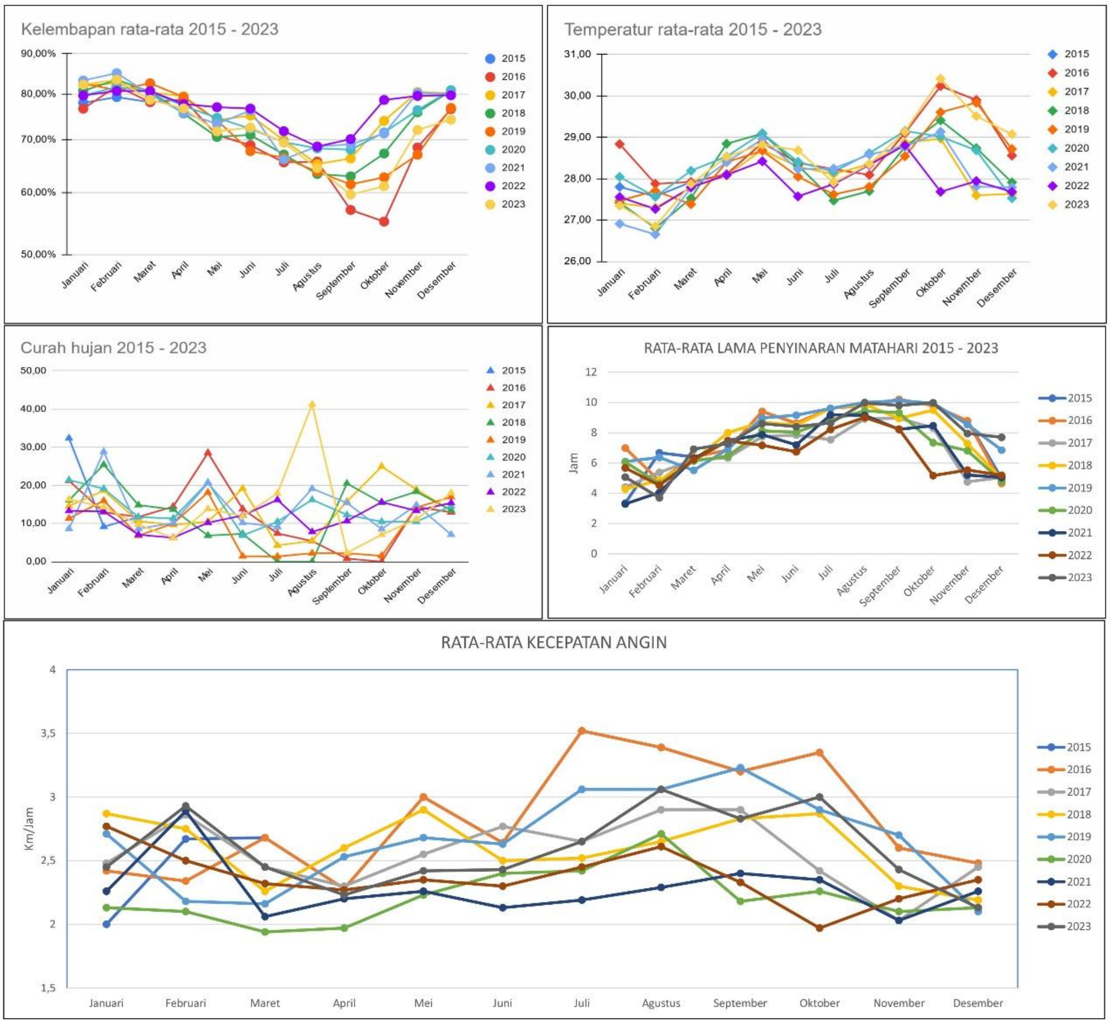

Figure 2. Average climatic conditions of Semarang city 2015-2023

The average climatic conditions in Semarang City from 2015 to 2023 significantly impact environmental factors that may induce Acute Respiratory Infections (ARI). The mean humidity is 73.49%, peaking at 85.07% in February 2021 and to a nadir of 55.10% in October 2015. Elevated humidity levels generally augment the likelihood of respiratory illnesses. The mean air temperature was documented as 28.31˚C, with the peak temperature occurring in October 2023 (30.41˚C) and the minimum in February 2021 (26.65˚C). Reduced temperatures are frequently linked to a compromised immune system, facilitating the rapid proliferation of infections. Rainfall averages 12.52 mm per month, peaking at 41.20 mm in August 2023, with instances of no precipitation occurring in July and August 2018.

High rainfall contributes to increased humidity which is favorable for the spread of ARI-causing microorganisms. The average length of sunshine was 7.42 hours per day, with the highest intensity in September 2015 (10.21 hours) and the lowest in January 2021 (3.3 hours). Low sunlight intensity reduces the antibacterial effect of UV rays, thus increasing the potential for disease spread. The average wind speed during this period was 2.55 km/h, with a peak in July 2016 (3.52 km/h) and a low in October 2022 (1.97 km/h). High wind speeds can help disperse airborne particles and pollutants, affecting air quality and respiratory health. By understanding these climate patterns, early warnings and appropriate preventive measures can be taken to reduce the impact of ARI in Semarang City.

Backward Regression Analysis

The results of the backward regression analysis show how each climate variable affects the number of ARI cases. The following table 1 shows the backward regression results consisting of six stepwise models.

TABLE 1. Backward Regression Analysis Results

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-61620,517	52957,987		-1,164	0,247
	Minimum temperature	3,349	23,17	0,046	0,145	0,885
	Maximum temperature	43,692	15,678	1,307	2,787	0,006
	Average temperature	-41,264	30,317	-0,67	-1,361	0,177
	Average humidity	4,404	2,903	0,679	1,517	0,133
	Average Rainfall	0,274	0,661	0,043	0,415	0,679
	Length of sunshine	1,956	6,162	0,079	0,317	0,752
	Maximum wind speed	-9,061	11,635	-0,145	-0,779	0,438
	Wind direction at maximum speed	0,37	0,103	0,494	3,604	0,000
	Average wind speed	-0,02	27,08	0	-0,001	0,999
2	(Constant)	-61637,806	47329,137		-1,302	0,196
	Minimum temperature	3,346	22,751	0,046	0,147	0,883
	Maximum temperature	43,694	15,28	1,307	2,86	0,005
	Average temperature	-41,261	29,785	-0,67	-1,385	0,169
	Average humidity	4,405	2,669	0,679	1,65	0,102
	Average Rainfall	0,274	0,653	0,043	0,42	0,675
	Length of sunshine	1,955	5,922	0,079	0,33	0,742
	Maximum wind speed	-9,068	7,018	-0,145	-1,292	0,199
	Wind direction at maximum speed	0,37	0,098	0,494	3,777	0,000
3	(Constant)	-63374,807	45607,44		-1,39	0,168
	Maximum temperature	42,825	14,023	1,281	3,054	0,003
	Average temperature	-37,234	11,669	-0,605	-3,191	0,002
	Average humidity	4,612	2,255	0,711	2,045	0,043
	Average Rainfall	0,265	0,647	0,041	0,409	0,683
	Length of sunshine	1,85	5,85	0,075	0,316	0,752
	Maximum wind speed	-8,939	6,929	-0,143	-1,29	0,2
	Wind direction at maximum speed	0,368	0,097	0,492	3,813	0,000
4	(Constant)	-62377,991	45295,204		-1,377	0,172
	Maximum temperature	43,641	13,722	1,306	3,18	0,002
	Average temperature	-37,309	11,614	-0,606	-3,212	0,002
	Average humidity	4,363	2,104	0,672	2,074	0,041
	Average Rainfall	0,265	0,644	0,041	0,412	0,681
	Maximum wind speed	-8,951	6,898	-0,143	-1,298	0,197
	Wind direction at maximum speed	0,357	0,09	0,477	3,982	0,000
5	(Constant)	-64022,647	44934,729		-1,425	0,157
	Maximum temperature	43,238	13,632	1,294	3,172	0,002
	Average temperature	-36,438	11,374	-0,592	-3,204	0,002
	Average humidity	4,481	2,075	0,69	2,159	0,033
	Maximum wind speed	-8,826	6,863	-0,141	-1,286	0,201
	Wind direction at maximum speed	0,352	0,088	0,47	3,98	0,000

6	(Constant)	-83109,959	42547,577		-1,953	0,053
	Maximum temperature	44,378	13,646	1,328	3,252	0,002
	Average temperature	-34,746	11,333	-0,564	-3,066	0,003
	Average humidity	5,32	1,977	0,82	2,691	0,008
	Wind direction at maximum speed	0,302	0,08	0,404	3,788	0,000

The results of the backward regression analysis showed a significant influence of several climate variables on the number of ARI cases in Semarang City. The regression model is organized in six stepwise stages as listed in Table 1. In Model 1, the maximum temperature variable showed the highest beta coefficient with a significant value (Sig. = 0.006), followed by wind direction at maximum speed which was also significant (Sig. = 0.000). In Model 6, variables such as maximum temperature, average temperature, average humidity, and wind direction at maximum speed continued to show significance, with wind direction showing the strongest influence (Sig. = 0.000).

Model Summary

The model summary results provide an overview of how well the regression models built together explain the variation in ARI case data. The following is a discussion of the model summary results of the six stepwise models

Table 2. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.438a	192	118	433.243.244
2	.438b	192	127	431.049.595
3	.438c	192	135	428.935.793
4	.437d	191	143	427.020.411
5	.435e	190	150	425.278.563
6	.420f	176	144	426.626.771

TABLE 3. Model Summary

	R	R Square	Adjusted R Square	Std. Error of the Estimate
Maximum temperature	103	.011	.001	460.967.414
Average temperature	147	.022	.012	458.391.879
Average humidity	137	.019	.010	459.044.486
Wind direction at maximum speed	291	.085	.076	443.297.709

Based on Table 2, the R Square value in each model indicates the proportion of variation in ARI cases that can be explained by climate variables. Model 1 to Model 6 gradually simplified the predictors without significantly reducing the explanatory power of the model, with Model 6 achieving an R Square value of 0.176 and an Adjusted R Square of 0.144. The smaller standard errors from Model 1 to Model 5 indicate an increase in the accuracy of the model in predicting ARI cases, although in Model 6 there is a slight increase in the standard error. Furthermore, Table 3 shows the individual effect of each climate variable, where wind direction at maximum speed has the highest Adjusted R Square value of 0.076, indicating a greater contribution in explaining the variability of ARI cases than other variables. Maximum temperature, average temperature and average humidity also had an effect, albeit with a lower contribution. Climate change affects respiratory health directly through increased exposure to environmental risk factors and worsening of respiratory disease conditions[11] . These results emphasize the important role of climate fluctuations in triggering ARI cases, especially in relation to variations in temperature, humidity and wind conditions. This understanding could potentially help in the development of mitigation policies and early warning systems for ARI control in Semarang City.

[11] Cheong et al.

Analysis of the Relationship Between Climate and ARI Cases in Semarang City

Analysis showed a significant relationship between climate variables and ARI cases in Semarang City. An increase in maximum temperature was significantly positively correlated with an increase in ARI cases (p = 0.002), suggesting that high temperatures can worsen respiratory health due to degraded air quality, increased pollutants, and heat stress that weakens the immune system. This is in line with a 2021 Unicef study showing that poor air quality is associated with increased cases of respiratory diseases, including ARI[10]. In addition, hot weather can lead to dehydration and heat stress which weakens the immune system, making individuals more susceptible to infections and Masiero's study that extreme temperatures are closely associated with increased mortality and morbidity, especially in respiratory diseases.[12] .

The findings of another study also showed that low temperature was associated with the risk of ARI cases[13] . Meanwhile, the average temperature showed a negative correlation with ARI cases (p = 0.002), where low temperatures increase the risk of respiratory infections, especially in urban environments with high pollution levels, as supported by Morabito's study which examined Air temperature exposure and outdoor occupational injuries: a significant cold effect in Central Italy. In the study, it was found that exposure to low temperatures was significantly associated with increased respiratory symptoms in urban areas[13]. This suggests that low temperatures can affect respiratory health, especially in urban environments where factors such as air pollution can exacerbate conditions. Respiratory diseases are a major contributor to morbidity and mortality rates globally, with ambient temperature shown to be an environmental factor that plays a significant role in increasing the risk.[14]

Average humidity also has a significant effect (p = 0.008), with ARI cases in Semarang City having a positive pattern, meaning that an increase in average humidity is also associated with an increase in ARI cases. This result is in line with several studies on the potential impact of humidity on ARI disease[15] , and more potentially in the case of infants and children[16] . According to the Minister of Health Regulation No. 1077 of 2011, good air humidity ranges from 40 - 70%. Conditions outside the optimal range of 40-60% can have a significant impact on health, including facilitating the transmission of infections and exacerbating respiratory diseases[17] . In the case of children, humidity in the home affects the incidence of ARI. Humidity in the home environment has a 5-fold risk of causing ARI in toddlers (OR=5.00; 95% CI 0.79-31.51)[18] . The higher the humidity, the greater the potential for dust to clump, allowing it to settle and fall to the ground under the influence of gravity[18].

If high humidity leads to high contact transmission of influenza and viral respiratory diseases, this will clearly have implications for the future burden of disease[19] . Respiratory diseases also affect vulnerable groups, especially infants, toddlers and the elderly, especially for those who live in homes with inadequate humidity, providing a greater chance of disease than living in homes with adequate

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humidity[20] . Understanding the impact of humidity on respiratory health, allergies and the immune system is necessary to develop effective prevention measures and public health policies .[21]

Wind Direction at Maximum Speed has a significant influence on ARI cases with a positive pattern, meaning that any increase in the wind direction at maximum speed parameter is associated with an increase in ARI cases. Temperature, humidity, and extreme weather events have been shown to have a significant relationship with increased incidence of respiratory infections[22] . Concentration of pollutants from the source is continuously related to wind speed. The higher the wind speed, the greater the dispersion of air pollutant particles or molecules so that the concentration is smaller. Strong winds are weakly turbulent so that the concentration of contaminants becomes concentrated[23].

This is also in line with the results of research conducted in the city of Banjarmasin, which concluded that monthly air temperature and wind speed direction are associated with the incidence of ARI[24] . Although this is different from the results of research also conducted in the same city but a different time period that wind direction does not significantly affect ARI cases .[25]

CONCLUSION

Variability in climate parameters such as maximum temperature, average temperature, average humidity, and wind direction at maximum speed have a significant influence on the number of ARI cases in Semarang City from 2015 to 2023. Maximum temperature shows a positive pattern towards ARI cases, where an increase in temperature is associated with an increase in cases. Average temperature has a negative pattern, indicating that a decrease in temperature also increases ARI cases. High average humidity contributes to an increase in ARI cases, while wind direction at maximum speed plays a role in spreading pollutants that worsen air quality. On the other hand, average rainfall and length of sunshine did not have a significant relationship with ARI cases.

Based on these findings, the Semarang City Health Office is expected to develop promotive and preventive measures, paying attention to climate patterns that have the potential to increase ARI cases each year. Increased public awareness of the importance of prevention and early recognition of ARI symptoms is also needed, especially during seasonal changes and in times of high public activity, to minimize the risk of transmission and impact of respiratory diseases.

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DECLARATION OF CONFLICTING INTERESTS

The authors declare that there is no conflict of interest in this research or the publication of this research.

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