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# Data mining for epidemiology: The correlation of typhoid fever occurrence and environmental factors

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**Abstract**

Typhoid fever is an endemic disease that burdens Indonesia and has a potentially fatal infection multisystem. *Salmonella typhi* bacterium is responsible for typhoid fever disease. Poor sanitation, crowding, and slums are the main factors of increasing typhoid fever incidences. Environmental factors directly connected to meteorological factors are the main factor in breeding the *Salmonella typhi* bacterium. This study aims to identify the correlation between meteorological parameters and typhoid fever disease occurrence. The study was carried out in Jakarta, Indonesia, and the Bureau of Meteorological, Climatology, and Geophysics (BMKG) provided the meteorological parameter data. In addition, the Jakarta health surveillance office provided information on typhoid fever hospitalizations from 2019 to 2021. Pearson's concept was utilized d to investigate the correlation between typhoid fever incidences and the meteorological parameters. Humidity, precipitation, and wind speed are the meteorological parameters that significantly affect in contribute to the occurrence of typhoid fever disease. These findings might be used as a reference for Indonesia's government in making public policy to prevent typhoid fever in Indonesia.



*Keywords:* typhoid fever; salmonella typhi; endemic disease; meteorological factors

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## 1. Introduction

Typhoid fever is a febrile illness that often burdens urban areas with poor sanitation[1]. *Salmonella typhi* is kind of the bacterium that causes typhoid fever disease [2]. The transmission of *Salmonella typhi* usually occurs via water and food [2,3], and the bacterium enters the human body and infects the immune system. The symptoms of typhoid fever include prolonged fever, abdominal discomfort, malaise, fatigue, headache, nausea, constipation, or diarrhoea [4]. In some cases, the symptoms of typhoid fever disease may include a rash, and if left untreated, severe instances might result in fatal consequences [5,6]. Moreover, the detection of typhoid fever disease has to be confirmed through blood testing [7].

Referring to the burdened area of typhoid fever disease, the urban area with poor sanitation is where the incidences of typhoid fever disease occur. Jakarta, the capital city and urban area, is the most affected area by typhoid fever [8]. A study proposed by Ochiai et al. [9], said that the incidences of typhoid fever disease in Jakarta's slums areas were expected to occur at a rate of 148.7 per 100,000 person-years in the age group of children ages 2-4, 180.3 in the age group of children ages 5-15, and 51.2 in those over the age of 16, with a mean age of onset of 10.2 years [9]. The environmental and meteorological factors are the most factors that inform the slum area in Jakarta [10,11]. The environmental factors that affect typhoid fever include an insufficient wastewater management system and an untreated water supply, non-residential type of house, residential living conditions, drainage, and the chemical composition of soil and water as possible sources of exposure to *Salmonella typhi* [11,12]. Moreover, the meteorological factors that correlate to typhoid fever disease are rainfall, humidity, temperature, sunshine, and wind speed [8,10,13–15]. Besides, lifestyle is another factor that affects typhoid fever disease, such as non-hygiene food, street-vendor food, and contaminated drinking water [1–3,16].

The Centers for Disease Control and Prevention (CDC) data estimated that there are 11 to 21 million typhoid fever incidences each year globally. Due to the lack of public information and effective treatment, typhoid fever disease has a case-fatality rate of 10-30%. However, this percentage is decreased to 1-4% in those receiving the correct medication [2]. Referring to the guideline for managing typhoid fever disease, there are several treatments and preventions for the disease, including vi-polysaccharide and vi-conjugate vaccines programs, fluoroquinolone therapy, antibiotics prescribed by a doctor, striving for a clean and healthy life, especially in food and drink, and checking the *Salmonella typhi* bacterium in the body [4,5,9,17]. In the advanced treatment and prevention of typhoid fever disease, the government's lack of information, data, and knowledge is still the main problem in treating and preventing the disease [4,6,18–20].

Furthermore, to prevent typhoid diseases more effectively, it is crucial to have sufficient information related to the problems. With the rapid advancement of Artificial intelligence (AI) and Data Science (DS)[21,22], it is essential to make public policy on typhoid fever disease to decrease the incidences of typhoid hospitalizations [23,24]. Several pieces of research related to the DS in typhoid fever have been done and described in the next chapter. To summarise this section, this research proposed an analytical study of typhoid fever disease that correlates to the environmental factor.

## 2. Previous Works

Typhoid fever disease generally burdens developing countries, particularly in low-and middle-income countries (LMICs). The slum lifestyle and sanitation mainly affect fever disease [3,5,7,25–27]. The first research on the meteorological parameters correlation with typhoid fever disease was conducted by Cherrie et al. The research analyzed pathogen seasonality and correlated it with the meteorological parameters in Wales and England. The research identified that the meteorological parameters: temperature, sunshine, and vapor pressure, had a positive correlation, while there was a negative correlation between wind speed, humidity, ground frost, and air frost [13]. The second research by Herrador et al. proposed an analytical association of precipitation and temperature connected to waterborne infections due to drinking water. According to the research, increasing temperatures or precipitation positively correlate with infections caused by waterborne diseases [10]. Besides, the meteorological factor that has proven to correlated with typhoid fever is rainfall. The research found that extended periods of rainfall also do not help reduce the prevalence of *Salmonella typhi* infection. In other words, the rainfall is directly proportional to the typhoid fever incidences in Sunyani-Ghana [28].

Besides, several countries studies have also been done on typhoid fever disease correlated with environmental parameters. Mainly the research was reported from the region of Asia. The research from Shafei et al. discovered a correlation between environmental variables and typhoid fever disease after a flood in north-eastern Malaysia. The research found that the environmental factors were non-treated water supply, inadequate wastewater management, and non-residential type of houses [11]. Moreover, the other research proposed by Dewan et al. found the environmental factor associated with typhoid fever disease in Dhaka, Bangladesh. The research concluded that temperature, rainfall, and river level were significantly affected by the incidences of typhoid fever disease [8]. In the Fijian region, the research was also proposed by Jenkins et al. The research found that inadequate drainage, floods, and sanitation conditions increase local exposure to polluted water and soil, which are environmental factors [12]. In addition, the factors of *Salmonella* transmission also being essential factors that correlate with typhoid fever disease incidences. Such as residential location analysis, residential living circumstances[12], and non-hygiene food such as street-vendor food and milk [3,29].

Based on the brief of some related studies on the correlation between typhoid fever disease incidences with several factors, in this study, we proposed an analytical study of meteorological parameters with the hospital admission data of typhoid fever disease in Jakarta based on categorical seasons that are wet and dry.

## 3. Research Methodology

### *3.1 Data Collection*

The research data was collected from open portals provided by the Jakarta health surveillance office represented by Indonesia's Ministry of Health (MoH). The data collected were hospitalized in the last three years, from 2019 to 2021. The total number of data patients hospitalized and analyzed was 2614 patients. To support this study's analytical purpose, we collected open public meteorological data to analyze and visualize the correlation between typhoid fever disease incidences in Jakarta. The open public data are available on worldweatheronline.com. Refers to the Jakarta health surveillance office, we illustrate the locations for data collection and data hospitalized from 2019 to 2021 [30,31].

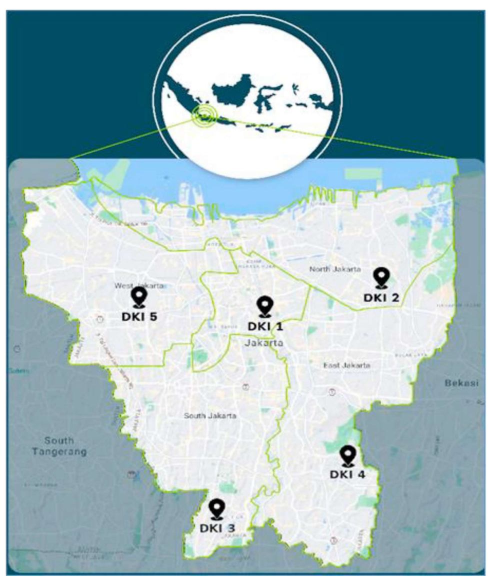


Fig. 1. Locations of research: Jakarta, Indonesia.

Refers to Fig.1, this study's location covered the Jakarta region. There are five locations for this data research. The location DKI-1 represented the area of Central Jakarta, DKI-2 for North Jakarta, DKI-3 for South Jakarta, DKI-4 for East Jakarta, and DKI-5 for West Jakarta [30].

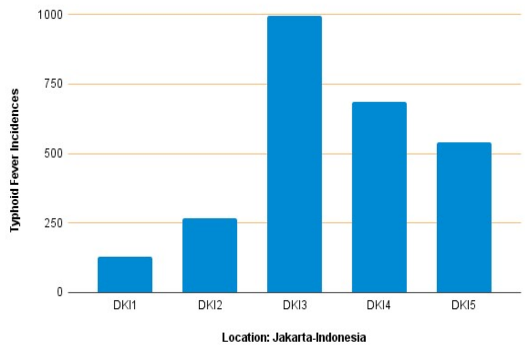


Fig. 2. The visualization of the hospitalized patient with typhoid fever disease (2019-2021).

### *3.2 Data Processing and Data Visualisation*

The data processing and visualization part started with data cleaning to get the final version of the data and analyzed it with statistical modeling. After getting the final data, the next step was combining the data with the meteorological parameters. The meteorological parameters analyzed in this study were humidity, temperature, precipitation, and wind speed. In an additional step in this study, we also add the data on the seasons that are wet and dry. The aim of adding the information on the season is to identify the difference between typhoid fever disease in the two seasons based on the climate in Jakarta [31]. The season data were referred to the Bureau of Meteorology Climatology and Geophysics (BMKG) of Indonesia's republic [30]. In addition, we used the Python software's Pandas and Matplotlib libraries to visualize the typhoid fever disease incidences with meteorological information. The Scipy.stats and scikit post hoc are two statistical packages in Python 3.9 that were used to perform the statistical analysis.

### *3.3 Statistical Analysis*

Pearson's statistical model was proposed in this paper to analyze the correlation between typhoid fever disease and meteorological parameters. Since the count data typically does not follow a normal distribution. The Mann-Whitney U test was first used to statistically compare the incidences of typhoid fever disease across two seasons. To further examine the importance of the suggested continuous meteorological variables in the two seasons, multiple student t-tests were used [32]. Locations then combined the typhoid fever data, and the null hypothesis that there is no significant variation in the number of typhoid fever diseases among the five locations was tested using Kruskal-Walli's test. A non-parametric posthoc analysis using Dunn's test was then carried out to uncover pair-wise statistical comparisons of typhoid fever disease in the five locations since the test revealed significant statistical. In order to prevent type I error, the Bonferroni correction was used in this instance to modify the p-value for the numerous pair-wise comparisons [22]. Finally, Pearson's correlation test was used to measure the correlation between typhoid fever disease incidences and meteorological factors. The test result is a p-value that indicates the statistical likelihood that the absolute value of the rho ( $\rho$ ) is not zero, and rho ( $\rho$ ) values indicate the monotonic correlation between the variables. We used a standard significance level of 5% throughout our analysis. Therefore, a p-value of less than 0.05 is recognized as statistically significant.

## 4. Result and Discussion

The correlation between the meteorological factors significant to the typhoid fever disease incidences in Jakarta will be discussed in this section. In Fig. 2, we could evaluate the incidences of typhoid fever disease in Jakarta from 2019 to 2021. (DKI-3) that represents South Jakarta as the highest case compared to other locations. Next locations followed by East Jakarta (DKI-4), West Jakarta (DKI-5), and North Jakarta (DKI-2), and the last and lowest cases incidences of typhoid fever disease in Central Jakarta (DKI-1). Fig. 3 shows that more typhoid fever disease incidences lead to hospitalizations compared to the dry season during the wet season. With a different percentage of instances in each season, this trend is found in all locations of Jakarta. Besides, referring to the data visualization in Fig. 4, we evaluated differences between the hospitalized data in the wet and dry seasons. The number of patients in the wet season is higher than in the dry season. On the other hand, it also can be concluded that the total incidences of typhoid fever disease in each location DKI-1 until DKI-5 are directly proportional. In other words, if the incidences of typhoid fever in the wet season are high, the incidences in the dry season are also high in each location. Furthermore, the characteristic of the meteorological parameters in wet and dry seasons will show in Table 1.

Table 1. Characteristics of meteorological parameters in wet and dry seasons (2019-2021)

| Variable | Dry Season Mean(std) | Wet Season Mean(std) | p-value |
|---|---|---|---|
| Number of DHF Cases | 19(25) | 36(46) | <0.001* |
| Average Temperature | 30.1(1.1) | 30.2(0.9) | 0.600 |
| Humidity | 66.8(4.6) | 67.1(4.8) | 0.640 |
| Precipitation | 142.2(118) | 300.6(170) | <0.001* |
| Wind Speed | 8.0(1.2) | 10.0(2.3) | <0.001* |

*Statistically significant at p-value < 0.05

We evaluated the statistically significant difference between the monthly incidence of typhoid fever disease during the wet and dry seasons, combined throughout the five locations in Jakarta from 2019 to 2021, shown in Table 1, using the Mann-Whitney U test. The trend in Figure 3 was further supported by our discovery that the typhoid fever disease incidences in the two seasons are significantly different (p-value 0.001). A further Mann-Whitney U test on typhoid fever disease data in each location, with p-values of 0.001 for all calculations in the five locations, further supported this. Meanwhile, we used the student's t-test to determine a statistical association between meteorological parameters and the season to characterize the two seasons. We discovered that only precipitation and wind speed significantly correlate with seasons (p-value 0.001) after combining all the data from 2019 to 2021 in five locations. Table 1 provides a summary of the findings.

Additionally, typhoid fever disease incidences seemed to vary in five areas. To further clarify, we used a Kruskal Wallis test to compare the incidence of typhoid fever disease across five locations in Jakarta to rule out the null hypothesis that the median number of cases is the same across all locations. The null hypothesis may be firmly rejected based on our discovery of a p-value of 1e-8, and we concluded that there were substantial disparities in the incidences of typhoid fever disease in at least two locations throughout the observed time. We investigated this using a non-parametric Dunn's test posthoc analysis to determine whether locations had significantly different occurrences of typhoid fever disease. Table 2 summarizes Dunn's test table and the findings we observed. We found that the locations are locations of DKI-1&DKI-3, locations of DKI-1&DKI-4, locations of DKI-1&DKI-, locations of DKI-2&DKI-3, and locations of DKI-2&DKI-4 had significantly different typhoid fever disease incidences. This indicates the difference in typhoid fever disease in several Jakarta locations.

Table 2. Dunn's test to examine typhoid fever cases in different locations (p-value)

| | Loc 1 | Loc 2 | Loc 3 | Loc 4 | Loc 5 |
|---|---|---|---|---|---|
| **Loc 1** | >0.99 | 0.333 | <0.001* | <0.001* | <0.001* |
| **Loc 2** | 0.333 | >0.99 | 0.003* | 0.057* | 0.180 |
| **Loc 3** | <0.001* | 0.003* | >0.99 | >0.99 | >0.99 |
| **Loc 4** | <0.001* | 0.057* | >0.99 | >0.99 | >0.99 |
| **Loc 5** | <0.001* | 0.180 | >0.99 | >0.99 | >0.99 |

*Statistically significant at p-value < 0.05

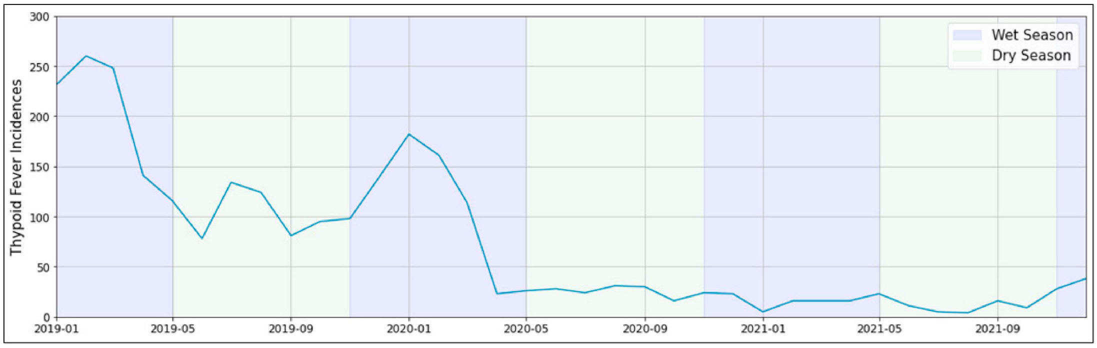


Fig. 3. Typhoid fever disease hospitalized data in Jakarta from 2019-2021 (based on the seasons).

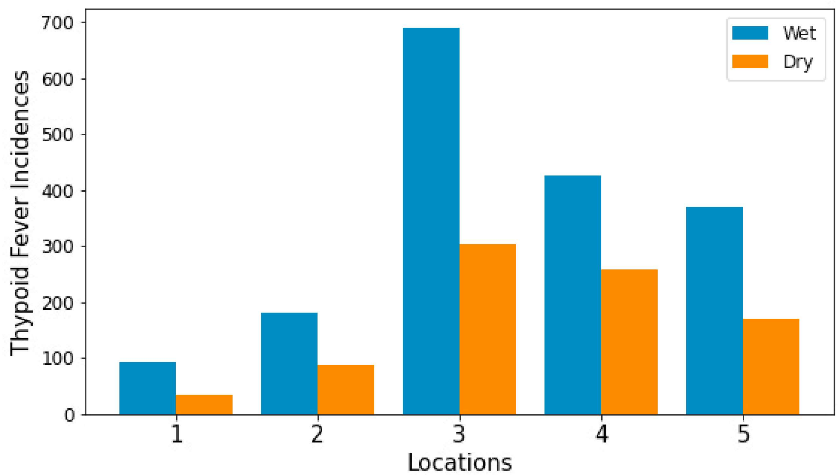


Fig. 4. Typhoid fever disease hospitalized data in Jakarta from 2019-2021 (based on the locations).

Table 3. Pearson's correlation between typhoid fever cases and meteorological variables for different years

| **Variable** | **2019-2021** | | **Each year** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **2019** | | **2020** | | **2021** | |
| | **rho ($\rho$)** | **p-value** | **rho ($\rho$)** | **p-value** | **rho ($\rho$)** | **p-value** | **rho ($\rho$)** | **p-value** |
| Temperature | 0.003 | 0.976 | 0.020 | 0.873 | -0.227 | 0.080 | -0.020 | 0.878 |
| Humidity | 0.284 | 0.006* | 0.131 | 0.316 | 0.211 | 0.104 | 0.159 | 0.222 |
| Precipitation | 0.114 | 0.280 | 0.277 | 0.031* | 0.373 | 0.003* | -0.107 | 0.413 |
| Wind Speed | -0.200 | 0.058* | 0.023 | 0.856 | 0.206 | 0.113 | 0.044 | 0.734 |

*Statistically significant at p-value < 0.05

Based on Spearman's correlation concept, Table 3 indicates that the significant monotonic correlations between typhoid fever disease incidences and meteorological parameters from 2019 to 2021 were humidity and wind speed. Based on the rho (ρ) values, we determined the meteorological variables correlated to the typhoid fever disease incidences in Table 3, which provides data from 2019 to 2021. Typhoid-Humidity (p-value = 0.006*) and Typhoid-Precipitation (p-value = 0.058*) were significantly correlated meteorological parameters in this case. Based on the rho (ρ) values in the meteorological parameters indicated that typhoid fever disease and humidity have a weak correlation (ρ= 0.284), and typhoid fever disease and wind speed have a strong correlation (ρ= -0.200). These findings are also proven by research studying the correlation between typhoid fever disease and humidity and wind speed [8,33,34]. In other words, if the humidity and precipitation were increased, typhoid fever disease incidences also increased proportionally.

Furthermore, based on p-values, we found that in 2019, only precipitation had a statistically significant relationship between the incidences of typhoid fever disease and the meteorological parameters (p-value = 0.031* and (ρ = 0.277). We found the same parameter in 2020, indicating that precipitation significantly affected typhoid fever disease incidences (p-value = 0.003* and (ρ = 0.373). Furthermore, no meteorological parameters that were associated with the prevalence of typhoid fever disease were discovered for the final year of 2021. These findings indicate that from 2019 to 2021, typhoid fever disease cases were significantly impacted by humidity, precipitation, and wind speed. The findings that there is a correlation between humidity and precipitation growth of the *Salmonella typhi* bacterium have also been investigated in several previous research [35,36]. Additionally, this research showed how Jakarta, particularly, was affected by climate change throughout the last three years in the tropical country. Moreover, the demographics of Jakarta's society were not included in this study, and the limitations of the results focus on the correlation between the typhoid hospitality data and environmental factors that were investigated using Pearson's study correlation.

Table 4. Spearman's correlation between typhoid fever cases and meteorological parameters in wet and dry seasons

| Variable | Dry Season | | Wet Season | |
|---|---|---|---|---|
| | **rho (*ρ*)** | **p-value** | **rho (*ρ*)** | **p-value** |
| Temperature | -0.148 | 0.161 | 0.003 | 0.976 |
| Humidity | 0.123 | 0.245 | 0.284 | 0.006* |
| Precipitation | -0.283 | 0.006* | 0.114 | 0.280 |
| Wind Speed | 0.322 | 0.001* | -0.200 | 0.058* |

*Statistically significant at p-value < 0.05

According to Table 4, Spearman's correlation analysis, the significant monotonic correlations between typhoid fever disease incidences and meteorological parameters from 2019 to 2021. The meteorological parameters were humidity, precipitation, and wind speed. Based on the rho (ρ) values, we found the meteorological variables correlated to the typhoid fever disease incidences in Table 4, which contains data from 2019 to 2021. The Typhoid-Precipitation and Typhoid-Wind speed meteorological factors were highly correlated in the dry season. Besides, the Typhoid-Humidity and Typhoid-Wind Speed meteorological factors were highly correlated in the wet season. In other words, humidity, precipitation, and wind speed contribute significantly to the incidence of typhoid fever.

This research found that the significant meteorological parameters correlated to typhoid fever disease were humidity, precipitation, and wind speed. These findings are in agreement with Wang, Goggins, and Chan [35], found a positive association between Typhoid-Rainfall, and Typhoid-Humidity. The research concluded that extremely high humidity would increase Salmonella morbidity without other changes [35]. The other research that discussed the correlation between the *Salmonella typhi* bacterium and meteorological factor was conducted by Hwang, Rothrock, Pang, Guo, and Mishra [36], using meteorological parameters to predict Salmonella prevalence in pastured poultry farms. Humidity is the most crucial meteorological factor in the soil, and high wind speed and the face model's average temperature [36].

Furthermore, the same research topic was also proposed by K. et al. The research mentioned that precipitation positively correlates typhoid and paratyphoid fever (TPF) with meteorological factors. In addition, Nili et al. studied the effect of meteorological parameters on Salmonellosis incidences in Kermanshah, West of Iran [37]. The research found that the minimum humidity could increase the incidence of Salmonellosis in Iran. By the explained several pieces of research, we concluded that humidity, precipitation, and wind speed significantly affected the increasing number of typhoid fever diseases. In other words, the humidity, precipitation, and wind speed contribute to breeding of *Salmonella typhi*.

## 5. Conclusion

There are several main findings of this study. First, we found that the incidences of typhoid fever disease are higher during the rainy season than in the dry season. The highest incidences of typhoid fever in Jakarta, Indonesia, from 2019 until 2021 in South Jakarta. Furthermore, the analytical study of the correlation between meteorological parameters and typhoid fever disease incidences has discovered several findings. In the dry season, precipitation has a strong correlation with the occurrences of typhoid fever disease, and wind speed has a weak correlation with the incidence of typhoid fever disease. Compared to the wet season, we found that the humidity correlated weakly with typhoid fever disease, and wind speed correlated strongly with typhoid fever disease. Based on data on meteorological and typhoid fever patients hospitalized from 2019 to 2021, it was discovered that humidity and wind speed are the two meteorological factors that significantly correlate with typhoid fever disease. Furthermore, AI and DS concepts can be implemented for future research to prevent neglected tropical diseases, especially typhoid fever. These findings might be used as a reference to support typhoid fever disease prevention in Jakarta.

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