JOIN HEALTH
JOURNAL OF INTEGRATED HEALTH

ISSN : 3123-9412
p-ISSN : 3124-6478

Vol. 1.2. Juli 2026

Original Research

"Flooding, sanitation, and water exposure as key risk factors for leptospirosis in Krakitan village"

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Leptospirosis is a zoonotic disease caused by Leptospira *bacteria, ranging from mild infection to severe multi-organ disease, with transmission closely linked to environmental exposure—particularly contact with water, mud, or floodwater contaminated by reservoir animal urine—especially in the presence of skin wounds or mucosal exposure. This study aimed to analyze environmental and behavioral risk factors associated with leptospirosis incidence in Krakitan Village, Bayat Subdistrict, Klaten Regency, a flood-prone area with reported cases. A quantitative observational analytic study using an unmatched case-control design was conducted among 140 respondents (70 confirmed cases and 70 controls). Exposure variables included flooding/standing water, drainage condition, presence of rats, sanitation/waste management, exposure to risky water/mud/river sources, personal protective equipment use, high-risk occupation, wound history, and animal contact, with age and sex as potential confounders. Data were collected through structured interviews and environmental observation, and analyzed using chi-square/odds ratio and multivariate binary logistic regression. Bivariate analysis identified five significant factors: flooding/standing water, presence of rats, risky water/mud/river exposure, high-risk occupation, and wound history. After adjustment for age and sex, five factors remained significant: flooding/standing water (aOR=4.60), wound history (aOR=4.61), risky water/mud/river exposure (aOR=3.77), poor sanitation/waste management (aOR=2.38), and high-risk occupation (aOR=2.32), with a classification accuracy of 74.30%. These findings indicate that environmental factors (flooding, sanitation, water/mud exposure) combined with behavioral/occupational factors (wound history, high-risk occupation) jointly contribute to leptospirosis incidence, underscoring the need for integrated prevention—improved drainage and sanitation, rat control, protective equipment education, and prompt wound care—prioritized by local health authorities in flood-prone rural areas.*

KEYWORDS: Leptospirosis, risk factors, environmental sanitation, flooding, case-control study

ARTICLE HISTORY
Received :22 Mei 2026
Revised : 01 Juli 2026
Accepted :14 Juli 2026

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INTRODUCTION

1. General background

Leptospirosis is a zoonotic disease caused by pathogenic *Leptospira* bacteria, with clinical manifestations ranging from mild febrile illness to severe multi-organ complications involving the kidneys, liver, lungs, and hemorrhagic system. Globally, the disease is estimated to cause approximately 1 million cases and 60,000 deaths annually, with a loss of 2.9 million disability-adjusted life years, and the highest burden occurs in resource-poor tropical countries, where incidence exceeds 10 per 100,000 population compared with 0.1–10 per 100,000 in high-income temperate countries (Nisa et al., 2025). In Indonesia, transmission is closely tied to environmental exposure to water, mud, or flood-affected areas contaminated by the urine of reservoir animals, particularly rats, and Central Java remains one of the regions with persistently reported cases, including in Klaten Regency, where Krakitan Village in Bayat Subdistrict has recorded recurrent local transmission linked to seasonal flooding.

2. State of the art

Recent studies continue to highlight the multifactorial nature of leptospirosis transmission, spanning environmental, occupational, and behavioral domains. A nationwide case-control study in Aotearoa New Zealand identified behavioural, occupational, and environmental risk factors amid a changing disease epidemiology previously dominated by male livestock workers (Nisa et al., 2025), underscoring the need for context-specific risk factor analysis. In Indonesia, a case-control study in Kebumen Regency using logistic regression found that individuals with a history of wounds had 40.20 times higher odds of leptospirosis, men had 2.58 times higher odds, and poor use of personal protective equipment increased the odds by 2.27, with risk further elevated in areas where rats and standing water were prevalent (Lestari et al., 2025). A separate case-control study in the same district similarly reported that occupation, history of injury, use of personal protective equipment, and poor personal hygiene were significantly associated with leptospirosis incidence (Inayah & Santik, 2023). Earlier evidence from Boyolali Regency, Central Java, also demonstrated a significant association between poor waste management and leptospirosis occurrence, with an odds ratio of 2.40 (Setyaningsih et al., 2022, as cited in Andriani & Sukendra, 2020). Case–control study of leptospirosis in Aotearoa New Zealand reveals behavioural, occupational, and environmental risk factors +2

3. Gap analysis / novelty

Although prior Indonesian studies have established individual associations between specific environmental or behavioral factors and leptospirosis, most were conducted with relatively small and unequal case-control ratios (e.g., 22–53 pairs), focused on single-district surveillance areas such as Kebumen and Pacitan, and rarely applied multivariate logistic regression to simultaneously control for confounding while estimating adjusted effect sizes and model performance (e.g., classification accuracy, pseudo R^2). This leaves an important gap in locally-grounded, methodologically robust evidence specific to Bayat Subdistrict, Klaten, an area with recurrent flooding but no prior case-control investigation. The present study addresses this gap by using a balanced 70:70 case-control design (n=140) in Krakitan Village and applying multivariate logistic regression to concurrently evaluate five environmental and behavioral risk domains, offering the first locally-specific, statistically adjusted risk profile for this endemic area and providing a quantitative basis (adjusted odds ratios, classification accuracy) for targeted public health intervention.

4. Hypothesis

Environmental and behavioral risk factors — including flooding/standing water, presence of rats, poor sanitation/waste management, exposure to risky water/mud/river sources, and history of wounds — are hypothesized to be significantly associated with the incidence of leptospirosis in Krakitan Village, independent of age and sex.

MATERIALS AND METHOD

Research Design

This study used a quantitative observational analytic approach with an unmatched case-control design to examine the association between environmental and behavioral factors and the incidence of leptospirosis.

Study Location and Period

The study was conducted in Krakitan Village, Bayat Subdistrict, Klaten Regency, Central Java, Indonesia. Data collection followed the period specified in the internal research grant contract, ethical clearance, and research permit.

Population and Sample

The target population comprised residents of Krakitan Village potentially exposed to leptospirosis risk factors. The case group consisted of residents who met the operational case definition of leptospirosis, while the control group was drawn from the same source population and had no diagnosis of leptospirosis. A total of 140 respondents were enrolled, consisting of 70 cases and 70 controls, fulfilling the operational sample target with no deviation from the proposed sample size.

Variables

The outcome variable was the incidence of leptospirosis. Exposure variables comprised flooding/standing water, drainage condition, presence of rat signs, sanitation/waste management, exposure to risky water/mud/river sources, use of personal protective equipment, high-risk occupation, history of wounds, and contact with at-risk animals. Age and sex were treated as potential confounding variables.

Research Instruments

Data were collected using a structured questionnaire, an environmental observation checklist, a case data extraction form, and a house-to-drainage distance measurement form.

Data Collection Procedure

Data collection was preceded by obtaining ethical approval and informed consent, followed by coordination with the local Public Health Center (Puskesmas) and village government. Case verification and control selection were then carried out, followed by enumerator training and instrument pre-testing. Structured interviews and household environmental observations were subsequently conducted by trained enumerators. Collected data were cleaned, coded, and entered for analysis.

Data Analysis

Univariate analysis was performed to describe respondent characteristics and the distribution of exposure variables. Bivariate analysis was conducted using the chi-square test (or Fisher's exact test where the expected cell count was below 5) to calculate crude odds ratios (OR) and 95% confidence intervals (CI). Variables with $p < 0.25$ in the bivariate analysis were included as candidates for the multivariate model. Binary logistic regression was subsequently applied to obtain adjusted odds ratios (aOR) and 95% CI, controlling for age and sex as confounding variables. Model adequacy was evaluated using Nagelkerke pseudo R^2, Akaike Information Criterion (AIC), classification accuracy, and multicollinearity diagnostics among predictor variables.

Ethical Clearance
This study was conducted following approval from the institutional ethical clearance committee and an official research permit. All respondents provided informed consent prior to participation. Respondent identity confidentiality was maintained through data coding, and all data were securely stored. Respondents retained the right to refuse or withdraw from participation at any stage of the study without consequence.

RESULTS
Respondent Characteristics
Table 1 shows the distribution of respondent characteristics by case and control groups. The proportion of respondents aged above 40 years was slightly higher among cases (71.40%) than controls (67.10%), while the proportion of male respondents was comparable between cases (55.70%) and controls (58.60%). This baseline similarity supports the assumption that cases and controls originated from a comparable source population, indicating that differences in leptospirosis incidence were more likely attributable to differences in environmental and behavioral exposure rather than to demographic imbalance. This is consistent with the multivariate analysis (Table 4), in which age and sex showed no significant association after adjustment for other exposure variables.

Table 1. Respondent characteristics by case and control group

Characteristic	Category	Cases n (%)	Controls n (%)	Total n (%)
Age	≤40 years	20 (28.60%)	23 (32.90%)	43 (30.70%)
Age	>40 years	50 (71.40%)	47 (67.10%)	97 (69.30%)
Sex	Male	39 (55.70%)	41 (58.60%)	80 (57.10%)
Sex	Female	31 (44.30%)	29 (41.40%)	60 (42.90%)

Distribution of Risk Factor Exposure
The distribution of exposure to each risk factor among cases and controls is presented in Table 2. Flooding/standing water was the most prevalent exposure among cases (74.30%), followed by presence of rat signs (65.70%) and exposure to risky water/mud/river sources (62.90%), while these exposures were consistently less frequent among controls.

Table 2. Distribution of risk factor exposure among cases and controls

Variable	Total n (%)	Cases n (%)	Controls n (%)
Flooding/standing water	85 (60.70%)	52 (74.30%)	33 (47.10%)
Poor drainage	70 (50.00%)	39 (55.70%)	31 (44.30%)
Presence of rat signs	79 (56.40%)	46 (65.70%)	33 (47.10%)
Poor sanitation/waste management	75 (53.60%)	43 (61.40%)	32 (45.70%)
Exposure to risky water/mud/river	71 (50.70%)	44 (62.90%)	27 (38.60%)
Inadequate PPE use	74 (52.90%)	40 (57.10%)	34 (48.60%)

Variable	Total n (%)	Cases n (%)	Controls n (%)
High-risk occupation	64 (45.70%)	38 (54.30%)	26 (37.10%)
History of wounds	58 (41.40%)	38 (54.30%)	20 (28.60%)
Contact with at-risk animals	51 (36.40%)	28 (40.00%)	23 (32.90%)

Bivariate Analysis

Table 3 shows the results of the bivariate analysis. Five factors were significantly associated with leptospirosis incidence ($p < 0.05$): flooding/standing water (OR = 3.24; 95% CI 1.59–6.60), presence of rat signs (OR = 2.15; 95% CI 1.09–4.25), exposure to risky water/mud/river sources (OR = 2.70; 95% CI 1.36–5.34), high-risk occupation (OR = 2.01; 95% CI 1.02–3.95), and history of wounds (OR = 2.97; 95% CI 1.47–5.98). Poor sanitation/waste management showed a borderline association (OR = 1.89; $p = 0.062$) that did not reach statistical significance at this stage.

Table 3. Bivariate association between risk factors and leptospirosis incidence

Risk factor	Crude OR	95% CI lower	95% CI upper	p-value	Conclusion
Flooding/standing water	3.24	1.59	6.60	0.001	Associated
Poor drainage	1.58	0.81	3.08	0.176	Not associated
Presence of rat signs	2.15	1.09	4.25	0.027	Associated
Poor sanitation/waste management	1.89	0.96	3.71	0.062	Not associated
Exposure to risky water/mud/river	2.70	1.36	5.34	0.004	Associated
Inadequate PPE use	1.41	0.73	2.75	0.310	Not associated
High-risk occupation	2.01	1.02	3.95	0.042	Associated
History of wounds	2.97	1.47	5.98	0.002	Associated
Contact with at-risk animals	1.36	0.68	2.72	0.380	Not associated

Multivariate Analysis

The multivariate logistic regression model (Table 4) involved 140 respondents, with a Nagelkerke pseudo R^2 of 0.25 and a classification accuracy of 74.30%. Multicollinearity diagnostics showed a maximum inter-predictor correlation coefficient of 0.19, well below the commonly used threshold of 0.8, indicating no serious multicollinearity among the variables entered into the model. After simultaneous adjustment, five factors remained significantly associated with leptospirosis incidence: flooding/standing water (aOR = 4.60; 95% CI 1.93–10.97), history of wounds (aOR = 4.61; 95% CI 1.96–10.84), exposure to risky water/mud/river sources (aOR = 3.77; 95% CI 1.62–8.78), poor sanitation/waste management (aOR = 2.38; 95% CI 1.05–5.41), and high-risk occupation (aOR = 2.32; 95% CI 1.02–5.28). Presence of rat signs and poor drainage no longer reached statistical significance in the adjusted model, although both retained a positive direction of association, likely reflecting shared variance with flooding and sanitation variables.

Table 4. Multivariate logistic regression model of risk factors associated with leptospirosis incidence

Variable	aOR	95% CI lower	95% CI upper	p-value	Interpretation
Flooding/standing water	4.60	1.93	10.97	0.001	Significantly increases odds
Poor drainage	2.26	0.98	5.21	0.055	Not significant
Presence of rat signs	1.91	0.85	4.28	0.115	Not significant
Poor sanitation/waste management	2.38	1.05	5.41	0.038	Significantly increases odds
Exposure to risky water/mud/river	3.77	1.62	8.78	0.002	Significantly increases odds
High-risk occupation	2.32	1.02	5.28	0.045	Significantly increases odds
History of wounds	4.61	1.96	10.84	<0.001	Significantly increases odds
Age >40 years (confounder)	1.18	0.49	2.82	0.709	Not significant
Male sex (confounder)	0.88	0.39	2.02	0.771	Not significant

Model summary: n = 140; Nagelkerke pseudo $R^2 = 0.25$; AIC = 166.40; classification accuracy = 74.30%; maximum inter-predictor correlation = 0.19 (no serious multicollinearity).

Association Between Flooding/Standing Water and Leptospirosis

Flooding/standing water showed the strongest association in the bivariate analysis (OR = 3.24; p = 0.001) and remained the most dominant factor in the multivariate model (aOR = 4.60). This finding is consistent with the transmission mechanism of leptospirosis, in which standing water prolongs the duration of skin and mucosal exposure to *Leptospira*-contaminated urine from reservoir animals while also expanding the potential contact area around residential settlements.

Association Between Drainage and Leptospirosis

Poor drainage was associated with leptospirosis in the bivariate analysis but did not reach statistical significance (OR = 1.58; 95% CI 0.81–3.08; p = 0.176), and remained borderline in the multivariate model (aOR = 2.26; p = 0.055). This is likely explained by overlapping exposure between poor drainage and flooding, since houses with poor drainage tend to also experience standing water, meaning part of the effect of drainage was already captured by the flooding variable. Poor drainage nonetheless remains policy-relevant as an upstream cause of flooding.

Presence of Rat Signs

Presence of rat signs was significantly associated with leptospirosis in the bivariate analysis (OR = 2.15; p = 0.027) but weakened in the multivariate model (aOR = 1.91; p = 0.115). As rat presence was assessed through indirect signs (tracks, droppings, burrows) rather than trapping, this result should be interpreted as an indication of potential reservoir presence rather than confirmed *Leptospira* infection in the local rat population. The attenuation in the adjusted model is consistent with rats being more frequently found in locations that also had flooding and poor sanitation, resulting in overlapping effects with those variables.

Sanitation and Waste Management

Poor sanitation/waste management showed a borderline association in the bivariate analysis (OR = 1.89; p = 0.062) but became statistically significant after adjustment for other variables (aOR = 2.38; 95% CI 1.05–5.41; p = 0.038). Poor waste management is thought to attract rat populations toward residential areas as a food source, thereby indirectly increasing the likelihood of human contact with *Leptospira*-contaminated environments.

Exposure to Risky Water/Mud/River Sources

Exposure to risky water, mud, or river sources was one of the strongest and most consistent factors across both models (crude OR = 2.70; aOR = 3.77; 95% CI 1.62–8.78). Activities involving direct contact with water, mud, or rivers increase the likelihood of skin and mucosal contact with environments potentially contaminated by reservoir animal urine, particularly when performed without adequate personal protective equipment.

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(**a**) (**b**)

Figure 1. Field data collection activities in Krakitan Village. (a) Research team conducting household visits and structured interviews with respondents; (b) Community-based data collection session with residents attending at a household setting.

DISCUSSION

This study confirms the hypothesis that environmental and behavioral risk factors are jointly associated with leptospirosis incidence in Krakitan Village, independent of age and sex. Five factors remained significantly associated with leptospirosis after multivariate adjustment: flooding/standing water, history of wounds, exposure to risky water/mud/river sources, poor sanitation/waste management, and high-risk occupation. Flooding/standing water and history of wounds showed the strongest associations, indicating that both the environmental medium of transmission and the individual pathway of pathogen entry contribute substantially to disease occurrence in this setting. This pattern is consistent with the conceptual framework proposed at the outset of this study, in which environmental/behavioral exposure leads to pathogen contact and subsequently to infection, with host characteristics acting as confounders rather than primary determinants — a conclusion supported by the non-significant association of age and sex after adjustment. These findings align with recent case-control evidence from other endemic settings. A nationwide study in Aotearoa New Zealand similarly identified overlapping behavioural, occupational, and environmental risk factors amid shifting leptospirosis epidemiology (Nisa et al., 2025), reinforcing that no single risk domain fully explains transmission. Within Indonesia, a case-control study in Kebumen Regency also identified history of wounds and inadequate use of personal protective equipment as strong predictors of leptospirosis, alongside elevated risk in areas with standing water and rodent presence (Lestari et al., 2025), a pattern closely mirrored in the present study's dominant factors. Similarly, a separate Kebumen-based study reported significant associations between occupation, wound history, and poor personal hygiene with leptospirosis incidence (Inayah & Santik, 2023). The association between poor sanitation/waste management and leptospirosis observed here is also consistent with earlier findings from Boyolali Regency, where poor waste management was linked to increased leptospirosis risk (Setyaningsih et al., 2022). Taken together, these cross-study consistencies suggest that flooding, wound exposure, and poor sanitation represent recurring, generalizable risk pathways across multiple endemic districts in Central Java, rather than findings unique to a single study population. At the same time, some findings diverge in magnitude from prior studies. The wound history association in Kebumen was markedly stronger (aOR = 40.20; Lestari et al., 2025) than in the present study (aOR = 4.61), which may reflect differences in case definition, wound severity classification, or local exposure intensity rather than a fundamental difference in the underlying biological mechanism. This discrepancy highlights the importance of interpreting adjusted odds ratios within their specific study context rather than assuming universal effect sizes across settings. From a theoretical standpoint, these results reinforce the established transmission model of leptospirosis, in which environmental reservoirs of contamination (standing water, poor sanitation) interact with individual susceptibility pathways (skin breaks, occupational exposure) to determine infection risk. Practically, the findings suggest that single-domain interventions — such as promoting personal protective equipment alone — are unlikely to be sufficient, since high-risk occupation remained significant independent of PPE use, suggesting that the nature and frequency of environmental contact during work activities may outweigh protective equipment availability alone. This implies that prevention strategies in Krakitan Village should be multicomponent, combining drainage and flood management, rodent and waste control, and prompt wound care, rather than relying on any single measure.

Several limitations should be considered when interpreting these findings. First, the case-control design is inherently susceptible to recall bias, as exposure information was obtained through retrospective interviews. Second, environmental conditions assessed at the time of observation may not fully reflect conditions during the actual exposure period. Third, rat presence was assessed through indirect signs rather than trapping and laboratory confirmation, so it should be interpreted as an indicator of potential reservoir presence rather than confirmed *Leptospira* circulation. Fourth, although the sample size of 140 respondents provided adequate precision overall, confidence intervals for several variables remained relatively wide. Finally, the possibility of residual selection bias in control recruitment cannot be entirely excluded, despite controls being drawn from the same source population as cases. Future research should consider a cohort design or incorporate rodent trapping with laboratory confirmation to validate reservoir involvement, expand the geographic scope beyond a single village, and examine interaction effects among the identified dominant risk factors to better inform targeted, resource-efficient prevention strategies.

CONCLUSION

This study demonstrates that environmental and behavioral factors are significantly associated with the incidence of leptospirosis in Krakitan Village, Bayat Subdistrict, Klaten Regency, thereby answering the study objective and supporting the proposed hypothesis. After adjusting for age and sex through multivariate logistic regression, flooding/standing water, history of wounds, exposure to risky water/mud/river sources, poor sanitation/waste management, and high-risk occupation remained independently associated with leptospirosis occurrence, with flooding/standing water and history of wounds showing the strongest associations. These findings indicate that leptospirosis transmission in this setting is jointly driven by environmental conditions that sustain pathogen contamination and by individual behavioral pathways that facilitate pathogen entry, rather than by demographic characteristics alone. Given these findings, leptospirosis prevention in Krakitan Village should prioritize improving drainage and reducing standing water at flood-prone points, strengthening waste management to limit rodent population growth, and promoting the consistent use of personal protective equipment together with prompt wound care among residents engaged in high-risk occupational activities such as farming or work in muddy or riverine environments. Local health authorities and village government are encouraged to integrate these measures into routine environmental health surveillance, while future studies may consider cohort designs or rodent trapping with laboratory confirmation to further validate reservoir involvement and strengthen the evidence base for targeted intervention.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the Institute for Research and Community Service (LPPM) of Akademi Keperawatan Patria Husada Surakarta for providing the internal research grant that funded this study. The authors also thank the Bayat Public Health Center (Puskesmas Bayat) and the Krakitan Village government for their coordination and support throughout the research process, as well as all enumerators involved in data collection and the respondents who willingly participated in this study.

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