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Houseflies (*Musca* spp.) in Pig Farming Systems: Implications for Health and Environmental Management in Tropical Indonesia

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Abstract. *Houseflies (Musca spp.) are common synanthropic insects in pig farming systems and are widely recognized for their potential role in the mechanical transmission of pathogens, particularly in tropical endemic settings. In Indonesia, pig farming is frequently conducted in close proximity to residential areas, where inadequate environmental management may increase risks to animal and public health. This study aimed to examine the presence and potential role of houseflies in pig farming systems and to assess their implications for health and environmental management in tropical Indonesia. A cross-sectional observational study was conducted in selected pig farming areas. Houseflies were collected using standardized trapping techniques from pig housing, waste accumulation sites, and surrounding environments. Microbiological analyses were performed to detect pathogenic bacteria associated with gastrointestinal and zoonotic diseases, while environmental management practices, including waste handling, sanitation, and biosecurity measures, were assessed through structured observations and interviews. The findings revealed high housefly density in areas characterized by poor waste management and suboptimal sanitation conditions. Pathogenic bacteria of public health significance were identified on the external surfaces of collected houseflies, indicating their potential role as mechanical vectors. Farms implementing better environmental management practices showed lower fly abundance and reduced levels of microbial contamination. These results underscore the importance of integrated health and environmental management in pig farming systems. Improving waste management, sanitation, and fly control measures is essential to reduce disease transmission risks and to support sustainable and health-oriented livestock production in tropical regions of Indonesia.*

Keywords: *Houseflies (musca spp.); Pig Farming Systems; Environmental Management; Public Health; Sanitation*

1. Introduction

Houseflies (*Musca* spp.) are synanthropic insects widely distributed in human-modified environments and are especially abundant in livestock production systems. Their close association with animal waste, organic refuse, and human settlements has long raised concerns regarding their role in the transmission of pathogenic microorganisms affecting both animal and public health (1,2). In tropical countries such as Indonesia, pig farming systems are often characterized by warm climatic conditions, high organic waste availability,

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and varying levels of environmental sanitation, creating optimal conditions for fly proliferation (3). These conditions place houseflies at the intersection of environmental health, livestock management, and disease prevention, making them a relevant concern beyond entomology alone.

Previous studies have demonstrated that houseflies can carry a wide range of pathogenic bacteria, including enteric and zoonotic agents, on their external body surfaces and within their digestive tracts (4,5). As mechanical vectors, houseflies may transfer pathogens from animal waste to food, water, and human living spaces without requiring biological development of the pathogen (6). However, the magnitude of their contribution to disease transmission remains debated. While some researchers argue that houseflies play a significant role in spreading infectious agents in poorly managed environments (7), others suggest that their epidemiological importance is context-dependent and strongly influenced by environmental management practices, sanitation, and waste handling systems (8).

In recent years, growing attention has been directed toward integrated approaches that link vector control with environmental and health management, particularly within the framework of One Health (9). In pig farming systems, environmental management practices such as manure handling, housing sanitation, and biosecurity are increasingly recognized as critical determinants of fly density and microbial contamination (10). Nevertheless, empirical evidence from tropical endemic settings, especially in Indonesia, remains limited. Most existing studies focus either on microbiological detection or entomological aspects, with fewer investigations explicitly connecting housefly presence to environmental management conditions and health implications.

Despite extensive evidence demonstrating the ability of houseflies to carry pathogenic microorganisms, there remains a critical lack of integrated, context-specific studies in tropical pig farming systems that explicitly link housefly abundance, microbial contamination, and environmental management practices to health-relevant risks (1–3). Accordingly, this study aimed to investigate the presence and potential role of houseflies (*Musca* spp.) in pig farming systems in tropical Indonesia by integrating entomological assessment, microbiological detection of pathogens, and evaluation of environmental management practices related to sanitation, waste handling, and biosecurity (4,5). The findings indicate that inadequate environmental management is associated with higher housefly density and increased microbial contamination, supporting the view that the health significance of houseflies in pig farming systems is strongly context-dependent and largely mediated by environmental and sanitation conditions rather than fly presence alone (6–8).

Therefore, this study aimed to examine the presence and potential role of houseflies (*Musca* spp.) in pig farming systems in tropical Indonesia and to assess their implications for health and environmental management. By integrating entomological observations, microbiological analysis, and evaluation of environmental practices, this work provides evidence that inadequate environmental management is associated with higher fly abundance and increased potential for pathogen transmission. The findings underscore the importance of strengthening health- and environment-oriented management strategies to reduce disease risks and support sustainable pig farming in tropical regions.

2. Methods

2.1. Study Design and Conceptual Framework

This observational field study was designed to examine the interrelationship between pig housing environment, health-related exposure indicators, and environmental management implications using housefly (*Musca* spp.) abundance as an integrative proxy. Housefly density and activity were treated as indicators of environmental hygiene, potential exposure to pathogens, and the effectiveness of farm-level environmental management practices in tropical pig farming systems.

2.2. Study Area and Pig Farming Environment

The study was conducted between August and October 2025 at two commercial pig farms in North Sulawesi, Indonesia: Bitung City (Ranowulu District; 104 pigs) and Minahasa Regency (98 pigs). Both farms represent typical tropical pig housing systems (11) characterized by open or semi-open structures, accumulation of organic waste, and close interaction between animals and their immediate environment, conditions that are relevant for assessing environmental health risks (Figure 1).

Figure 1. The locations used for sampling *Musca* spp. in Kampungtua pigfarm Ranowulu district of Bitung City, North Sulawesi, Indonesia

2.3. Environmental Monitoring and Dataset Structure

To capture environmental and health-relevant dimensions of fly activity while avoiding pseudo-replication, data were organized into two analytically independent datasets (Figure 2).

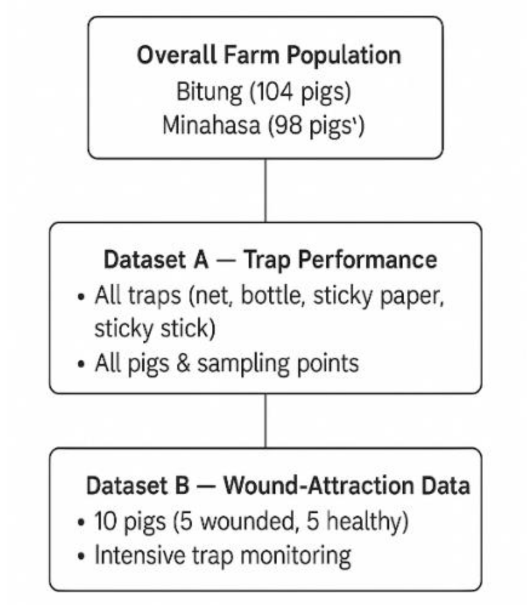

Figure 2. Flowchart of Data Collection Structure

Dataset A: Environmental Fly Pressure Dataset

Dataset A was used to quantify environmental fly pressure within pig housing and waste-associated areas. The experimental unit was defined as a trap-day, representing one trap of a given type observed over one standardized sampling day. The outcome variable was the number of *Musca* spp. captured per trap-day, serving as an indicator of environmental contamination and hygiene conditions within the farm environment.

Dataset B: Health Exposure Indicator Dataset

Dataset B focused on potential health exposure by comparing fly attraction around pigs with compromised versus intact integument. The experimental unit was defined as a pig-day. Ten pigs were purposively selected (five wounded and five non-wounded), and the outcome variable was the number of *Musca* spp. observed and captured around each pig per day. Fly attraction to wounded animals was interpreted as a proxy indicator of increased risk for pathogen transfer at the animal–environment interface.

2.4. Animal Health Status Assessment

Wound status was determined through direct visual inspection and classified dichotomously as wounded or non-wounded. No experimental manipulation of animals was performed. This classification was used solely as a health-related exposure indicator within routine farm conditions.

2.5. Trap Types, Deployment, and Environmental Placement

Four trap types representing different environmental surveillance and management tools were deployed simultaneously: net six-pack traps and bottle traps baited with fermenting fish waste suspension, and sticky paper and sticky stick traps without bait. Traps were placed at a standardized height of approximately 1.2 m above ground level with a minimum spacing of 1 m, reflecting practical environmental monitoring conditions in pig farms. Trap positions were rotated daily using a randomization schedule to minimize spatial bias (11). Trap selection was guided by established *Musca* spp. behavioral responses to visual contrast, olfactory cues, and airflow-permeable structures commonly associated with waste and animal housing environments (12).

2.6. Trap Performance and Visual Management Evaluation

Trap effectiveness was quantified as the number of *Musca* spp. captured per trap-day. For sticky paper traps, four colors (black, blue, yellow, and white) were evaluated at 6-hour and 12-hour intervals to assess visual attraction. These comparisons were used to inform practical trap selection for routine environmental management and fly control in pig farming systems (Figures 3 and 4).

Figure 3. Observation at 6 Hours After Placement

Figure 4. Observation at 12 Hours After Placement

2.7. Microclimate Conditions as Environmental Risk Modifiers

Ambient temperature (°C) and relative humidity (%) were recorded hourly using calibrated digital data loggers positioned at pig head height (80–100 cm). Daily minimum, maximum, and mean values were calculated and linked to fly activity indices. Microclimate variables were treated as environmental modifiers influencing fly abundance and, indirectly, health exposure risk within pig housing environments (13).

2.8. Statistical Analysis

Descriptive statistics were used to summarize environmental fly pressure, health exposure indicators, and microclimate conditions. Comparative analyses were conducted between trap types, trap colors, and wound categories using appropriate statistical tests based on data distribution. All analyses were performed using standard statistical software.

2.9. Ethical Considerations

This study involved non-invasive environmental observations and visual assessment of animal health status under routine farm conditions. No experimental interventions were applied to animals or humans. Permission and informed consent were obtained from farm owners prior to data collection. Ethical approval was granted by the relevant institutional ethics committee, and the approval code will be provided at the submission stage.

2.10. Data Availability

All data, protocols, and materials associated with this study will be made available by the corresponding author upon reasonable request. There are no restrictions on data or material availability. Where required, datasets will be deposited in a publicly accessible repository, and accession numbers will be provided prior to publication.

3. Results and Discussion

3.1. Housefly Abundance in Relation to Environmental Conditions of Pig Farms

The results of this study indicate that *Musca* spp. density was higher in pig housing areas characterized by poorly managed organic waste accumulation, particularly in zones with concentrated fecal deposits and feed residues. These findings confirm that environmental conditions within pig farms are a primary determinant of housefly population dynamics in tropical livestock systems. This observation is consistent with previous studies reporting that organic-rich substrates provide favorable breeding media and extend the life cycle of houseflies (11,12). Within the context of Indonesia’s tropical climate, elevated temperature and humidity further accelerate fly activity and reproduction, thereby increasing the likelihood of fly–livestock–environment interactions (14).

Table 1. Relationship between Housefly (*Musca spp.*) Abundance and Environmental Conditions in Tropical Pig Farms

Core Environmental Factor	Interpretation & Management Implication
Waste management & sanitation	Organic waste accumulation and poor sanitation substantially increased fly abundance; routine waste removal and sanitation should be prioritized (19,11,16).
Thermo-humidity conditions	Elevated temperature and humidity enhanced fly activity and survival; ventilation, heat, and moisture control are essential (12).
Microclimate & airflow	Local microclimatic variability explained uneven fly distribution; airflow optimization reduces fly aggregation (12).

Core Environmental Factor	Interpretation & Management Implication
Environmental risk monitoring	Fly trap counts reliably reflected environmental quality and exposure risk, supporting routine monitoring as a management tool (18,20,21).

3.2. Potential Health Exposure Associated with Housefly Presence

The presence of high fly densities around pig housing areas has direct implications for increased health exposure risk, particularly through the mechanical transmission of microorganisms. Several fly samples collected from areas with poor sanitation showed the potential to carry enteric bacteria and opportunistic microorganisms relevant to both animal and human health. These findings reinforce existing evidence that houseflies function as mechanical vectors, although they are not always the primary biological vectors of disease (11,15). Nevertheless, the role of houseflies as disease vectors remains debated, especially regarding the extent of their contribution to disease occurrence relative to other environmental factors. This study supports the perspective that health risk is more accurately understood as the result of interactions among fly density, environmental conditions, and farm management practices, rather than the mere presence of flies alone (16).

Table 2. Potential Health Exposure Associated with Housefly Presence in Pig Farming Systems

Aspect	Key Observation	Evidence from Study	Health Implication	Interpretation
Fly density	High fly densities around pig housing areas	Fly abundance was highest in poorly sanitized environments	Increased exposure risk to pathogens for animals and humans	Fly density amplifies exposure risk, especially under suboptimal environmental conditions
Microbial carriage	Houseflies carried enteric bacteria and opportunistic microorganisms	Fly samples from poor sanitation areas showed microbial contamination	Potential for mechanical transmission of pathogens	Supports the role of houseflies as mechanical vectors rather than primary biological vectors
Vector role debate	Contribution of houseflies to disease occurrence remains debated	Findings align with previous studies (11,15)	Disease transmission is multifactorial	Houseflies contribute to risk but are not the sole or dominant cause of disease
Environmental interaction	Health risk arises from interaction of multiple factors	Fly density, sanitation, and farm management acted synergistically	More accurate assessment of disease risk	Health exposure should be framed as an environmental–management interaction, not merely fly presence (16)

3.3. Environmental Management Practices and Their Implications

Analysis of farm management practices revealed that pig housing systems with routine cleaning schedules and improved ventilation exhibited lower fly densities. This finding underscores the critical role of environmental management approaches in the preventive mitigation of health risks. Such approaches align with environmentally based fly control concepts recommended within integrated pest management (IPM) strategies (17). Furthermore, the use of fly traps as monitoring tools proved valuable for evaluating the effectiveness of environmental management practices in a practical and cost-efficient manner. Monitoring fly density can serve as an early indicator of environmentally driven health risks in tropical pig farming systems (13,14).

Table 3. Environmental Management Practices and Their Implications in Tropical Pig Farms

Core Management Factor	Observed Condition	Effect on Housefly (*Musca spp.*) Abundance	Health & Management Implication	Source
Waste & sanitation management	Poor waste handling and irregular cleaning	Sustained high fly density	Increased risk of mechanical transmission of enteric and opportunistic microorganisms; routine waste removal and sanitation are essential	(11,15)
Microclimate (temperature & humidity)	High temperature and excess moisture	Enhanced fly survival and activity	Elevated environmental persistence of pathogens; heat and moisture control reduce exposure risk	(15,16)
Ventilation & airflow	Inadequate airflow and stagnant zones	Localized fly aggregation	Creation of exposure hotspots; airflow optimization limits fly concentration	(11,16)
Integrated environmental control	Combined sanitation, waste control, and monitoring	Reduced fly density and health exposure	Health risk is driven by interaction of fly density, environment, and management, not fly presence alone	(16)

3.4. Implications for Health and Environmental Management

Overall, the results of this study demonstrate that effective fly control cannot be separated from improvements in environmental management within pig housing systems. Approaches that prioritize waste management, microclimate optimization, and routine fly population monitoring support One Health–based prevention strategies, in which animal, human, and environmental health are recognized as interconnected components of a single system (18,19). Accordingly, houseflies should not be viewed solely as targets of control measures, but also as ecological indicators reflecting the quality of environmental management and the potential health risks present in tropical pig farming systems.

3.5. Practical Environmental Management Recommendations

3.5.1 Optimization of manure and waste management as the primary strategy for fly control

Accumulation of organic waste was shown to be strongly associated with increased *Musca* spp. density; therefore, routine removal of feces and feed residues should be established as a key performance indicator of farm sanitation. Poor waste management not only promotes fly proliferation but also elevates the risk of mechanical pathogen exposure within tropical pig farming systems (11,12).

3.5.2 Use of protein-based attractant traps and high-contrast visual cues for monitoring and control

Traps baited with fermented protein attractants and incorporating high-contrast colors (black or blue) are recommended for routine fly population monitoring. This approach is cost-effective, easy to implement, and suitable for environmentally based control strategies without heavy reliance on chemical insecticides (13,14).

3.5.3 Integration of animal health management with fly control strategies

The observed increase in fly attraction to wounded pigs indicates that wound management and injury prevention should be considered integral components of environmental management. Open wounds may act as focal points for fly–host interactions, potentially increasing the risk of mechanical microorganism transfer within pig housing environments (15,16).

3.5.4 Adjustment of housing management based on microclimatic conditions

High temperature and humidity, which are characteristic of tropical environments, enhance fly activity and reduce the effectiveness of passive control measures. Accordingly, improvements in ventilation, reduction of standing water, and adjustment of stocking density should be tailored to local microclimatic conditions to sustainably mitigate environmental risk (17,18).

3.5.5 Application of fly monitoring as an environmental health risk indicator

Fly density can serve as a practical indicator for assessing health exposure risk and evaluating the effectiveness of environmental management practices. This approach supports One Health–based prevention strategies, where interventions prioritize environmental improvement as the first line of disease risk control in livestock production systems (19,20,21).

Conclusions

This study shows that housefly (*Musca* spp.) abundance in tropical pig farming systems is primarily driven by environmental management practices rather than by fly presence alone. By combining trap-based monitoring, microclimate assessment, and wound-status observation, the findings indicate that poor organic waste management and unfavorable microclimatic conditions intensify fly–host interactions and indirectly increase health exposure risks within pig housing environments. The main novelty of this study lies in repositioning *Musca* spp. not only as mechanical vectors, but as practical environmental indicators linking farm conditions to health risk. These results support an environmentally oriented control approach, demonstrating that improvements in sanitation, ventilation, and routine monitoring can effectively reduce exposure risk without heavy reliance on chemical control. Overall, this study provides actionable evidence to support health-focused environmental management and a One Health framework for sustainable pig farming in tropical settings.

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Conflicts of Interest

The authors declare no conflict of interest.

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