

## LITERATURE REVIEW: RELATIONSHIP OF ENVIRONMENTAL RISK FACTORS AND THE INCIDENCE OF LEPTOSPIROSIS IN SETTLEMENTS (2018–2023)

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### Abstract

**Introduction:** Leptospirosis is zoonotic disease that transmits via natural transmission from vertebrate animals to human beings and vice versa. This disease is caused by an infection of the *Leptospira sp.* bacterium. It is estimated that there are 1 million cases of Leptospirosis that attack humans worldwide with 60 thousand deaths per year. In Indonesia, such cases and death rates have fluctuated. In 2021, there was a decrease in cases, but the CFR rate increased from 9.1% to 11.4%. Leptospirosis cases become endemic in many countries, especially in tropical and subtropical areas with high rainfall, especially in settlements with poor environmental conditions. Based on previous research, there were differences in the results between several research variables with the incidence of Leptospirosis. This gap underlies the writing of this article to bring together the existing results. **Discussion:** This study used literature review method for research articles on biotic and abiotic environmental risk factors with Leptospirosis in settlements sourced from scientific publication websites. After going through these stages, 14 final full text articles were obtained. The data used were research studies conducted from January 2018 to April 2023. The articles found show that environmental factors are closely related to the incidence of Leptospirosis in settlements. **Conclusion:** The variable abiotic environment factors associated with the occurrence of Leptospirosis are temperature, pH, the presence of sewers and puddles. The presence of rats and the presence of animals or livestock are related to biotic environmental factors.

## INTRODUCTION

Leptospirosis is an infectious disease caused by *Leptospira sp.* bacteria. The disease is transmitted through contact between human beings and the urine of animals exposed to *Leptospira sp.* bacteria directly or indirectly (1). Leptospirosis can occur due to complex interactions between disease carriers, hosts, and the environment. Clinical symptoms that occur in Leptospirosis are very diverse and non-specific (2). Leptospirosis has general symptoms that are similar to several other types of disease, resulting in an erroneous diagnosis and treatment (2–3). In addition, leptospirosis also causes complications on the sufferers, such as Acute Renal Failure (ARF), conjunctival infections in the eyes, jaundice after the fourth and sixth days with

hepatomegaly in the liver, arrhythmias and heart failure, and abortion and stillbirth in pregnancy (4).

The incidence of Leptospirosis is estimated to be 1,000 times more in tropical than subtropical countries (3). Leptospirosis cases that attack humans in the world are estimated to reach 1 million cases with 60 thousand deaths per year. In patients with Leptospirosis aged 50 years and over, the mortality rate can reach 56% (5). In Indonesia, 734 cases of Leptospirosis have been reported in 8 provinces including DKI Jakarta, West Java, Central Java, East Java, Special Region of Yogyakarta, Banten, East Kalimantan, and North Kalimantan based on data issued by the Indonesian Health Profile for 2021. The highest reported number of cases was from East Java Province with 312 cases. Of the cases reported by the 8

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provinces, there were 84 cases of death with the number of CFR of 11.4%. Despite the decrease in the number of cases from 2020, the CFR increased from 9.1% to 11.4% (1).

Leptospirosis is endemic in many countries and even the world (tropical-subtropical regions) with high rainfall, especially in residential areas with poor environmental conditions (6). Extreme heavy rainfall causes overflow river and sewer that causes flooding in the area and make rats come out of their nests and enter residential areas. It can be an optimal condition for rats to reproduce so that the rat population increases, and the probability of Leptospirosis also increases (7). Therefore, this disease is commonly found in flood-prone areas. According to studies on *Leptospira sp.* in rodents from peridomestic sites in endemic regions of Nicaragua, the success rate of trapping was 20.2% across all sites, with higher rates during the rainy season ( $p < 0.05$ ) (8). Habitat of rats that confirmed positive for *Leptospira sp.* include settlements, gardens, and yards. Laboratory tests showed that in Jakarta Province, *Leptospira sp.* bacteria pathogenicity was detected in domestic rats (*Rattus Tanezumi* and *Rattus Norvegicus*) in all cities in DKI Jakarta and Seribu Islands (9). In this case, several areas in Indonesia have become endemic areas for Leptospirosis. Until now, Leptospirosis in Indonesia continues to spread and cause death as flood areas in various parts of Indonesia are increasingly expanding, the presence of a population of rats (rodents) as the main reservoir of Leptospirosis increases, and poor sanitation conditions in residential areas contribute to increase the incidence of Leptospirosis.

A number of countries in the Southeast Asian region have reported Leptospirosis cases from time to time and most countries in Southeast Asia is a Leptospirosis endemic area. Most Leptospirosis cases in humans are reported from India, Indonesia, Thailand and Sri Lanka during the rainy season. Large outbreaks of Leptospirosis in the Southeast Asian region have been reported in Jakarta (2003), Mumbai (2005) and Sri Lanka (2008). Meanwhile, seasonal outbreaks were reported in northern Thailand and Gujarat (India) after heavy rains and flooding (10).

Several studies through the publication of journal articles showed that the environment influences the transmission of Leptospirosis. Most of these environmental variables are abiotic and biotic environments. The abiotic environment includes air temperature, humidity, water and soil pH, light intensity, history of flooding, and natural water bodies (rivers, sewers, and puddles). Meanwhile, the biotic environment includes the presence of vegetation, rats, and pets or livestock (11–12).

The environment is dynamic, and the risk of humans being infected depends on the exposure to risk factors. Risk factors usually do not cause disease but only change a person’s probability (or risk) of getting the disease. Several articles conducted research on this topic in various areas in Indonesia. Geographically, each region has different environmental conditions according to where the respondent lives and the time of study. Thus, there are varying results for each environmental risk factor variable with Leptospirosis in the previous articles. Therefore, this study aimed to analyze abiotic and biotic environment risk factors with the incidence of Leptospirosis in settlements from articles published in the range of January 2018 – April 2023.

### DISCUSSION

Leptospirosis is a zoonotic disease that can be transmitted naturally from vertebrates to human beings and vice versa. One of the factors that contribute to Leptospirosis in settlements is environmental factors. These environmental risk factors include abiotic and biotic environmental factors. The abiotic environmental factors studied were air temperature, humidity, water pH, light intensity, floods, rivers, sewers, and puddles contaminated with infected reservoir urine. Meanwhile, the biotic environmental factors studied were the presence of vegetation, rats, and pets or livestock.

This study used literature review method with published research articles related to the topic of environmental risk factors for Leptospirosis in settlements. The articles are sourced from scientific publication websites such as Google Scholar, Research Gate, Neliti, DOAJ, Crossref, Pubmed, and ScienceDirect with the keywords “risk factors for abiotic Leptospirosis” and “risk factors for biotic Leptospirosis”.

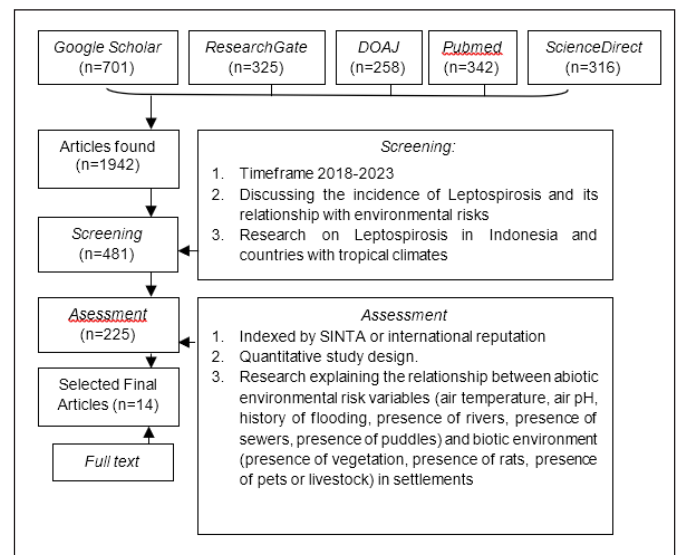


Figure 1. Journals Selection Process

**Table 1. Summary of Articles Included in Relationship of Environmental Risk Factors and the Incidence of Leptospirosis in Settlements**

Authors	Titles	Method	Sample	Result	Conclusion
Nugroho A, Trapsilowati W, Yuliadi B, Indriyani S (35)	Biotic Environmental Factors in Leptospirosis Outbreaks in Tangerang District, Banten	The research design was cross-sectional through an observational approach.	The number of samples was 35 residential houses adjacent to the case houses for biotic environmental examination.	<ol style="list-style-type: none"> <li>1. Conditions around the house by 91.4% have no vegetation, 8.6% have vegetation, <math>p(0.579) &gt; \alpha(0.05)</math>.</li> <li>2. People do not own pets by 54.3%, while 45.7% have pets, <math>p(0.653) &gt; \alpha(0.05)</math>.</li> <li>3. As many as 50 rats were caught within the house (trap success rate: 18.65%) and 3 rats were caught outside the house (9.37%).</li> </ol>	<ol style="list-style-type: none"> <li>1. Vegetation is not a risk factor for Leptospirosis.</li> <li>2. Pets are not a risk factor for Leptospirosis.</li> <li>3. High trap success can be a potential risk of Leptospirosis.</li> </ol>
Samekto M, Hadisaputro S, Adi MS, Suhartono, Widjanarko B (33)	Factors Affecting the Incidence of Leptospirosis (Case-Control Study in Pati District)	Analytical observational study with case-control study design.	The sample in this study consisted of 44 cases and 44 controls using consecutive sampling techniques.	<ol style="list-style-type: none"> <li>1. Puddles (present) obtained p-value of <math>p(0.200) &gt; \alpha(0.05)</math></li> <li>2. Sewer condition (poor) obtained p-value of <math>p(0.088) &gt; \alpha(0.05)</math></li> <li>3. Presence of rats (present) obtained p-value of <math>p(0.001) &lt; \alpha(0.05)</math></li> </ol>	<ol style="list-style-type: none"> <li>1. The presence of puddles has been shown to not affect the incidence of Leptospirosis.</li> <li>2. The condition of bad sewers is proven to not affect the incidence of Leptospirosis.</li> <li>3. The presence of rats in and around the house was found to have an effect on Leptospirosis.</li> </ol>
Andriani R, Sukendra DM (31)	Environmental Factors and Leptospirosis Prevention Behavior in Endemic Areas	The cross-sectional research design for observational analysis.	A representative sample of 68 houses for each family head in the Bonang I Health Center's service area as of July 2019.	<p>The results of the cross-tabulation between the physical environment and the incidence of Leptospirosis:</p> <ol style="list-style-type: none"> <li>1. The distance from the house near the sewer is <math>\leq 700</math> meters, <math>p(0.007) &lt; \alpha(0.05)</math>.</li> <li>2. Presence of puddles, <math>p(0.004) &lt; \alpha(0.05)</math>.</li> </ol>	<p>Physical environmental factors associated with the occurrence of Leptospirosis:</p> <ol style="list-style-type: none"> <li>1. The distance between the house and the sewer</li> <li>2. Presence of puddles</li> </ol>
Putri CPA, Saraswati LD, Adi MS (30)	Analysis of Water Characteristics, <i>Leptospira sp.</i> Bacteria, and Environmental Factors in Leptospirosis Cases in Boyolali District	Analytical research using observational methods with a case-control approach.	The comparison between the case group sample and the control was 1:1. Total of 34 cases and 34 controls.	<ol style="list-style-type: none"> <li>1. The presence of rats obtained the value of <math>p(0.151) &gt; \alpha(0.05)</math></li> <li>2. The presence of a river obtained the value of <math>p(0.253) &gt; \alpha(0.05)</math></li> <li>3. The presence of sewer obtained the value of <math>p(0.493) &gt; \alpha(0.05)</math></li> <li>4. Presence of pets obtained the value of <math>p(0.011) &lt; \alpha(0.05)</math>.</li> </ol>	<ol style="list-style-type: none"> <li>1. There is a significant relationship (<math>p &lt; 0.05</math>) between the presence of pets and the incidence of Leptospirosis.</li> <li>2. Rats, rivers, and sewers are not significantly associated with the prevalence of Leptospirosis (<math>p &gt; 0.05</math>).</li> </ol>
Dewi HC, Yudhastuti R (26)	Risk Factors for Leptospirosis in Gresik Regency (2017-2018)	Observational research using a case-control design.	Cases and control samples include 14 persons divided into 7 districts with random sampling.	<p>Statistical Test Results:</p> <ol style="list-style-type: none"> <li>1. Presence of puddles with a value of <math>p(0.001) &lt; \alpha(0.05)</math></li> <li>2. The condition of the sewer with a value of <math>p(0.053) &lt; \alpha(0.05)</math></li> <li>3. History of flooding with a value of <math>p(1.000) &gt; \alpha(0.05)</math></li> <li>4. Presence of vegetation <math>p(0.430) &gt; \alpha(0.05)</math></li> </ol>	<ol style="list-style-type: none"> <li>1. The presence of puddles is the risk factor of Leptospirosis.</li> <li>2. History of flooding and the presence of vegetation are not the risk factors of Leptospirosis.</li> <li>3. The condition of the sewers is weakly related to the incidence of Leptospirosis.</li> </ol>
Ariani N, Wahyono TYM (29)	Factors Affecting the Occurrence of Leptospirosis In 2 Districts Location of the Sentinel Leptospirosis Surveillance in Banten Province In 2017–2019	Cross-sectional research.	The sample was 205 people who met the inclusion and exclusion criteria from 222 people in the total population.	<ol style="list-style-type: none"> <li>1. Statistical test results for the presence of rats obtained value <math>p(0.000) &lt; \alpha(0.05)</math>.</li> <li>2. Statistical test results for the presence of pets obtained the value of <math>p(0.009) &lt; \alpha(0.05)</math></li> <li>3. The results of the statistical test for flooding in the last 2 weeks are <math>p(0.058) &gt; \alpha(0.05)</math></li> </ol>	The presence of rats and pets had a significant relationship ( $p$ -value $< 0.05$ ) with the incidence of Leptospirosis. Meanwhile, flooding in the last 2 weeks was not-related ( $p$ -value $> 0.05$ ).
Kurniawati RD, Nuryati S (32)	The Correlation Between Physical Environmental Factors and the Occurrence of Leptospirosis	The analytical survey used a cross-sectional approach.	The sample was 100 people from 23,013 residents of Sukahaji Village using a proportional stratified random sampling technique.	<ol style="list-style-type: none"> <li>1. As much as 95.2% of Leptospirosis sufferers live near rivers <math>p(0.000) &lt; \alpha(0.05)</math></li> <li>2. As much as 86.2% Leptospirosis sufferers have sewers at home <math>p(0.000) &lt; \alpha(0.05)</math></li> <li>3. As much as 88.9% Leptospirosis sufferers have puddles at home <math>p(0.000) &lt; \alpha(0.05)</math></li> </ol>	Most of the residents of Sukahaji Village, Babakan Ciparay District, Bandung suffer from Leptospirosis. Physical environmental risk factors related to rivers, sewers, and puddles
Listianti DE, Suryono, Wartini (44)	Related Factors with the Leptospirosis Event in Boyolali District Central	Analytical observational research using a case control design.	26 cases (all population with Leptospirosis) and 26 controls (not sufferers of Leptospirosis)	<p>Statistical Test Results:</p> <ol style="list-style-type: none"> <li>1. The presence of puddles has p-value of 0.023</li> <li>2. The presence of rats has p-value of 0.048</li> <li>3. The presence of pets has p-value of 0.001</li> </ol>	The presence of puddles, the presence of rats, and the presence of pets are related factors to the incidence of Leptospirosis in Boyolali District, Central Java.

Authors	Titles	Method	Sample	Result	Conclusion
Notobroto HB, Mirasa YA, Rahman FS (45)	Sociodemographic, Behavioral, and Environmental Factors Associated with the Incidence of Leptospirosis in Highlands of Ponorogo Regency, Province of East Java, Indonesia	Analytical observational research with a case-control design.	The case group was 28 people and the control was 112 people with a comparison of 1-4.	Environmental factor statistical test results: 1. Density of houses have $p(0.013) < \alpha(0.05)$ 2. Livestock ownership has $p(0.004) < \alpha(0.05)$ 3. Distance from house to cowhouse has $p(0.024) < \alpha(0.05)$ 4. Cow ownership has $p(0.010) < \alpha(0.05)$ 5. Goat ownership has $p(0.258) > \alpha(0.05)$ 6. Puddles have $p(0.117) > \alpha(0.05)$ 7. The presence of rats in the house has $p(0.050) < \alpha(0.05)$ 8. The presence of rats around the house has $p(0.735) > \alpha(0.05)$ 9. Vegetation has $p(0.411) > \alpha(0.05)$	Environmental factors associated with the incidence of Leptospirosis were: house density (0.013), livestock ownership (0.004), distance from house to the barn (0.024), cow ownership (0.010), and presence of rats in the house (0.050) with $p < 0, 05$ .
Setyaningsih Y, Bahtiar N, Kartini A, Pradigdo SF, Saraswati LD (14)	The Presence of <i>Leptospira sp.</i> and Leptospirosis Risk Factor Analysis in Boyolali District	Analytic observational research study with a case-control method approach.	The comparison of the case and control group samples was 1:1, obtaining 34 controls, 34 cases, and 100 water samples.	1. Statistical test results: a. The presence of river has $p(0.253) > \alpha(0.05)$ b. The presence of rats has $p(0.151) > \alpha(0.05)$ c. Pets $p(0.011) < \alpha(0.05)$ 2. The measurement results of positive <i>Leptospira sp.</i> a. Districts with cases each year: 1) Cawas river 1: 30°C/pH 6.9/DO 12 2) Cawas River 2 24°C/pH 6.8/DO 6.9 3) Trucuk rice field 28°C/pH 7.4/DO 9.2 b. Districts with cases almost every year: 1) Kebon arum rice fields 31°C/pH 6.8/DO 8.7 2) South Klaten well 1 28°C/pH 7.5/DO 4 3) South Klaten well 2 28°C/pH 7.2/DO 5.7	1. The presence of pets has a significant relationship with the incidence of Leptospirosis in Boyolali District. 2. <i>Leptospira sp.</i> can survive in water bodies where Leptospirosis cases occur, including wells, rivers, and rice fields.
Munawaroh SM, Widiyanto A, Atmojo JT, Duarsa ABS, Handayani RT, Rokhmayanti R, et al (55)	The Effect of Sewer Conditions on Leptospirosis	Case-control study	As many as 88 research subjects were chosen using a simple random sampling method, consisting of 44 cases and 44 controls.	Bivariate analysis showed that sewer conditions increased the incidence of Leptospirosis, but not statistically significant (OR= 1.16; 95% CI= 0.94 to 2.22; $p= 0.136$ )	There is no relationship between sewer conditions and the incidence of Leptospirosis and is statistically significant.
Ginting GKRB, Indiarjo S (24)	Environment, Personal Hygiene Behavior, and Use of PPE Against Leptospirosis	Analytic observational with a case control design	As many as 45 cases and 45 controls samples were taken with proportionate stratified random sampling and systematic random sampling techniques	Statistical Test Results: 1. Bad sewer condition has $p(0.026) < \alpha(0.05)$ 2. The presence of rats inside and outside the house has $p(0.030) < \alpha(0.05)$ 3. The presence of puddles has $p(0.671) > \alpha(0.05)$ 4. The presence of pets/livestock has $p(0.664) > \alpha(0.05)$ 5. History of floods has $p(0.748) > \alpha(0.05)$	There is a relationship between the condition of sewer and the presence of rats with the incidence of Leptospirosis. However, the presence of puddles, pets/livestock, and historical floods is not related.
Tolistiawaty I, Hidayah N, Widayati AN (56)	Abiotic Environmental Factors and Leptospirosis Incidence in Rats in Lalombi Village, Donggala District, Central Sulawesi	Observational research with cross sectional research design	Residents' houses and gardens around residents' settlements where 32 rats were caught from 100 mouse traps.	1. Results of the Abiotic Environment Measurement in the Village of Colombi: a. Settlements: soil pH 6, temperature 32.05°C, and humidity 43%. b. Garden: soil pH 6.5, temperature 31.7°C, and humidity 48.5%. 2. A total of 32 rats were caught (trap success 10.67%), all of them were of the <i>Rattus tanezumi</i> type, and 7 mice (21.87%) were infected with Leptospirosis.	The abiotic environment of Lalombi Village has the potential to transmit Leptospirosis, so it is necessary to be aware of the transmission of Leptospirosis to humans.
Ahmadi H, Mufida DC, Syafriadi M (57)	Determinants of Environmental Aspects at Risk of Occurrence  Transmission of <i>Leptospira sp</i> Bacteria from Rats Confirmed in Bondowoso Regency	Quantitative observational analytic research with cross-sectional design	The population and samples of this study were 47 houses in the post-outbreak location	Statistical test results showed that physical condition of the sewer with a value of $p(0.001) < \alpha(0.05)$	There is a significant relationship ( $p < 0.05$ ) between the condition of the sewer and the presence of <i>Leptospira sp.</i>



The articles used were published in the last five years, namely from January 2018 – April 2023 in order to get the latest developments. After going through the screening and assessment processes for elimination based on inclusion and exclusion criteria, 14 final full text articles were obtained. All selected articles focus on research conducted in the Indonesia area. The situation of Leptospirosis in Indonesia from 2009 to 2018 saw very significant fluctuations, both in terms of the number of cases and deaths and an extraordinary incident of Leptospirosis occurred again in Tarakan City, North Kalimantan in 2019.

Most of the articles obtain findings that vary in each variable studied because there are differences in environmental condition in respondent’s settlements and the time of research in each article. The data analysis technique was carried out by grouping the extracted data according to the results measured to answer research questions using the narrative method. Based on data from 14 full-text final articles, a summary will be made with a table, which includes the name of the researcher, year of publication of the journal, research title, method, as well as research results and research conclusions. The journal summary was then analyzed using the journal content analysis method. The data that have been collected were then searched for similarities and differences so that conclusions can be drawn.

**Abiotic Environmental Risk Factors**

Abiotic environmental factors on the occurrence of Leptospirosis include temperature, pH, historical of floods, presence of rivers, sewers, and puddles. Table 2 below describes the relationship between the independent variables of the abiotic environment.

**Table 2. The Relationship Between Abiotic Environmental Independent Variables**

Abiotic Environmental Independent Variables	Related	Not Related
Temperature	1 study	-
pH	1 study	-
Historical of floods	-	3 studies
Presence of river	1 study	2 studies
Presence of a sewer	4 studies	3 studies
Presence of puddles	4 studies	3 studies

**Relationship of Temperature with Leptospirosis Incidence in Settlements**

One of the environmental risk factors closely related to Leptospirosis incidence is temperature. The existence of pathogenic *Leptospira sp.* bacteria in the environment depends on temperature because temperature can affect the survival time of *Leptospira sp.* in water and soil. *Leptospira sp.* are obligate aerobes with optimal ambient temperatures in the range of 28°C-30°C (13).

The research results in Boyolali District found that water samples were detected positive for *Leptospira sp.* by PCR at 6 points of the research location. The *Leptospira sp.* positive water samples came from the Sub-district with cases occurring every year (2 rivers and 1 rice field) and Sub-district with cases occurring almost every year (2 wells and 1 rice field). The results of temperature measurements obtained at these locations are in the range of 24°C –31°C (14). When compared to the optimal temperature range, the measurement locations with temperatures of 24°C and 31°C are not suitable for the growth of *Leptospira sp.* bacteria in water. However, the PCR results stated positive for *Leptospira sp.* The same result was obtained by another previous study carried out in Semarang found that water samples were detected positive for *Leptospira sp.* by PCR at 5 points of his research location with temperature measurement results obtained were in the range of 31°C –34°C (15).

**Table 3. The Average of Temperature Measurement**

Authors	Title	The Average of Temperature Measurement	Optimal Range	Conclusion
Setyaningsih Y, Bahtiar N, Kartini A, Pradigdo SF, Saraswati LD (14)	The Presence of <i>Leptospira sp.</i> and Leptospirosis Risk Factor Analysis in Boyolali District, Indonesia	28,1°C (6 location points, temperature range of 24°C - 31°C)	28°C-30°C	Related

According to previous studies, *Leptospira serovar Hardjo*, which was tested in several types of water, explained that in ditch water under sunlight (32°C), it could survive for 6 hours (16). Even though the temperature is not an optimal condition for the survival of *Leptospira sp.* bacteria, in a certain range the bacteria can still live with reduced virulence. In fact, this bacterium can survive in freezer storage at -70°C and up to several years without reducing virulence (17). At the point of thermal death of *Leptospira sp.* showed when suspended in water, *Leptospira sp.* is killed at 45°C for 30 minutes, at 50°C for 10 minutes, at 60°C for 10 seconds, while at 70°C the organism cannot survive more than 10 seconds (16). These results indicate the ability of *Leptospira sp.* to survive in various environmental conditions. The survival ability of *Leptospira sp.* in the environment is affected by variations in soil and water conditions in the contaminated area (14). Conditions of water bodies and water reservoirs affect temperature, so that the survival time for *Leptospira sp.* also has an effect. In addition, several other factors such as pH value, humidity, optimal light intensity also play a role (14–15).

**Relationship between pH and Leptospirosis Incidence in Settlements**

In water and soil media, pH also influences the survival of *Leptospira sp.* outside the host. A previous study reported its findings in mice that detected Leptospirosis through PCR testing, where the pH of water and soil is optimal for the development of *Leptospira sp.* effect on the incidence of Leptospirosis in rats with optimal water pH (7.0–7.4; p-value=0.04) and optimal soil pH (7.2-8.0; p-value=0.04) (17). Similar research further discovered that the pH range of 7.0–7.4 in water and mud media is very suitable for *Leptospira sp.* bacteria to live (18).

**Table 4. The Average of pH Measurement**

Authors	Title	Average of pH Measurement	Optimal Range	Conclusion
Setyaningsih Y, Bahtiar N, Kartini A, Pradigdo SF, Saraswati LD (14)	The Presence of <i>Leptospira sp.</i> and Leptospirosis Risk Factor Analysis in Boyolali District, Indonesia	6 location points, range pH 6.8-7.5	pH 7.2-7.6	Related

The survival ability of *Leptospira sp.* at a pH value > 7 has a duration of 21–152 days. However, it will break down in a matter of minutes or hours if the pH is too low or too high (<5–<8.5) (18). Etiologically, the *Leptospira sp.* bacteria is sensitive to acidic conditions and can live for +/- 1 month in freshwater. However, when it is in seawater, sewer water, and urine without dilution, it will die quickly (19). Furthermore, *Leptospira* pathogens cannot survive in salt water for more than a few hours, but non-pathogenic (*saprophytic*) *Leptospira* strains, namely *L. biflexa*, have been isolated from seawater (20).

Another study has been performed to assess the survival time of *Leptospira interrogans serovar Hardjo* which were inoculated into a number of types of water, soil and urine of livestock (16). The study has shown that seawater (pH 6.5–6.8) with dissolved solid salt concentrations of between 3.78% and 3.85% had the lowest survival in water. *Leptospira sp.* nearly died shortly after inoculation into seawater. Meanwhile, *serovar Hardjo* in undiluted pure bovine urine was able to survive for no more than 2 hours under direct sunlight (pH 8; temperature 32°C) and for 6 hours in the shade (pH 8; temperature 27°C).

*Leptospira sp.* has a survival time that varies in both water and acidic solutions depending on the temperature of the environment in which it is maintained. These results show that humans and animals exposed to contaminated environments will become the source of infections from surviving organisms (16).

**The Relationship between the Historical of Floods and the Incidence of Leptospirosis in Settlements**

In the period from 2018 to 2023, three selected articles discuss the history of floods and the incidence of Leptospirosis. The three articles stated that there was no relationship between them. Floods and rob increase the risk of contact with puddles (21). The number of Leptospirosis cases is higher during the rainy season and the number increases after floods. Groundwater that is flooded after flooding provides suitable conditions for the growth of *Leptospira sp.* (22). If there is contact with humans, floods may carry a lot of garbage and mud, and puddles may be a source of transmission of Leptospirosis, because the water is most likely contaminated with rat urine. If urine is infected with *Leptospira sp.* bacteria, it can potentially become a medium for transmission of Leptospirosis (23).

High rainfall and the altitude of a residential area are related to the location of the flood area and determine the distribution of Leptospirosis cases in a residential area. The presence of the pattern of irrigation rivers that spreads is a potential factor for flooding in the rainy season (6). The high number of Leptospirosis cases is supported by environmental conditions that often experience flooding. Puddles can cause Leptospirosis in humans if the puddles contain *Leptospira sp.* bacteria (24). Floods cause changes in the environment such as puddles, muddiness, and piles of garbage which make it easy for *Leptospira sp.* bacteria to multiply (25).

The flood made the rat’s nest stagnant so that many rats came out of their places. A history of floods is a risk factor for Leptospirosis because rats and other animals can excrete their urine or feces in flood waters (26). Contact with flooding is a risk factor that significantly increases the occurrence of Leptospirosis (27).

**The Relationship between the Presence of a River and the Incidence of Leptospirosis in Settlements**

Three articles focusing on the presence of rivers with regard to Leptospirosis incidence during the period from 2018–2023 have been chosen. Among the three articles, one found a relationship between the variables, while two articles did not. When rivers are flooded during the rainy season, areas adjacent to them may be exposed to river overflows (28). Rivers are an indirect medium for Leptospirosis transmission. When it rains with high intensity, it can cause river water to overflow and inundate the area around the settlement. Streams of river water that drown settlements can be a source of transmission of Leptospirosis if the water is contaminated with rat urine which contaminated with *Leptospira sp.* bacteria. Leptospirosis cases are found in houses less

than one kilometer from a river (23). Leptospirosis do not only occur in the house environment but can also occur in other places such as rice fields, rivers, or workplaces (24). The risk of getting Leptospirosis is two times higher for someone who is active in rivers, ponds, or water than someone who is not active in water (29). Leptospirosis cases in respondents whose houses have rivers are 1.944 times greater than those in respondents whose homes do not have rivers (30).

**Relationship Between the Presence of Sewers and The Incidence of Leptospirosis in Settlements**

In the period from 2018 to 2023, seven selected articles discuss about sewer’s presence and the incidence of Leptospirosis. The seven articles stated that four articles found a relationship between the variables, while three articles did not. The relationship between the sewer and the occurrence of Leptospirosis is related to the existence of the sewer, the distance between the sewers and the house, and the condition of the sewers around settlements. People who live less than 700 meters from the sewer have an increased risk of suffering Leptospirosis by 2.690 times more compared to people with a house with more than 700 meters away (31). Meanwhile, people who have the sewer with bad conditions have a 4.286 times greater chance of suffering from Leptospirosis than people who have good sewer conditions (24).

Sewers are often used as a place to live or as a pathway for *wirok* rats (*Bandicota bengalensis*, *Bandicota indica*), rats (*Rattus norvegicus*), and house rats (*Rattus diardii*) to enter the house because of the condition that water disposal from inside the house generally has a channel connected to the sewer in the house environment (32). Sewers are an indirect medium for the transmission of Leptospirosis. Sewers play a part in the spread of Leptospirosis when the water becomes tainted by the urine of a reservoir for the disease infected with *Leptospira sp.* (33). When the sewer is closed, the flow is smooth, and there’s no way for rats to get in the house, it’s a good sewer condition (21). When the condition of sewer is open, has puddles, and is lower than the house, the water can overflow and inundate the yard and around the house during the rainy season. This condition will certainly be risky if the water is contaminated with *Leptospira sp.* which is then supported by ditch spacing of mostly  $\leq 700$  meters. In addition, if the sewer is too close to the house, the sewer water will easily enter the house (31).

**The Relationship between the Presence of Puddles and the Incidence of Leptospirosis in Settlements**

In the period from 2018 to 2023, seven articles have been chosen which concern on the puddles as

a possible source of Leptospirosis. The seven articles stated that four articles found a relationship, while three articles did not. Puddle is a factor in the transmission of Leptospirosis (26). Overall, 7 of the 11 selected articles stated that puddles was associated with the occurrence of Leptospirosis in settlements. Rats infected with *Leptospira sp.* bacteria can urinate or pass through puddles, causing the water to be contaminated with *Leptospira sp.* bacteria and at risk of infecting humans who pass through it (26). The urine of animals that infected with *Leptospira sp.* will be carried away by puddles and contaminate the environment around the house in muddy places. Puddles, given their direct or indirect contact with rats and intermediate hosts, enable *Leptospira sp.* bacteria to enter the human body (28).

Respondents who have contact with puddles have 2 times the risk of getting Leptospirosis compared to those who have no contact with puddles around the house (29) ( $p=0.040$ ) (31). Then, based on research in Ponorogo in 2019, contact with puddles correlates with the incidence of Leptospirosis. A person who is in contact with puddles is 10 times more at risk of contracting Leptospirosis (21). Historical of floods and rob increases the risk of contact with puddles. The condition of the gutters that overflow when it rains can cause puddles around the house. Rainwater, which may have been contaminated with *Leptospira sp.* bacteria through rat urine, flows through the river and overflows, forming puddles on the highway (34).

**Biotic Environmental Risk Factors**

Biotic environmental factors on the occurrence of Leptospirosis include the presence of vegetation, rats, and pets or livestock. Table 5 below is a data presentation of the relationship between the independent variables of the biotic environment.

**Table 5. The Relationship between Biotic Environmental Independent Variables**

Biotic Environmental Independent Variables	Related	Not Related
Presence of vegetation	-	3 studies
The presence of rats	6 studies	2 studies
Presence of pets or livestock	5 studies	2 studies

**Relationship Between the Presence of Vegetation and the Incidence of Leptospirosis in Settlements**

Vegetation is a collection of plant species that contribute to the presence of rats as bushes, shrubs, plants with branches, and bamboo clumps around the house (35–36). Vegetation does not only act as a source of food but also as a place for shelter or a nest for rats (35). A study conducted on the Otago Peninsula stated that the presence of rats showed a significant relationship



with the presence of vegetation (p-value 0.009) (37). Other research also states that there is a relationship between two of them with p-value of 0.005 (38).

Several types of vegetation that rats often encounter include shrubs (*Rattus tiomanicus*) and fields (*Rattus exulans*) (26). However, based on other studies, *Rattus tiomanicus* was also found in riverside areas in the middle of rice fields. The research location was near settlements belonging to the peridomestic habitat. Apart from that, *Rattus tiomanicus* is also caught in the small hill area far from settlements in the form of a secondary forest dominated by pine forests which are classified as sylvatic habitats (39).

Some rats are also found on the edge of the village and irrigation embankment which are the main habitat of the field rat (*Rattus argentiventer*) in the irrigated rice field ecosystem. The habitat on the edge of the village is used as an alternative source of food and a temporary shelter from the threat of predators. Irrigation embankments are primarily habitats for breeding because they are close to water and feed sources and high irrigation embankment buildings are relatively safe from flood conditions (40).

Rice fields are the most preferred habitat for rats. The diversity of vegetation in the paddy field ecosystem affects the density and types of rats because the birth of field rats occurs mostly during the growing season of sweet potato, peanut, yam, cassava, soybean, and corn (12). For example, field rats (*Rattus argentiventer*) who like rice plants in the early generative period enter the pregnancy phase. Because, this phase is a source of quality feed to support their development (40).

The presence of vegetation and Leptospirosis incidence in the period from 2018–2023 were discussed in three chosen articles. These three articles stated that there was no relationship between them. In contrast to research (36), spatial analysis shows that the incidence of Leptospirosis was found in locations with a diversity of 3 or more types of vegetation. The difference in the results of this article is probably because the research location in the selected article is a densely populated settlement with close proximity, so vegetation around the house is rarely found. Rats do not like well-maintained and neat vegetation. Unlike the dirty environment covered with grass or shrubs, it is a favorite place for rats (12). Another reason is that the results between the control group and the cases are not too far apart. Since the houses between the groups are located in the same area so the statistical test results do not get a significant difference (26).

### **The Relationship between the Presence of Rats and the Incidence of Leptospirosis in Settlements**

The presence of rats in an environment is an indicator of poor environmental sanitation which can trigger the transmission of Leptospirosis. There are 4.51 times increased risk of getting Leptospirosis from the presence of rats in their vicinity compared to houses with no rats (p=0.003; 95% CI = 1.66–12.28) (33). It has been supported by a study carried out in Banten Province in 2017 and 2019, which showed an increased risk 4 times greater of developing Leptospirosis with rats at home compared to houses where no rats (p=0.000, POR = 4.08 95 % CI: 1.738–9.566) (29). In the 2022 study, the results of the OR were greater, namely OR = 9.514.

The character of the house affects the number of rats that are found in it. The characteristics of the respondent's house that rats often encounter are the rough walls of the house made of wood or bricks, where there are holes in the walls of the house, the door, the roof, as well as sewerage for rats to pass through and become a way for rats to enter and exit home (24). The presence of rats at home will disturb the occupants, damage furniture, eat food eaten by humans, leave feces everywhere, and cause an odor that comes from rat urine (41).

Under normal circumstances, rats occupy their habitat according to their natural habits. However, the need for food sources drives rats out of their natural habitat towards more food sources (29). One of the best places to find food and shelter is a landfill. This is supported by prior research, which shows that landfilling conditions are a major factor affecting rat presence. Houses that have poor garbage disposal conditions have a 4.117 times chance of causing a rat population in the settlement. The condition of an open landfill is a potential place that rats like the most due to the presence of piles of garbage, namely leftover food, fish, bread, etc. Other research states that other environmental factors associated with the presence of rats are gutter conditions (p=0.016), landfill conditions (p=0.002), lighting (p=0.049), presence of vegetation (p=0.005), and presence of predators (p=0.028) (38).

Signs of the presence of rats are finding rat droppings in the house, rat bite marks, holes in the house ventilation gauze, traces and carcasses of rats around sewage drains, roads, fences, and even in residents' homes (42). The existence of rats will be very detrimental to society. The presence of rats can disturb comfort of the occupants of the house, the activity become disrupted,



work becomes inappropriate, damages goods and home furnishings, a possibility of food is eaten by rats, leftover food from rats is eaten by humans causing humans to become sick, window and ceiling diseases which are not tight so that it makes it easier for rats to enter. The third factor is the behavior of the occupants of the house in cleaning the kitchen, still paying little attention to kitchen cleanliness, organizing piles of goods, cleaning up leftovers and food ingredients scattered in the kitchen, and also the behavior of disposing of trash (43).

### **The Relationship between the Presence of Pets or Livestock and the Incidence of Leptospirosis in Settlements**

In the period of 2018 to 2023, seven articles were selected for discussion on pets or livestock related occurrence of Leptospirosis. In this case, there were five articles that stated that there was a relationship between the variables, while two articles stated that there was no relationship. This proves that there is indeed a relationship between the presence of pets or livestock and the incidence of Leptospirosis. The risk of developing Leptospirosis is 2.560 times greater for respondents who have pets in the neighborhood compared to those who do not have (44). The risk of transmitting Leptospirosis may increase by 3.146 times between the cage and an adjacent residence less than 10 m away. This is due to the fact that symptoms may not always be present in infected cattle. The environment of the house, for example sewers, water supply and plants, shall be polluted by contaminated livestock manure (45).

Rodents (rats) are the primary reservoir hosts for the transmission of Leptospirosis. However, pets and livestock are also transmission sources of Leptospirosis. The pets in question include cats and dogs, while farm animals are cows, goats, sheep, buffalo, pigs, chickens, ducks, birds, and insects. In the same way, wild animals like civets, squirrels, hedgehogs, and bats may act as carriers for *Leptospira sp.*, while foxes are also capable of doing so (46).

Livestock infected with Leptospirosis are very likely to transmit the disease to humans around them, but because Leptospirosis has symptoms similar to other acute febrile illnesses, cases of Leptospirosis are often diagnosed as other infectious diseases or even go unreported. In a study carried out in Yogyakarta, it was stated that 33.3% of cattle positively contained the pathogenic *Leptospira sp.* bacteria (47). Other research states that the cause of Leptospirosis in sheep and goats in Demak Regency, namely *Leptospira serovar Ichterohaemorrhagiae*, *Djasiman*, *Robinsoni*, *Bangkinang*, *Pyrogenes*, and in goats, is caused by

*serovar Habdomadis* (48). In order to estimate the impact of chronic Leptospirosis on cattle reproductive disorders, studies have been carried out. A total of 500 cows were selected and randomly tested for Leptospirosis in 25 different dairy herds with a history of reproductive losses in Rio de Janeiro, Brazil, and a total of 32% of the herds tested positive for *serogroup Sejroe*. Multiple factors are involved in reproductive failure and the exact impact of infectious disease can vary from region to region. In spite of this, the results of this study show that Leptospirosis, even in its silent chronic form, plays an important role in the physiopathology of reproductive disorders in the study area and that this scenario is likely to be similar to other tropical regions (49).

*Serovar L. interrogans Celledoni* is known to cause subclinical Leptospirosis, while *Bataviae* causes clinical Leptospirosis in dogs in Yogyakarta (50). The most frequently reported of clinical manifestations include acute kidney injury, hepatic impairment, pulmonary hemorrhage, and hemorrhagic diathesis. Early diagnosis and treatment may increase survival by around 80%, based on reports from a number of institutions. However, if the conditions, in this case get worse, the mortality rate can reach 70% (51). Fever, lethargy, anorexia, vomiting, jaundice, kidney disorders, dyspnea, polyuria, yellow urine, dehydration, and death are the clinical symptoms of Leptospirosis reported in dogs in Indonesia (50).

Moreover, Leptospirosis in cats rarely causes clinical problems, but cats can transmit *Leptospira sp.* through urine to other animals, humans, and the environment. There is a case of subclinical Leptospirosis in cats in the Yogyakarta region caused by *Leptospira interrogans serovar Tarrasovi* (52). Approximately 1 out of 10 cats may be exposed to *Leptospira sp.* and the disease is more frequently found in cats with walkway access. There is a three times increased risk for the occurrence of Leptospirosis infection in cats with street access. It is similar to what is found in dogs (53).

However, infected pets and livestock sometimes show no symptoms but can transmit Leptospirosis (29). *Leptospira sp.* site on the infected kidney causes little or no harm and maintenance of infection in that animal. After infection occurs in the kidney, livestock will eliminate *Leptospira sp.* in urine for up to 542 days (54). Pets and livestock are not always a risk factor for Leptospirosis because they are not infected with *Leptospira sp.*, so it will not cause Leptospirosis (24). However, the risk of transmission can occur when cleaning the cage, passing through the area around the shed, and washing pets or livestock. The thing to watch out for is when carrying out activities that touch pets and livestock and the surrounding environment. When this

livestock are infected by *Leptospira sp.*, it does not rule out the possibility of polluting the environment along the way or while in the river through their urine. The chance for Leptospirosis to occur is quite large, considering that many people still do bathing, washing, and swimming in the river.

## CONCLUSION

The results of the analysis of abiotic and biotic environment risk factors with the incidence of Leptospirosis in settlements from articles published in the range of January 2018 – April 2023 show that temperature, pH, the presence of sewers, and the presence of puddles are risk factors for the abiotic environment associated with the incidents of Leptospirosis. In addition, the presence of rats and the presence of pets and livestock are abiotic environmental risk factors associated with the incidence of Leptospirosis. Obstacles in the process of article analysis are the limited reference sources for the latest articles that are appropriate to the topic and the suitability of the variables with the depth of the discussion. The authors hope that there will be further research regarding environmental risk factors with the incidence of Leptospirosis because the incidence of Leptospirosis caused by environmental factors still fluctuates significantly every year, both in terms of the number of cases and deaths.

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