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Correlation study of climate variability, population density, altitude, and low birth-weight rates on the incidence of children pneumonia in Bogor Regency

Ariani[1]*, Ririn Arminsih Wulandari[1]

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[1] Departement of Environmental Health, Faculty of Public Health, Universitas Indonesia, Indonesia

***Correspondence:**
ariani080892@gmail.com

Abstract

Purpose: This study aims to analyze the correlation between climate variability (temperature, humidity, rainfall, sunshine duration, and wind speed), population density, altitude, and low birth weight (LBW) rate on the incidence of under-five years old children pneumonia. **Methods:** This research uses a combination study design based on place and time (mixed design ecological study). **Results:** There was no significant relationship between climate variability and lag effect of 0-2 months with the number of under-five pneumonia cases in Bogor Regency in 2018-2022, as well as the altitude variable (p=0.0619). Meanwhile, the variables of population density (r-value = 0.439) and LBW rate (r-value = 0.338) showed a positive correlation with the number of under-five pneumonia cases in Bogor Regency. **Conclusion:** This research shows the incidence of pneumonia among under-fives in Bogor Regency is influenced by population density and LBW rates. Ensuring access to proper sanitation, a complete basic immunization program, adequate housing, and also personal protective measures is important to reduce the spread of pneumonia.

Keywords: altitude; climate variability; low birth-weight; pneumonia; population density

INTRODUCTION

Pneumonia, an inflammatory condition of the lungs, is a leading cause of death in children, accounting for approximately 1.3 million deaths among children aged <5 years in 2010-2011 [1]. Based on the International Vaccine Access Center's 2020 report, Indonesia is included in the focus list of countries that have a high burden of pneumonia in children under five [2]. The estimated number of under-five pneumonia cases in Indonesia reached 890,151 cases, with a prevalence rate of 3.55% In Indonesia's Health Profile in 2022, pneumonia was the leading cause of death among under-fives (12.5%) [3].

West Java Province is among the top ten largest under-five pneumonia coverage in Indonesia. In 2022, the national coverage of under-five pneumonia in Indonesia is 38.8%, while West Java Province is above Indonesia at 44.9%. The highest cause of death in the under-five age group in West Java Province was pneumonia with 15 cases [3].

Environmental conditions is closely related to the spread of respiratory infections [4]. Environmental factors such as ventilation area, air temperature, lighting, humidity, and population density are associated with pneumonia cases in under-fives. Optimal air temperature would allow bacteria to grow and multiply better [5].

Climate change is known to cause extreme weather events in various regions of the world.

Globally, the average temperature anomalies of land and ocean surfaces continue to increase [6]. In addition, the changing conditions brought about by climate change can increase the risk of transmission of many infectious diseases [7].

Children at the age stage of 1-5 years are in an active period of activity that allows to recognize and explore the surrounding environment [8]. Changes in weather conditions can affect endurance and respiratory health's system. Weather fluctuations can create environmental conditions that support the survival of pathogens such as pneumonia [9]. In addition, adequate sunlight for children is also very beneficial, especially type B ultraviolet as a source of stimulants for vitamin D which functions as a support for the body's immune system [10].

Incidences of pneumonia are likely higher in lowlands because climatic conditions will be influenced by the altitude of the region [11]. Differences in altitude between one region and another can also show differences in temperature between the areas [12]. A study in Fukuoka, Japan stated that every 1^0C increase in average temperature caused an increase in Mycoplasma pneumoniae by about 16.9%. [13]. Later, in a time series ecological study conducted in Korea, it was found that temperature, humidity, and PM2.5 were significantly associated with weekly pneumonia incidence [14].

Low birth weight (LBW) is a significant risk factor for under-five pneumonia due to low immunity and the possibility of lung damage [15]. LBW infants have incomplete organ growth and maturation, making them more prone to complications and infections such as pneumonia and other respiratory diseases. This is in line with research in Bantul showing that there is a relationship between LBW and the incidence of pneumonia [4].

Population is the most fundamental element in the development process. Each year, the population continues to increase, which is accompanied by a growing need for facilities and infrastructure [16] [17]. Population density has a specific relationship with pneumonia in children under five because the transmission speed of disease agents becomes faster when population density is high [18].

Bogor Regency has a population of 5,427,068. This makes Bogor Regency the most populated regency in West Java Province, even in Indonesia [19]. Several subdistricts in Bogor Regency are close to the national capital and areas with high mobility, characterized by the existence of the commuterline and train station [16].

Determining relationship between climate variability, population density, altitude and LBW with area-based pneumonia needs to be investigated to help inform public health strategies and interventions to reduce the burden of pneumonia, especially in vulnerable and at-risk populations. This study not only highlights the relationship between these factors and pneumonia, but also the distribution of pneumonia over five years and the regional characteristics of Bogor district with subdistrict units related to pneumonia.

In addition, spatial analysis was conducted to analyze the distribution patterns of pneumonia disease over five years in Bogor Regency. The presentation of data on mapping format is expected to provide information and develop prevention programs according to areas at risk.

METHODS

This research uses a combination ecological study or mix design consisting of time series ecological studies and spatial analysis with the unit of analysis in the form of groups (multiple groups), so that it can allow to identify how ecological patterns change in space and time [20].

The ecological study design used is a time series with a data span of the last five years from 2018 to 2022 to see the relationship between climate variability with the number of pneumonia cases in children under five years old in Bogor Regency. Spatial analysis of 40 subdistricts (multiple groups) in Bogor District was conducted to see the relationship between population density, altitude, and LBW rate with the number of pneumonia cases in Bogor District in 2022. The variables of the number of pneumonia cases, population density, and LBW rate in the distribution and correlation maps were classified using natural breaks from QGIS Desktop 3.22.15 software.

The data sources are secondary data on the number of pneumonia cases in children under five years of age from 2018 to 2022 obtained from the Bogor District Health Office. Daily climate data was collected through direct access from the website of the Meteorology Climatology and Geophysics Agency (http://dataonline.bmkg.go.id). Data sources for population density, LBW, and altitude were obtained from the Bogor dalam Angka's profile in 2022 (https://bogorkab.bps.go.id).

Data were analyzed using univariate analysis to see the distribution patterns and frequencies of each variable, such as climate variability, population density, altitude, LBW rate, and the incidence of under-five pneumonia cases in Bogor Regency. A

bivariate analysis was then conducted to identify the relationship between climate variability, population density, altitude, and LBW rate with the number of pneumonia cases in Bogor Regency. Spatial analysis using the QGIS Desktop 3.22.15 application for spatial depiction of information with sub-district analysis units in Bogor Regency. In this study, spatial analysis was only conducted on the variables of population density, altitude, and LBW rate in the form of mapping.

This study has been approved by the Ethic Commission for Health Research, Faculty of Public Health, Universitas Indonesia (Ket-124/UN2.F10.D11/PPM.00.02/2024).

RESULTS

Distribution of under-five pneumonia cases

The highest number of pneumonia cases among under-fives occurred in December 2018, with 1,796 cases. While in August 2020 the number of pneumonia cases was the lowest at 356 cases **(Table 1)**. Sukamakmur and Jasinga subdistricts had no pneumonia while Dramaga subdistrict had 592 pneumonia cases among under-fives.

Table 1. Frequency distribution of climate variability, population density, altitude, LBW and pneumonia in Bogor Regency

Variable	Amount	Min-Max	Mean	Median	95% CI	P value
Temperature	60	20.51 - 22.38	21.49	21.46	21.38 - 21.61	0.2
Humidity	60	76.10 - 93.21	85.67	86.67	84.62 - 86.72	0.02*
Rainfall	60	5.80 - 687.10	259.21	244.65	216.74 - 301.69	0.2
Sunshine Duration	60	0.63 - 6.58	3.74	3.74	3.33 - 4.14	0.2
Maximum Wind Speed	60	2.26 - 3.35	2.79	2.77	2.73 - 2.85	0.2
Number of Pneumonia Cases per month 2018-2022	60	356 - 1796	785.32	743	698.77 – 871.86	0.014*
Population Density	40	310 - 10535	2768.25	2226	2027.42 – 3509.08	0.000*
Altitude	40	51 – 789	271.75	183	207.66 – 335.84	0.000*
LBW	40	14 – 116	49.80	49.50	41.91 – 57.69	0.097
Pneumonia Cases in 2022	40	0 - 592	84.33	50	49.63 – 119.02	0.000*

The distribution pattern of pneumonia cases among under-fives from 2018 to 2022 experienced significant fluctuations. In 2018 and 2019, the western part of Bogor Regency had a very high number of under-five pneumonia cases in Sukajaya, Gunung Sindur, and Tenjolayas subdistricts. Then in 2019, the number of very high category pneumonia cases moved to the eastern side, i.e Ciawi and Babakan Madang sub-districts. In the following year, the number of very high cases gradually decreased in only one sub-district, Dramaga sub-district. Although the distribution of very high category cases is decreasing, the number of high category pneumonia cases in 2021-2022 still exists in at least 7 subdistricts in Bogor District **(Figure 1)**.

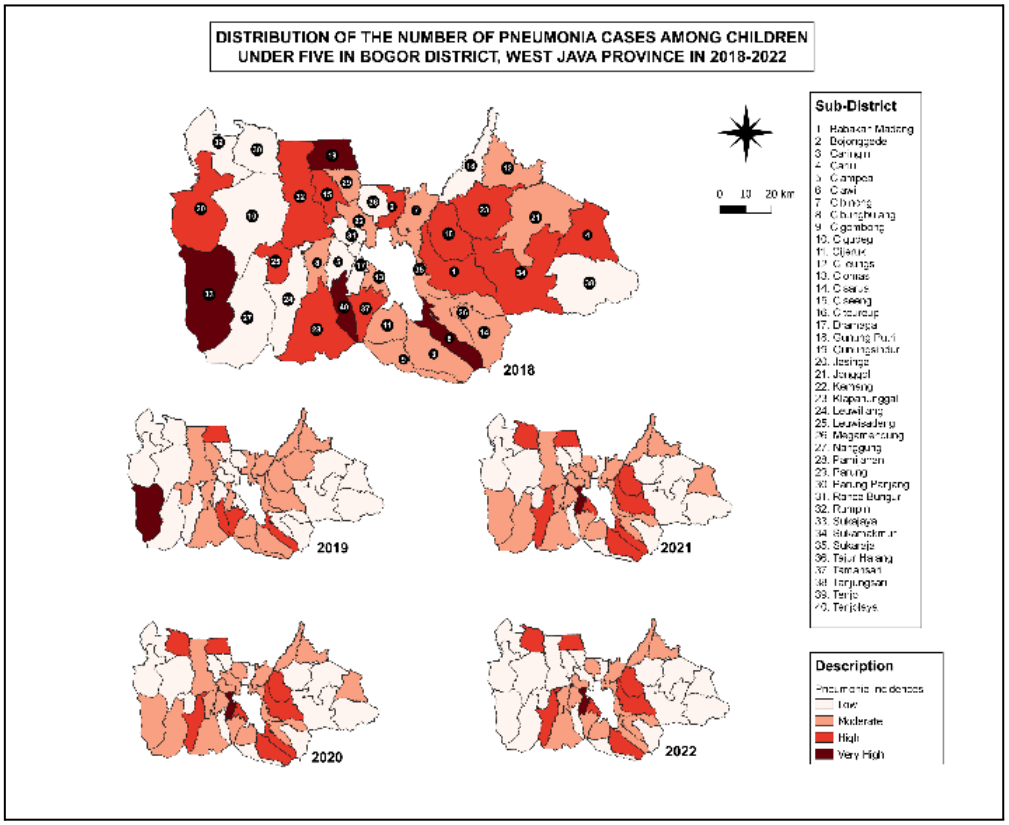


Figure 1. Map of the distribution of the number of pneumonia cases among toddlers in Bogor Regency in 2018-2022.

Climate variability, population density, altitude, low birth-weight and pneumonia in Bogor District

Based on data measured from Citeko climatology station, the average air temperature of Bogor Regency in 2018-2022 is 21.490C with a known maximum temperature of 22.380C and has not changed much **(Figure 2)**. Likewise, the humidity variable has an average of 85.67%, with a maximum humidity of 93.21%. The average wind speed is 2.79 m/s and looks stable in 2021 and 2022 (Table 1) (Figure 2). Overall, rainfall and sunshine duration variables tend to fluctuate. The highest peak of rainfall is seen in every January, while the length of sunshine is highest in September and decreases in January (Figure 2).

Population density is the ratio between the number of residents and the area occupied in an area. The average population density of Bogor Regency in 2022 is 2768.25 people/km2, this figure has increased from 2019 which is 2,293 people/km2. Cariu sub-district has the lowest population density in Bogor district at 310 people/km2. Meanwhile, the highest population density is in Bojonggede sub-district at 10,535 people/km2 (Table 1).

The altitude of the Bogor Regency area is divided into two, the highlands are found in the northern part such as Cisarua Subdistrict which has an altitude of 789 meters above sea level, while the lowlands are found in the southern part, namely Parung Panjang Subdistrict with an altitude of 51 meters above sea level (Table 1).

Based on data from Bogor dalam Angka's profile, Cibinong Sub-district had the highest incidence of LBW in Bogor District in 2022, with 116 cases. Meanwhile, the region with the lowest LBW incidence is Parung Sub-district with 14 cases. The average LBW rate is quite high at 49.80 cases with normally distributed data (Table 1).

Correlation between climate variability and pneumonia cases in Bogor Regency, 2018-2022

The correlation analysis between climate variability and the number of pneumonia cases in children under five years old used 3 lag scenarios. The use of lags also allows pathogens to survive and transmit through contact with surfaces. Therefore, the use of lag in climate variability is necessary.

Based on the correlation statistical test, none of the climate variability was associated with the number of pneumonia cases among under-fives in 2018-2022 in Bogor Regency (p value > 0.05) **(Table 2)**.

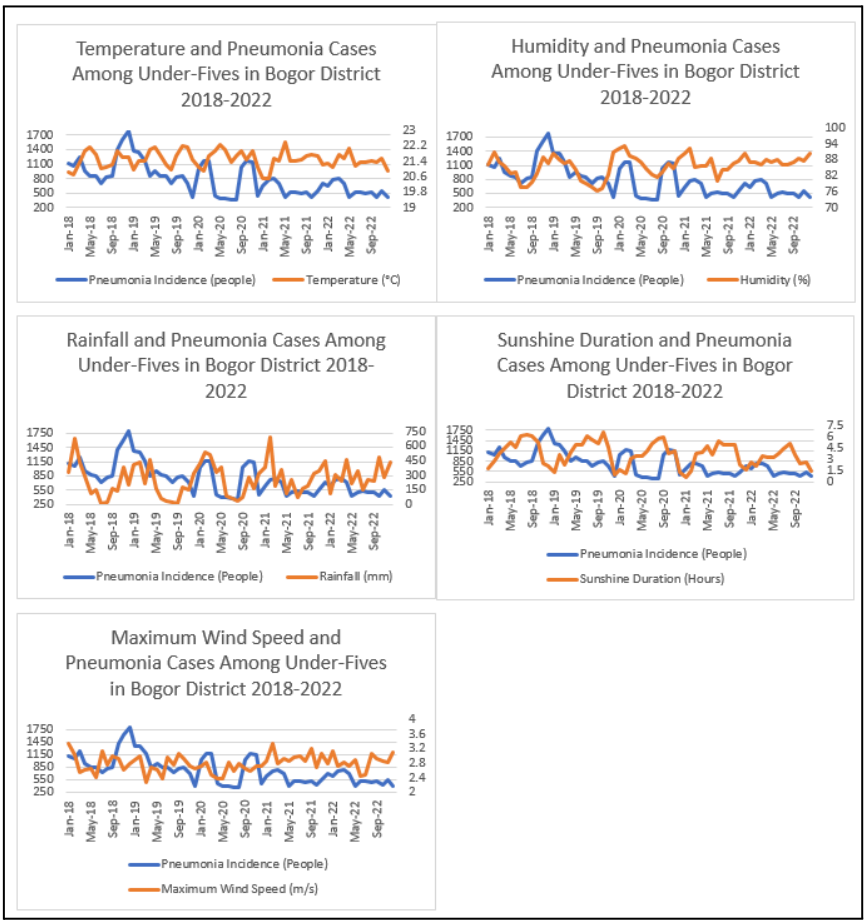


Figure 2. Climate variability and pneumonia cases in Bogor Regency 2018-2022

Table 2. Correlation of climate variability with the pneumonia cases among under fives in Bogor Regency 2018-2022

Variable	Scenario	P Value	Correlation Value (r)	Correlation Strengths
Temperature	*Lag* 0	0.640*	-0.062	Weak
	Lag 1	0.075*	-0.234	Weak
	Lag 2	0.089*	-0.225	Weak
Humidity	*Lag* 0	0.980*	0.003	Weak
	Lag 1	0.641*	0.062	Weak
	Lag 2	0.402*	-0.112	Weak
Rainfall	*Lag* 0	0.328*	0.129	Weak
	Lag 1	0.609*	0.068	Weak
	Lag 2	0.236*	-0.158	Weak
Sunshine Duration	*Lag* 0	0.804*	-0.033	Weak
	Lag 1	0.600*	-0.070	Weak
	Lag 2	0.696*	0.052	Weak
Maximum Wind Speed	*Lag* 0	0.445*	-0.100	Weak
	Lag 1	0.671*	0.056	Weak
	Lag 2	0.861*	0.023	Weak

*not correlated

Table 3. Correlation analysis of population density, altitude, and LBW rates with the number of pneumonia cases in 2022

Variable	P Value	Correlation Value (r)	Correlation Strengths
Population Density	0.005	0.439	Moderate
Altitude	0.619*	0.081	Weak
LBW Rates	0.033	0.338	Moderate

*not correlated

Correlation between population density, altitude, lbw rate with pneumonia cases in Bogor Regency in 2022

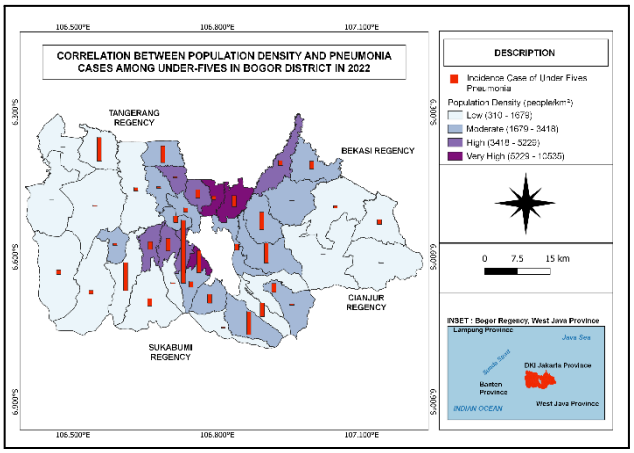
Based on the correlation analysis, the p value is 0.619, so it can be stated that there is no correlation between altitude and the number of pneumonia cases among children under five. Meanwhile, the variables of population density and LBW rate were found to be correlated with the number of pneumonia cases. The p values were 0.439 and 0.338, respectively, indicating a moderate relationship strength with a positive correlation **(Table 3)**. This can be interpreted as the higher the population density and LBW rate, pneumonia cases among under-fives would be greater.

Map of correlation between population density, area altitude, and LBW rate with the number of pneumonia cases in Bogor District in 2022

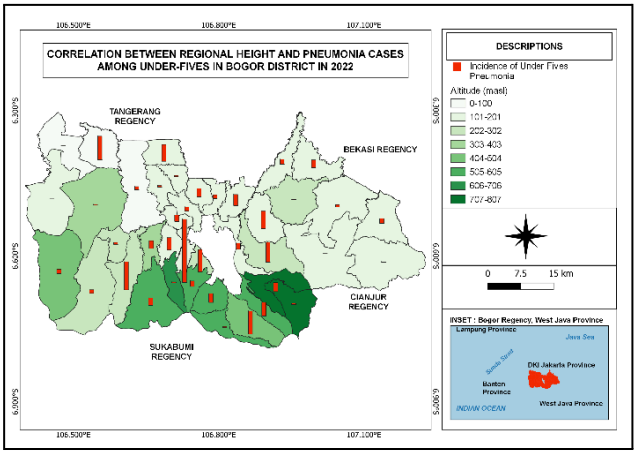
The correlation map shows that subdistricts with low population density tend to have fewer pneumonia cases. Subdistricts such as Jasinga, Sukamakmur, and Tanjungsari that have fewer under-five pneumonia cases show lower population density. Vice versa, the number of under-five pneumonia cases tended to be higher in subdistricts with high and very high population density such as Dramaga and Ciomas **(Figure 3)**.

The correlation between the number of pneumonia cases among under-five children and altitude, as seen in the map, shows an irregular trend. There is a high rate of pneumonia cases in low-altitude subdistricts below 200 meters above sea level, such as Parung Panjang subdistrict. Meanwhile, subdistricts with an altitude of more than 400 meters above sea level, such as Ciawi and Caringin, also show a relatively high number of under-five pneumonia cases (Figure 3).

Some subdistricts with low LBW rates tend to have fewer under-five pneumonia cases on the correlation map. The low LBW rates seen in Tenjolaya, Cigudeg, and Tanjungsari subdistricts are directly proportional to the low number of pneumonia cases. On the contrary, Citeureup sub-district, which has a high LBW rate, also has a high number of under-five pneumonia cases (Figure 3).



(a)



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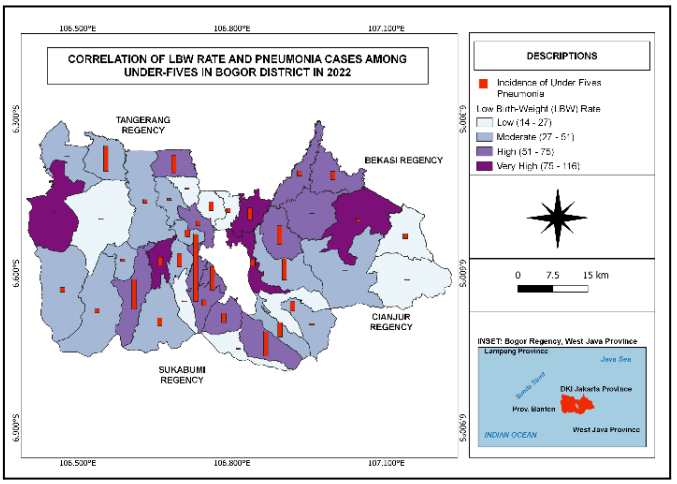

(c)

Figure 3. a) Correlation map between population density map and pneumonia cases in Bogor Regency in 2022; b) Correlation map between altitude area and pneumonia cases in Bogor Regency in 2022; c) Correlation map between lbw and pneumonia cases in Bogor Regency in 2022

DISCUSSION

The number of pneumonia cases among under-fives in Bogor Regency tended to increase during 2018-2022. Environmental factors can affect the immune system of toddlers, one of which is through exposure to climatic factors. Bogor Regency has 40 sub-districts and 435 villages. In terms of climate, Bogor Regency has a wet tropical climate in the north and a very wet tropical climate in the south, with average annual rainfall reaching 3000-3500 mm [21]. The life cycle and incubation of a microorganism are closely related and sensitive to changes in climate variability [22].

Overall, it was found that exposure to climate variability (temperature, rainfall, humidity, wind speed, and length of sunshine) was not associated with pneumonia cases among under-fives in Bogor District, either simultaneously or during the exposure time gap. This finding is consistent with a study conducted in Semarang that there was no significant correlation between temperature and the incidence of pneumonia in children under five [23]. Research in Thailand, which has a similar climate to Indonesia, noted a negative relationship between air temperature in the previous two months and the number of new pneumonia cases [24]. S.pneumoniae bacteria can thrive at temperatures of 21-37^{0}C [25]. Air temperature conditions in Bogor Regency tend to stabilize in the range of 20-22^{0}C so that these conditions are ideal characteristics for bacteria to survive.

In climate variability, several variables influence each other, such as the rainy season period which has an impact on the length of sunlight, temperature, and humidity. Factors that have the potential to cause differences in findings are differences in geographical location, research time span, socio-economic conditions of the population in the region, and demographics such as limited data from climatology stations. Bogor Regency only has one air monitoring station, Citeko Station, which is located in Cisarua District. It could cause bias because Bogor Regency is a quite large area. Citeko Station cannot reach each sub-district area so that it can affect differences in climatic conditions, especially since Cisarua District is a highland area. Differences in altitude can affect climatic conditions, so the incidence of pneumonia in under-fives can be influenced by climatic variations caused by bacteria that are sensitive to fluctuations in air temperature, air humidity, and other condition factors [11].

In the period 2011-2019, the average population growth rate of Bogor Regency was above the average population growth rate of West Java Province [26]. This study found that population density had a significant association with under-five pneumonia in Bogor District. This finding is in line with research in Kebumen Regency, which found a significant relationship between population density and the incidence of pneumonia [18]. Bojonggede and Cibinong subdistricts have the highest population density in Bogor Regency. Population density can affect the speed of transmission of disease agents because houses that are close together can reduce the space for people to move [27]. Population density also affects air circulation in the environment which has the potential for external contamination that can increase the risk and intensity of infection which can accelerate disease transmission [28].

Communicable diseases, including pneumonia, are closely related to sanitation. Therefore, it is necessary to improve sanitation and hygiene such as ensuring access to clean water in each region, proper waste disposal, and handwashing behaviour [29]. Housing is also important to reduce the risk of pneumonia. Ensuring adequate housing conditions such as proper ventilation to mitigate aerosol-based infections. Encouraging physical activity to improve overall physical fitness and providing diverse public facilities within the community to fulfill daily needs should be facilitated by local governments. In high-density communities, optimizing the layout and accessibility of these facilities becomes particularly critical [30].

Findings in Brazil show higher infection rates in large cities than small towns [31]. Therefore, improving access to healthcare services, particularly in underserved areas, can help ensure timely diagnosis and treatment of infectious diseases. As for disease spread control, social distancing and crowd control measured is also important. Promoting remote work, and personal protective measures such as encouraging proper hand hygiene before boarding on public transportation or considering the use of face masks for passengers if physical distancing couldn't be implemend.

Bogor Regency area has varied altitude differences. The results of the correlation analysis in this study showed that altitude did not have a significant relationship with pneumonia cases among under-fives. This is in line with research in Riau Province that there was no difference in pneumonia cases between plains, slopes, and valleys. Air pollution that causes respiratory problems is not only caused by topographical factors, but other factors such as wind speed and direction need to be taken into account [32]. In contrast, this finding is inconsistent with the research in Manado City which showed spatially that toddlers had more pneumonia in low-lying areas compared to areas with medium or high altitude due to lowlands being suitable places for construction activities [11]. However, the prevalence of chronic lung disease (COPD) is lower at high altitudes, but the mortality rate is greater. Patients with COPD have a high risk of respiratory infections including pneumonia. Although living at higher altitudes may protect against disease progression, it may adversely affect mortality when the disease develops [33].

Babies born with low birth weight have deficiencies in the formation of anti-immune substances. As a result, low birth weight infants have a higher risk of complications and infections, particularly pneumonia and other respiratory diseases [34]. This study found a significant relationship between LBW rates and under-five pneumonia cases in Bogor District. Infants with low birth weight (LBW) often face several problems, including ineffective breathing patterns due to delays in respiratory organ development, nutritional imbalances due to the body's inability to absorb properly, the risk of body temperature imbalances, and the risk of infection related to an immature immune system [4]. Government need to promote the importance of complete basic immunization program that could help to reduce the spread and severity of pneumonia [35].

This study has analyzed climate variability within a five-year time span due to the limited data on pneumonia in the past ten years in Bogor Regency. It is important to note that other contributing factors may also be important when considering pneumonia disease management such as socioeconomic factors or individual factors. However, the limitation of the study is that individual data collection has not been possible. The results of this study hopefully could provide an overview and contribute valuable information, as well as practical solution for the stakeholders to reduce the impact of population density on the spread of communicable diseases, especially pneumonia.

CONCLUSION

The incidence of pneumonia among under-fives in Bogor Regency is influenced by population density and LBW rates. Meanwhile, climate variability and altitude do not have a specific relationship with the incidence of pneumonia among under-fives in Bogor Regency. Bogor District Health Office should complete regular pneumonia case records from Puskesmas, hospitals, and other health facilities so that program monitoring and evaluation can be conducted. Cooperation in programs with related stakeholders is also needed to control pneumonia based on sub-district units that have high population density, as well as conduct regular surveillance of LBW infants related to the prevention of respiratory diseases, especially pneumonia. Ensuring access of proper sanitation, complete basic immunization program, adequate housing, and also personal protective measures is important to reduce the spread of pneumonia.

REFERENCES

1. Cheng C-Y, Cheng S-Y, Chen C-C, Pan H-Y, Wu K-H, Cheng F-J (2019) Ambient air pollution is associated with pediatric pneumonia: a time-stratified case–crossover study in an urban area. Environmental Health 18:77
2. IVAC at John Hopkins Bloomberg School of Public Health Pneumonia & Diarrhea Progress Report 2020. Available from: [WEBSITE]
3. Kementerian Kesehatan Republik Indonesia (2023) Profil Kesehatan Indonesia 2022. Jakarta. Available from: [WEBSITE]
4. Ceria I (2016) Hubungan Faktor Risiko Intrinsik Dengan Kejadian Pneumonia Pada Anak Balita. Jurnal Medika Respati.
5. Rahmiza M, . S, . N (2019) The Relationships Between Physical Environmental Conditions of House with Pneumonia Incidence on Children Under Five Years, in the Working Area of Ngesrep Health Centre, Semarang City. KnE Life Sciences 4:324
6. NOOA (2020) State of the Climate: Global Climate Report for Annual 2020. Available from: [WEBSITE]
7. Watts N, Amann M, Arnell N, et al (2021) The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. The Lancet 397:129–170
8. Clark H, Coll-Seck AM, Banerjee A, et al (2020) A future for the world's children? A WHO–UNICEF–Lancet Commission. The Lancet 395:605–658
9. Liu Y, Liu J, Chen F, Shamsi BH, Wang Q, Jiao F, Qiao Y, Shi Y (2016) Impact of meteorological factors on lower respiratory tract infections in children. Journal of International Medical Research 44:30–41
10. Subramanian K, Bergman P, Henriques-Normark B (2017) Vitamin D Promotes Pneumococcal Killing and Modulates Inflammatory Responses in Primary Human Neutrophils. Journal of Innate Immunity 9:375–386
11. Wartono JA, Asrifuddin A, Kandou GD (2017) Analisis Spasial Kejadian Penyakit Pneumonia Pada Balita Di Wilayah Kerja Puskesmas Tuminting Kota Manado Tahun 2017. 7:
12. Syafei M, Hidayati R (2018) Pengaruh Ketinggian Tempat dan Curah Hujan Pada Penyakit Diare (Studi Kasus: Kabupaten Bogor). Agromet 28:33
13. Onozuka D, Chaves LF (2014) Climate Variability and Nonstationary Dynamics of Mycoplasma pneumoniae Pneumonia in Japan. PLoS ONE 9:e95447
14. Huh K, Hong J, Jung J (2020) Association of meteorological factors and atmospheric particulate matter with the incidence of pneumonia: an ecological study. Clinical Microbiology and Infection 26:1676–1683
15. Fadl N, Ashour A, Yousry Muhammad Y (2020) Pneumonia among under-five children in Alexandria, Egypt: a case-control study. Journal of the Egyptian Public Health Association 95:14
16. Ristiantri YRA, Syetiawan A, Tambunan MP, Tambunan R (2021) Rencana Strategis Penentuan Alternatif Rumah Sakit Rujukan Covid-19 (studi Kasus Kabupaten Bogor). Majalah Ilmiah Globe 23:1
17. Fernandina M, Mujio M, Septiawan Y, Hidayat JT, Armadi DA, Ningsih NW, Nugraha H, Rahayu RA, Sari DK (2023) Penentuan Pusat Pertumbuhan Sebagai Arahan Pengembangan Kawasan Perdesaan Di Kecamatan Cijeruk Kabupaten Bogor. Jurnal Litbang Sukowati : Media Penelitian dan Pengembangan 7:9–23
18. Mardani RA, Pradigdo SF, Mawarni A (2018) Faktor Risiko Kejadian Pneumonia Pada Anak Usia 12-48 Bulan (studi Di Wilayah Kerja Puskesmas Gombong Ii Kabupaten Kebumen Tahun 2017). Jurnal Kesehatan Masyarakat 6:581–590
19. Jabar Open Data (2020) Kabupaten Bogor Berpenduduk Terbanyak Se-Indonesia. Available from: [WEBSITE]
20. Alwi, Juwitriani, Sari, Mega, Adnyana, I Made Dwi, et al Metode Penelitian Epidemiologi. Media Sains Indonesia, Bandung. ISBN 978-623-195-687-3
21. Rosiyanti AW, Susilowati MHD (2017) Perkembangan Objek Wisata di Kabupaten Bogor.
22. Susilo B (2021) Mengenal Iklim dan Cuaca di Indonesia. Diva Press, Yogyakarta. ISBN 978-623-293-571-6
23. Kumbasari TA, Budiyono B, Dewanti NAY (2017) Perbandingan Kejadian Pneumonia Pada Balita Yang Tinggal Di Dataran Tinggi Dan Dataran Rendah Ditinjau Dari Faktor Iklim Kota Semarang Tahun 2012 – 2016. Jurnal Kesehatan Masyarakat 5:898–905
24. Thongpan I, Vongpunsawad S, Poovorawan Y (2020) Respiratory syncytial virus infection trend is associated with meteorological factors. Scientific Reports 10:10931
25. Chen Z, Ji W, Wang Y, Yan Y, Zhu H, Shao X, Xu J (2013) Epidemiology and associations with climatic conditions of Mycoplasma pneumoniae and Chlamydophila pneumoniae infections among Chinese children hospitalized with acute respiratory infections. Italian Journal of Pediatrics 39:34

26. Nedalia W, Rustiadi E, Janthy Trilusianthy Hidayat (2022) Perkembangan Kawasan Permukiman di Sekitar Titik Transit Kabupaten Bogor. Biro Penerbit Planologi UNDIP 24:
27. Syani FE, Budiyono B, Raharjo M (2017) Hubungan Faktor Risiko Lingkungan Terhadap Kejadian Penyakit Pneumonia Balita Dengan Pendekatan Analisis Spasial Di Kecamatan Semarang Utara. Jurnal Kesehatan Masyarakat 3:732–744
28. Prajapati B, Talsania N A Study On Prevalence Of Acute Respiratory Tract Infections(Ari) In Under Five Children In Urban And Rural Communities Of Ahmedabad District. National Journal of Community Medicine
29. AbouKorin SAA, Han H, Mahran MGN (2021) Role of urban planning characteristics in forming pandemic resilient cities – Case study of Covid-19 impacts on European cities within England, Germany and Italy. Cities 118:103324
30. Hu Y, Lin Z, Jiao S, Zhang R (2023) High-Density Communities and Infectious Disease Vulnerability: A Built Environment Perspective for Sustainable Health Development. Buildings 14:103
31. Ribeiro HV, Sunahara AS, Sutton J, Perc M, Hanley QS (2020) City size and the spreading of COVID-19 in Brazil. PLoS ONE 15:e0239699
32. Nuryana (2016) Kejadian penumonia akibat kebakaran hutan di Provinsi Riau tahun 2014-2015 dengan analisis geographically weighted regression (GWR)= Pneumonia and forest fires in Riau Province on 2014-2015 with geographically weighted regression analysis (GWR). Universitas Indonesia
33. Burtscher M (2014) Effects of Living at Higher Altitudes on Mortality: A Narrative Review. Aging and Disease
34. Efni Y, Machmud R, Pertiwi D (2016) Faktor Risiko yang Berhubungan dengan Kejadian Pneumonia pada Balita di Kelurahan Air Tawar Barat Padang. Jurnal Kesehatan Andalas
35. Sutriana VN, Sitaresmi MN, Wahab A (2021) Risk factors for childhood pneumonia: a case-control study in a high prevalence area in Indonesia. Clinical and Experimental Pediatrics 64:588–595