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Risk Assessment of *Salmonella* spp. Exposure Among Chicken Farm Workers in Phatthalung Province, Southern Thailand

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Abstract

This study examined the risk of *Salmonella* spp. exposure among chicken farm workers by evaluating occupational health management practices. The probability of exposure was determined by assessing the number of contamination points. Sampling for *Salmonella* spp. contamination was conducted at 7 and 45 days of chicken batches across five areas, alongside evaluation of worker behaviors to assess exposure risk. Three of the 12 large closed-system farms, each housing >10,000 chickens, were selected. Results indicated that boots were the most contaminated items. Workers generally adhered to habitual boot-wearing, which reduced the risk of exposure. Moderate levels of workers' exposure prevention practices, combined with good farm environmental management, resulted in low contamination levels. Reducing *Salmonella* spp. accumulation was therefore crucial for minimizing contamination. In brief, the chicken farm workers in Phatthalung face measurable risks of *Salmonella* spp. Exposure reduction, strengthening occupational health management, and improving workplace practices are essential to mitigating these risks and protecting both farm workers and the broader community.

Keywords: chicken farm, exposure, risk assessment, *Salmonella* spp., workers

Introduction

The chicken farming sector in Thailand is a significant contributor to the national economy. Thailand ranks among the top 10 global chicken producers.¹ Bangkok-based companies, which are among the world's largest chicken producers, slaughter approximately 685 million chickens annually. These companies dominate chicken food production and maintain extensive agrifood networks across Asia and Europe.² Poultry farms in Thailand predominantly operate as closed-system farms, where environmental factors such as temperature, humidity, light, and ventilation are strictly controlled.³

Closed-system farming ensures optimal growth conditions and protection against infectious diseases, increasing production efficiency. However, inadequate management can make it difficult to isolate the farm from external contamination, leading to pathogen introduction, especially in farms that prioritize low operational costs. Previous studies indicate that contamination is significantly associated with the implementation of effective biosecurity and hygiene measures, including clean farm equipment, rodent control, and proper worker hygiene.³

Production standards, such as vaccination and standardized pathogen management measures, help control disease transmission in chickens and reduce the risk to consumers.⁴ However, farm workers often lack adequate protection and standardized practices to prevent exposure to harmful pathogens.⁵ *Salmonella* spp. contamination is a common issue on chicken farms, primarily resulting from exposure to chicken feces, droppings, and contaminated surfaces or soil.⁶ Chicken infected with *Salmonella* spp. can transmit the pathogen through fecal matter, which may contaminate water, feed, or the farm environment. Previous studies found pathogenic *Salmonella* spp. contamination in up to 65% of samples collected from closed-system farms,⁴ highlighting the ongoing occupational risk to workers.

Exposure of chicken farm workers to *Salmonella* spp. requires serious attention due to the potential for human illness,⁷ particularly foodborne disease, which can range from mild to severe and occasionally result in serious complications. Workers are exposed through direct contact with animals, improper handling of chicken feces or other waste, contact with contaminated surfaces or tools, and inadequate handwashing before eating.⁸⁻¹⁰ Typically, symptoms

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of *Salmonella* spp. infections in humans include fever, abdominal discomfort, diarrhea, nausea, and vomiting, appearing between 6 and 72 hours after exposure.¹¹ Complications can include septicemia or systemic infection.¹² In northern Thailand, typhoid *Salmonella* spp. incidence has been reported at 8.6 cases per 100,000 people per year,^{13,14} while *Salmonella* spp. contamination among workers was detected in 13.4% of animal farming areas in northeastern Thailand.¹⁵

The risk of *Salmonella* spp. exposure among workers is influenced by farm management and compliance with farming standards, including hygiene, environmental controls, wastewater management, and pathogen transmission prevention.¹⁶⁻¹⁸ Studies indicate that workers are most likely to contact contaminated surfaces such as door locks, boots, water faucets, gloves, and feeding dishes. Exposure may also occur via contaminated hands while handling food or beverages.¹⁰ Thus, hygienic work behavior is an important factor affecting risk.¹⁹⁻²¹ Insufficient caution and poor hygiene practices in contaminated environments increase the likelihood of *Salmonella* spp. exposure and associated occupational illness.

This study examined the risk of exposure to *Salmonella* spp. among workers on chicken farms by assessing the number of contamination points within the farm environment and the management of occupational health practices. Samples were collected to determine both the level of contamination and the increase of *Salmonella* spp. at high-risk contact points, and worker behaviors were evaluated to understand potential exposure pathways.²² The authors expect that the findings will provide practical evidence to improve occupational health management in chicken farms, particularly by guiding farm owners and workers to adopt effective hygiene and biosecurity practices. This study is also expected to serve as a reference for policymakers in developing regulations and interventions that reduce occupational exposure to *Salmonella* spp., thereby protecting both workers' health and the broader food supply chain.

The novelty of this study lay in conducting a context-specific risk assessment of *Salmonella* spp. exposure among chicken farm workers in southern Thailand, a region where chicken farming is both economically and culturally significant but underrepresented in the scientific literature. Unlike most previous studies that focus primarily on food products or animal carriers, this study integrated environmental sampling, microbial analysis, and behavioral assessment of workers to comprehensively evaluate exposure risks. This combined approach offered new insights into how human behavior, workplace management, and environmental contamination interact to influence the transmission dynamics of *Salmonella* spp. within chicken farms.

Method

This study employed a cross-sectional design to assess the risk of *Salmonella* spp. exposure among chicken farm workers. The design focused on evaluating occupational health management, *Salmonella* spp. contamination, and work practices associated with potential pathogen transmission. The study population comprised chicken farms in a subdistrict of Phatthalung Province, Southern Thailand. These farms represented typical large-scale chicken production systems in the region. Purposive sampling was used to select the study sites. Three of the 12 chicken farms in the subdistrict were selected as representatives of large, closed-system operations, each housing at least 10,000 chickens and meeting the standards of the Department of Livestock Development, Thailand. Selection criteria included similarity in production scale and management practices. Participation in the study was voluntary, and data collection was conducted from January to May 2022.

Data collection consisted of three stages. First, assessment of occupational health management and the work environment, second, sampling for *Salmonella* spp. contamination at contact points within the farm, and third, evaluation of workers' practices and behaviors that may increase exposure risk. A structured checklist was used to assess occupational health and farm environment conditions. The checklist was adapted from the chicken farm standards of the Department of Livestock Development and the Thai Chicken Exporters Association (2016),²³ as well as the occupational health and safety standards from the Department of Labor Protection and Welfare.²⁴ The checklist contained 18 items covering hygiene and environment management, clean water provision, wastewater and sewage management, and pathogen control measures within the farm.

The swab method was used to detect *Salmonella* spp. contamination at five potential exposure points: gloves, feeding dish, boots, water tap, and door latch. Samples were enriched in Rappaport-Vassiliadis (RV) broth to promote *Salmonella* spp. growth and streaked onto Xylose Lysine Deoxycholate (XLD) agar for selective isolation and identification based on colony morphology.^{25,26} Sampling was conducted at all three farms. Each of the five sampling points was swabbed three times to ensure reliability. Sampling occurred during two chicken growth periods: 7 days (early stage) and 45 days (late stage). In total, 90 samples were collected. Figure 1 illustrates the sampling points.

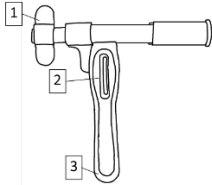
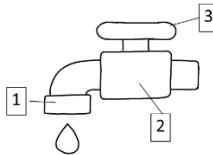
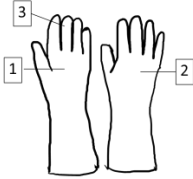
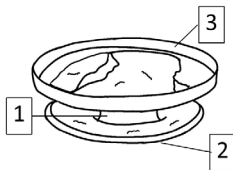

Location of Sample Collection	Illustration	Location of Sample Collection	Illustration
Door Latch Point 1: door latch Point 2: top of handle Point 3: bottom of handle		Water Tap Point 1: faucet head Point 2: the faucet Point 3: water valve	
Glove Point 1: palm position Point 2: back of the hand Point 3: finger position (middle finger)		Food Plate Point 1: central Point 2: lower part Point 3: upper part	
Shoe Point 1 on the side Point 2: front of shoe sole Point 3: back of shoe sole			

Figure 1. The Sampling Points

The following are *Salmonella* spp. analysis procedure: (1) Collect swab samples into Buffered Peptone Water (BPW); (2) Incubate BPW at 35°C for 24 hours; (3) Transfer cultures to Rappaport-Vassiliadis broth (1:10 dilution) and incubate at 35°C for 24 hours; (4) Streak culture onto XLD agar and incubate at 35°C for 24 hours; and (5) Count the number of colonies per plate. The evaluation of work-related behaviors posing a risk for *Salmonella* spp. exposure was conducted using a structured behavior observation checklist. Each farm employed 3–5 workers, and a total of 12 workers from the three farms were selected for observation. The authors recorded specific behaviors using a YES/NO scale, where YES indicated compliance with the recommended behavior and NO indicated noncompliance.

The checklist consisted of the following items: (1) wearing gloves while working, (2) wearing boots while working, (3) wearing a hygienic mask, (4) washing hands before leaving the farm, (5) cleaning tools after use, (6) having direct contact with chickens during work, and (7) dipping in disinfectant before entering or leaving the farm. Observations were recorded each time the worker performed the behavior, with observation sessions lasting 1–2 hours, depending on the work cycle. The work risk-behavior index was calculated by dividing the total number of YES responses by the total number of possible responses (YES + NO), providing a proportional measure of adherence to recommended practices. To ensure reliability, each worker was evaluated by three researchers, and the average score was used. Each item was then scored on a 4-point scale based on the percentage of compliant behavior: 4 points for 80%–100% adherence, 3 points for 50%–79% adherence, 2 points for 25%–49% adherence, and 1 point for <25% adherence. Scores were integrated as follows: good (3.26–4.00), moderate (2.51–3.25), and poor (1.00–2.50).

The risk assessment integrated scientific data and field observations to determine exposure risk, using a risk matrix based on contamination levels and worker behavior.²⁷ The risk level was determined by multiplying the probability of exposure by the contamination level. The probability scores were defined as 1 (low), 2 (moderate), and 3 (high). Contamination levels were similarly classified as 1 (low concentration), 2 (moderate concentration), and 3 (high concentration). Resulting risk scores were interpreted as follows: scores of 1, 2, or 3 indicated low risk; 4 or 6 indicated moderate risk; and 9 indicated high risk. A t-test was used to compare the levels of *Salmonella* spp. contamination between the 7-day and 45-day farming periods.

Results

Table 1. Assessment of Occupational Health Management and the Work Environment

Hygiene management	Sampling Area		
	Farm A	Farm B	Farm C
Adequate lighting in the building is suitable for chicken cultivation			
The ventilation system complies with the requirements of the Department of Livestock Development or product standards	✓	✓	✓
The inside road is surfaced with durable materials that do not cause dusting, or proper dust management methods are employed.	✓	✓	✓
Chicken food storage, feed mixing plant, chicken carcass, and waste are handled sanitarly.	✓	✓	✓
The entrance and exit are equipped with disinfectant methods, such as disinfectant plants or disinfectant ponds. ^a	✓	✓	✓
The surface stays dry. No stagnant water, simple to clean.	✓	✓	✓
The ceiling or roof must be at least 2-meter height.	✓	✓	✓
Tools, appliances, and materials must be cleaned and maintained in good condition.	✓	✓	✓
Water use, food sanitation, and potable water management			
Drinking water must be accessible, meet certain standards, and be in a separate location from the chicken house. ^b	-	-	-
The water used must be clean, suitable for use, free of animal manure, and sufficient for daily use.	✓	✓	✓
A kitchen or cafeteria that provides services to workers must comply to sanitary standards. ^c	-	-	-
Provide a clean sink and enough soap for handwashing.	✓	✓	✓
Management of wastewater, solid waste, hazardous waste, and sewage			
Manage all wastewater to control water pollution and odors.	✓	✓	✓
Provide containers that are clean and suitable for the waste type and amount.	✓	✓	✓
Provide a sufficient and hygienic toilet in a suitable location.	✓	✓	✓
Prevention and control of animals and disease-carrying insects			
Workers must receive training on hygiene and zoonotic disease prevention.	✓	✓	✓
An appropriate method to prevent animal-borne infections.	✓	✓	✓
After the chicken cultivation round ends, clean and disinfect the farm and its surroundings, and close the chicken house for at least 7–21 days.	✓	✓	✓

Notes: ^a = There is a disinfectant pond, ^b = There are no drinking water stations, ^c = The farm has no kitchen or eating area

Table 1 indicates that all three farms shared similar management practices. Each farm operated under a closed farming system and demonstrated hygienic management across all evaluated aspects. With respect to water use, food sanitation, and potable water management, none of the farms provided drinking water service points or eating areas within the farm. However, all farms had standard handwashing stations and adequate clean water. Regarding waste and wastewater management, each farm implemented measures to control pollution and odors consistent with the relevant standards. Furthermore, all farms applied methods to prevent the transmission of microorganisms, including disinfection procedures after each production cycle.

Table 2. Comparison of *Salmonella* spp. Colony Counts Across Sampling Times (7 Days and 45 Days)

Sampling Area	Day	Mean	SD	t-test	p-value
Latch	7	6.89	8.15	-1.608	0.127
	45	26.22	35.13		
Glove	7	0.56	1.01	-0.387	0.704
	45	0.78	1.39		
Boots	7	153.00	49.65	-2.132*	0.049
	45	191.22	20.70		
Water tap	7	7.00	11.92	0.271	0.790
	45	5.67	8.73		
Plate	7	2.56	2.51	-4.229*	0.001
	45	11.67	5.96		

Notes: SD = standard deviation, * = Independent t-test, p-value <0.05

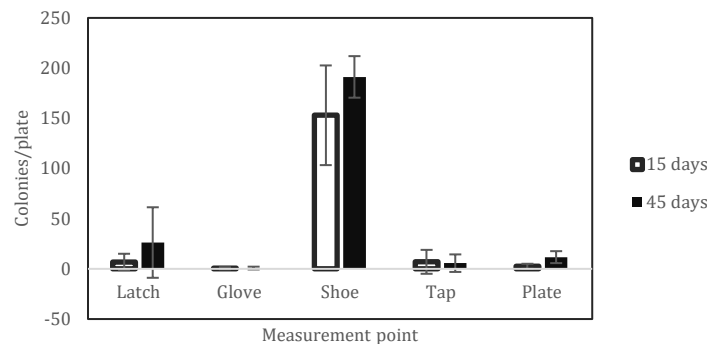


Figure 2. The Average Concentration of *Salmonella* spp. at the Sampling Areas

In Table 2, the results of *Salmonella* spp. sampling shows that boots had the highest contamination level at 7 and 45 days, with mean colony counts of 153 and 191 colonies per plate, respectively. These levels were significantly higher than those observed in the other areas. As illustrated in Figure 2, the amount of *Salmonella* spp. detected on the boots was substantially greater than that detected on the door latch, glove, water tap, and plate surfaces. The door latch showed mean counts of 6.89 and 26.22 colonies per plate at 7 and 45 days, respectively. Glove contamination was the lowest, with averages of 0.56 and 0.78 colonies per plate.

Table 3. Risk Assessment Based on Work-Related Behavior Observations

Behavior Observed	N	Average Score	SD	Result
1) Wear gloves while working	12	2.75	0.72	moderate
2) Wear boots while working	12	3.33	0.75	good
3) Wear a hygienic mask	12	3.08	0.76	moderate
4) Always wash hands before leaving the chicken farm	12	2.92	0.76	moderate
5) Clean the tools after each use	12	2.83	0.69	moderate
6) Have contact with chicken while working	12	3.08	0.49	moderate
7) Dip in disinfectant before entering or leaving the chicken farm	12	2.50	0.50	bad
Total	12	2.92	0.70	moderate

In Table 3, the evaluation of the behavior of workers in contact with *Salmonella* spp. showed that the average behavior of all workers as regards preventing infection was at a moderate level. The behavioral levels for reducing exposure risk were moderate. The employees consistently wear boots when they are working; this behavior was at a good level. It was found that dipping feet in a well of disinfectant was at a poor level. Most workers did not follow the correct steps for disinfectant dipping when leaving the farm.

Table 4. Risk Assessment of *Salmonella* spp. Exposure

Hygienic Work Behavior	Contaminated Area	Probability of Exposure	Contamination Level	Risk Level
Wear gloves while working	All areas that are touched by hands	2	1	2
Wear boots while working	boots and gloves	1	3	3
Wear a hygienic mask	Air	1	-	-
Always wash hands before leaving the chicken farm	Tap and gloves	2	1	2
Clean the tools after each use	Gloves	2	1	2
Have contact with chickens while working	Gloves, plate	2	1	2
Disinfect footwear by dipping it in disinfectant before entering and leaving the chicken farm	Boots	3	3	9

As shown in Table 4, the risk assessment integrates contamination risks and worker hygiene behaviors to determine overall exposure risk. Although the majority of behaviors resulted in low to moderate risk scores, failure to disinfect boots yielded a high-risk score of 9 due to high contamination on the boots and a high probability of exposure. These findings emphasized the critical role of boot disinfection practices in reducing *Salmonella* spp. transmission on poultry farms. Reinforcing biosecurity training and ensuring compliance in this specific behavior were essential to minimize pathogen spread and safeguard both worker health and poultry health.

Discussion

The results indicated a slight presence of *Salmonella* spp. in several areas, particularly at high-contact points such as the door latch, gloves, and water tap. These areas are highly vulnerable to contamination through hand contact.^{28,29} The findings showed that the gloves had minimal or no *Salmonella* spp. contamination. This may be because workers avoided direct contact with contaminated surfaces, cleaned their gloves after each use, and consistently wore gloves while working.³⁰ As a result, hand-contact surfaces such as the door latch and water tap showed low levels of contamination. These results were consistent with a previous study demonstrating that *Salmonella* spp. are more commonly found in chicken feces and chicken body surfaces than in the general farm environment.³¹ Accordingly, hand-contact areas were less likely to accumulate *Salmonella* spp. contamination. However, contamination at the door latch increased from day 7 to day 45. This might be related to repeated contact with contaminated equipment and frequent touching of the latch when entering and leaving the chicken house. Unlike gloves, which were cleaned after workers exited the farm area, there was no cleaning procedure for the door latch during cultivation.

Contamination levels on the feed plate were also low, despite repeated contact with the floor and chicken excrement. This might be explained by the regular cleaning of the plate after each use and by its plastic construction, which had a

smooth surface that can be cleaned easily and is less likely to support bacterial accumulation.³² In contrast, contamination on the boots was significantly higher than in other sampling areas. Boots come into direct contact with chicken feces and the farm floor, which likely contributed to the high contamination levels.^{32,33} Although workers consistently wore boots, they demonstrated poor compliance with disinfecting them before entering or exiting the farm area. As a result, areas contaminated via boot contact had substantially higher *Salmonella* spp. levels than hand-contact areas. However, disinfectant footbaths alone might not effectively reduce contamination if the disinfectant is improperly mixed, diluted by rainwater, or not replaced regularly. This suggested that proper maintenance of disinfection stations was critical to their effectiveness.

The comparison of contamination levels at 7 and 45 days showed a significant increase in *Salmonella* spp. as the cultivation period progressed. Although each farming cycle began with thorough cleaning and disinfection, microbial levels increased due to environmental factors, including the presence of chickens and feces, as well as high humidity.³⁴ These findings indicated that accumulation can occur even when routine cleaning is practiced. Therefore, an improved cleaning schedule targeting high-risk areas, particularly boots and entry points, may help reduce microbial buildup during the farming cycle.

The risk assessment results indicated that overall exposure risk to workers was low. Two primary factors influenced this risk: environmental contamination levels and workers' infection-prevention behaviors. While workers demonstrated only moderate adherence to hygiene practices, the farm's closed system and environmental management effectively minimized bacterial spread.¹⁵ However, because the boots exhibited both high contamination and low disinfection compliance, the risk of exposure related to this route was high. Overall, these findings suggest that the existing biosecurity measures are generally effective in maintaining a low baseline risk. However, targeted improvements, such as reinforcing boot disinfection procedures, monitoring compliance, and providing additional training, are necessary to further reduce occupational exposure. The study also highlights the interaction between environmental conditions and workers' behavior, indicating that both must be addressed together for effective risk reduction.

Structured checklists, repeated observations, and the use of multiple observers enhanced the reliability and validity of the behavioral data, while sampling across different growth phases and multiple risk points allowed a more comprehensive evaluation of contamination dynamics. The findings indicated that both environmental and behavioral factors contributed to worker exposure to *Salmonella* spp. suggesting a likely causal link between workplace practices and contamination levels. Targeted interventions, such as improving hand hygiene practices, reinforcing proper use of personal protective equipment, and increasing sanitation at identified high-risk points, could effectively reduce overall exposure risk. These findings highlighted the importance of integrated prevention strategies that combine behavioral training with environmental control measures in order to mitigate occupational exposure in chicken farms.

However, this study had limitations. The small sample size ($n = 12$) and variability in farm practices and production cycles may limit the generalizability of the findings. This absence of direct measures of airborne contamination, along with the possibility of observer bias, should also be noted. Additionally, data collection was restricted to farms that agreed to participate, potentially limiting the representativeness of all chicken farms in southern Thailand. Due to ethical considerations and COVID-19 restrictions, information regarding disease occurrence and individual exposure was not collected. Future research should increase the number and diversity of farms included and incorporate direct measures of health outcomes and exposure levels to better understand the relationships between *Salmonella* spp. contamination, occupational exposure, and infection risk in this work environment.

Conclusion

The overall risk of work exposure to *Salmonella* spp. among workers in the studied chicken farms is relatively low. Although worker compliance with preventive measures is moderate, effective environmental management within the farms helps reduce contamination levels, thereby lowering exposure risk. The high contamination observed on boots indicates that the floor and walkways were significant sources of contamination. However, consistent use of protective footwear helped lower the risk of exposure from these surfaces. Farm managers and policymakers prioritize regular training programs, systematic supervision of disinfection activities, and investment in effective environmental management systems to minimize occupational exposure and protect both workers and poultry production systems.

Abbreviations

RV: Rappaport-Vassiliadis; XLD: Xylose Lysine Desoxycholate; BPW: Buffered Peptone Water; SD: standard deviation.

Ethics Approval and Consent to Participate

Formal ethical approval was not sought because the study involved minimal risk and did not collect sensitive personal data. Participation was voluntary, and verbally informed consent was obtained from all participants before data collection.

Competing Interest

The authors declare no competing interests.

Availability of Data and Materials

Data is available from the authors upon request.

Authors' Contribution

NO conducted literature reviews, developed conceptual frameworks and methodologies, collected samples, performed data analysis, interpreted results, drafted the manuscript, and contributed to revisions. NM assisted with literature review, data analysis, result interpretation, and manuscript writing and revisions. All authors read and approved of the final manuscript.

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