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BIOSECURITY ADOPTION IN SOUTH ASIAN POULTRY SYSTEMS

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Biosecurity adoption depends on whether farmers can interrupt consequential contacts within households, farms, and poultry trading networks. This critical narrative review examines evidence published before May 2022, asking what farmers know, which precautions they can implement, and who controls remaining exposures. Targeted retrieval and primary-source checks identified 27 regional empirical publications covering seven South Asian countries. Knowledge, facility availability, reported and observed practice, pathogen detection, and production outcomes were evaluated separately. Disease awareness often coexisted with limited procedural knowledge, inaccessible veterinary services, or financial barriers. Farmers sometimes controlled returning egg trays while permitting the buyer to enter. Education and bundled support were followed by some improvements in knowledge or reported practice, but uncontrolled designs and limited follow-up weakened causal interpretation. A comparison of assisted and unassisted Bangladeshi markets found no clear difference in environmental H5N1 detection despite better reported practices. Credit, labor, care seeking, and trading arrangements shaped who could change relevant contacts. Future evaluations should measure repeated performance, biological outcomes, and the distribution of costs across participants. Uneven country coverage and incompatible instruments precluded a regional adoption estimate.

Key words: *Poultry biosecurity, South Asia, farmer knowledge, disease prevention, implementation barriers.*

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Introduction. Biosecurity requires people to interrupt contacts through which infectious agents enter, circulate within, or leave a flock. The biological objective is shared across poultry systems, but its implementation changes with housing, flock composition, labor, and trade. A broiler house can be emptied between batches, whereas a household may keep breeding hens and chicks together and a mobile duck flock depends on movement for feed. Effective guidance must specify the exposure it addresses and the person able to change it [1].

The feasibility problem was already recognized in Conan and colleagues' systematic review of backyard poultry in developing countries [2]. The present review examines the South Asian evidence published before May 2022 through three questions. What do farmers know about infection? Which precautions can they put into practice? Who controls the exposure that remains? Its contribution is to compare decision authority across households, commercial farms, and trading networks, while distinguishing reported knowledge, installed facilities, repeated behavior, and health outcomes. This distinction prevents a change in a questionnaire score from being interpreted automatically as protection against disease.

Review approach and evidence coverage. Eligibility required publication before May 1, 2022, irrespective of fieldwork year. No lower publication-date limit was imposed. An exact search query was '"biosecurity" "poultry" "Sri Lanka" before:2022-05-01'. Search operators did not reliably exclude later records, so publication dates were checked against publisher or bibliographic records. PubMed, PubMed Central, publisher websites, and institutional repositories supplied article text and metadata reached through results and reference tracing. Supplementary Section S1 records the queries and selection process.

Empirical reports were eligible if they concerned poultry production or directly connected household and trading activities in South Asia and measured knowledge, practices, resources, implementation, or a related biological or production outcome. Technical

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recommendations without uptake data and laboratory reports without a management connection were excluded from empirical synthesis. Contradictions were retained and examined by population, design, measurement, and period. Source-internal inconsistencies and unavailable details were recorded in Supplementary Table S2. Selection was purposive rather than exhaustive, and no independent duplicate screening or formal riskof-bias score was performed. SANRA informed the reporting of purpose, search methods, referencing, reasoning, and outcomes [3].

The selected corpus contains 27 regional empirical publications, distributed across Bangladesh (15), Nepal (4), Bhutan (2), Pakistan (2), Sri Lanka (2), Afghanistan (1), and India (1). These counts concern publications, with known linked research noted in Table S2. No comparable eligible Maldives farm-adoption study was identified. Local samples, uneven country coverage, and the prominence of avian-influenza studies limit generalization. The review treats a reported precaution, an observed action, pathogen detection, and production performance as distinct outcomes, summarized in Table 1. Incompatible adoption scores and infection measures were not pooled. The evidence describes what was known before the cutoff and does not estimate current regional compliance.

Table 1. Measures of biosecurity adoption and related outcomes

Measure	**Example and evidentiary basis**	**Interpretive limit**
Reported knowledge	Awareness and precaution recall in worker questionnaires [6].	Knowing an answer does not verify performance.
Facility availability	Reported foot dips and fencing in southern Bhutan [14].	Availability does not establish functionality or use.
Reported practice	Questionnaire reports of handwashing before and after visits [7].	Recall and desirable responding can differ from routine action.
Observed practice	Buyer entry and exclusion of returned egg trays [13].	Observation covers specified occasions and settings.
Farm-level viral RNA detection	Influenza A RNA in flock-associated fecal samples from nomadic ducks [19].	Detection does not identify the infecting contact or confirm H5.
Production outcome	Egg counts before and after management changes, without an untreated group [20].	Birds' progression through laying provides an alternative explanation.

What farmers know about infection. Awareness of a disease can coexist with uncertainty about prevention or access to help. All 150 commercial farmers surveyed in Chitwan had heard of avian influenza, but only about half believed it could be prevented. Recognition of poultry signs exceeded recognition of human signs [4]. In the Thimphu city area, 55 of 62 backyard keepers knew of the local outbreak, while only 17 knew how to obtain veterinary assistance [5]. These gaps concern different decisions. Explaining transmission, demonstrating a precaution, and making veterinary contact practical therefore require separate responses.

Procedural knowledge may be more relevant to action than exposure to information alone. Among 96 poultry workers in Rupandehi, Nepal, knowledge of protective measures and paid-worker status were associated with reporting more precautions. Media exposure was associated with knowledge but showed no corresponding association with reported practice [6]. Employment could provide equipment or supervision, although the study did not establish that mechanism or the direction between learning and practice. Its contribution is to separate the ability to recall advice from the conditions under which advice is used.

A separate survey of 122 workers from 44 farms in Sindhuli found that 93.4% had heard of avian influenza. Handwashing was reported much more often after farm visits than before entry [7]. The questionnaire relied substantially

on self-report and item denominators varied. Nonetheless, the direction of the difference is informative. Protecting the person after handling birds and protecting birds from an arriving person are different purposes, and an undifferentiated handwashing item would obscure which contact a reported practice addressed.

The distribution of poultry ownership also affects whom outreach reaches. A 2007 survey of 304 households in five accessible Afghan provinces included owners and nonowners. Poultry ownership was more common among poorer households, whereas higher socioeconomic status was associated with higher knowledge, attitude, and practice scores. Scores were higher in provinces receiving intensive outbreak communications, but outbreak experience and communication occurred together [8]. The contrast cannot isolate campaign effectiveness. It does show why a population-wide awareness gain may inadequately represent the households doing the daily feeding and care.

Belief-based explanations likewise require a behavioral endpoint. Gupta and colleagues modeled perceived capacity to carry out influenza precautions among backyard, broiler, and layer farmers in Bangladesh. Perceived benefits and barriers related differently to selfefficacy across production systems [9]. These associations do not establish that a precaution occurred. Confidence may reflect genuine access to resources, and low confidence may accurately identify their absence. Questions about beliefs are therefore most informative when paired with observation of the task and identification of the person who controls the necessary resources.

An uncontrolled qualitative study in two Bangladeshi villages examined whether greater awareness was followed by safer handling. After illustrated courtyard messages and household posters, participants described greater awareness of avian influenza, while initial postintervention observation found little behavioral change. There was no untreated comparison. Participants described inconvenience, discomfort, ridicule, and doubts about local disease presence. The study also included a later revisit during a poultry die-off [10]. These findings support the educational value of communication while limiting claims about sustained adoption. They favor investigating why a particular action remains difficult after its rationale is understood.

Antimicrobial decisions provide a related but distinct test of the knowledge–practice relationship. In a survey of 420 commercial poultry farmers in Bangladesh, knowledge and reported practice were positively correlated, while the attitude–practice correlation was not statistically significant. One-third sought antimicrobials outside registered veterinary advice [11]. The study included only men and did not measure microbiological resistance. Its findings support examining accessible advice and prescribing decisions alongside prevention, while withholding a causal claim that knowledge alone changes antimicrobial use or resistance.

Which precautions farmers can put into practice. A precaution can serve one protective purpose while increasing another exposure. In two Bangladeshi communities, backyard raisers recognized sick birds and bird-to-bird spread but did not recognize the corresponding zoonotic risk. Sick hens could be placed under a bed for care, then slaughtered, consumed, or sold if they failed to recover [12]. “Separating sick birds” would describe only part of this sequence. The appropriate assessment must identify the location of separation, contacts with people, and subsequent handling. Otherwise, a favorable questionnaire answer can conceal a consequential exposure.

Observation of small commercial farms reveals similar selectivity. Rimi and colleagues studied eight broiler and eight layer farms in Gazipur and Tangail. Sheds stood close to dwellings, and 15 farms had incomplete fencing or none. Farmers sometimes prioritized fencing the road-facing side. Some kept buyers’ returning egg trays outside while allowing the buyer to enter [13]. The contrast demonstrates practical understanding of one contact without establishing control of another. It also shows why fencing and visitor access should be assessed as working arrangements rather than simply present-or-absent features.

Entry infrastructure has several functions. Of 96 southern Bhutanese poultry holdings, 87 reported a foot dip, 30 a fence, and seven a visitor record. General education showed little

evidence of association with uptake in that sample [14]. These observations do not establish whether dips were functional or consistently used. In the Kathmandu Valley, absence of a visitor-boot rule was associated with H9 case status among 50 laboratory-confirmed case farms and 50 controls, with adjusted odds ratio 4.32 (95% confidence interval 1.52–12.29) [15]. A rule may represent broader management differences. The association identifies an entry procedure worth evaluating, without predicting the effect of purchasing boots alone.

Feed, water, and waste can maintain exposure despite entry controls. In Bangladesh, 16 farms supported to adopt good practices were compared with 16 conventional farms. Campylobacter occurred in bird, water, and attendants' hand-rinse samples. After slaughter in market stalls, three of 16 carcasses traced to supported farms and nine of 16 traced to conventional farms were positive [16]. Farm selection and later transport or slaughter could influence the contrast. Paired source-water and drinker sampling, interpreted with cleaning routines, would help locate contamination. Carcass differences support further investigation of the whole production chain, while leaving individual measures' effects unresolved.

Sri Lankan evidence illustrates the same distinction between compliance scores and biological outcomes. A survey of 80 Central Province broiler farms found uneven management, but correlations of the biosecurity score with mortality and feed conversion were not statistically significant. Sparse methodological detail and only one farm in the highest category limit interpretation [17]. In a separate processing study using 2006–2007 samples, Campylobacter was detected in caeca from 86 of 127 flock batches. Some caecalnegative batches yielded contaminated neck skins after processing. Nonrandom facilities and unequal pooling limited comparison of processing systems [18]. These findings support examining contamination across handovers, without attributing a processing result solely to the originating farm.

Waste removal can improve a shed while transferring exposure elsewhere. Bangladeshi small commercial farmers used or sold untreated poultry droppings as fertilizer or fish feed [13]. The material's economic value creates an incentive to remove it, but safe handling also depends on the recipient, transport, and destination. A removal score ending at the farm boundary misses these contacts. Similarly, permanent confinement would replace the feeding system of nomadic ducks. In 62 northeastern Bangladeshi duck flocks studied during 2011–2012, 58 had H5-antibody-positive eggs and 33 had influenza-A-RNA-positive fecal samples [19]. These are different biological signals. Neither identifies a transmission route, but both justify examining shared feeding and overnight sites within the mobile production system.

Production gains are meaningful to farmers, although before-and-after comparisons need care. Among 30 West Bengali backyard flock keepers receiving management advice, mean egg output increased from approximately 495 in the preceding three months to 618 in the following three. Birds averaged 24–25 weeks at enrollment, making progression through the laying cycle a plausible alternative explanation. The study lacked a concurrent untreated group, and flock totals did not adjust for daily numbers of laying hens [20]. The result supports measuring productivity in future evaluations, without establishing how many additional eggs a specific biosecurity practice produces.

A larger Bangladeshi program combined subsector training with technical support and cost-shared infrastructure at 12 commercial farms and four markets. Awareness and some reported precautions improved, but the changing survey samples, concurrent surveillance and culling, and absence of an untreated group prevented attribution of falling reported outbreaks to biosecurity alone. The authors reported that the apparent effect on disease incidence was limited several months after completion [21]. Compared with a short communication intervention, this approach addressed more material constraints. Its evaluation nevertheless shows why a larger package still requires separate measurement of implementation, infection, and persistence.

Who controls the remaining exposure. Control extends beyond the person tending the birds. Bangladesh production-network research combined interviews with producers, distributors, and other stakeholders to describe dependence on credit and input suppliers [22].

Ethnographic work showed how income volatility, debt, and concern about losses influenced farmers' assessments of biosecurity and rapid sale [23]. Dealers also enabled production that growers could not finance independently. Effective prevention must therefore consider what happens to debt, collection arrangements, and sale opportunities when illness appears. Removing an intermediary's influence without replacing those services could leave the underlying constraint unresolved.

Movement studies make this shared responsibility epidemiologically specific. Interviews with 1,389 vendors at 119 Bangladeshi markets and 520 mobile traders identified different connections in Dhaka and Chattogram. Inter-market transactions were prominent in Dhaka, while mobile traders supplying multiple markets created substantial connections in Chattogram [24]. These were potential routes, not observed chains of viral transmission. Nevertheless, a single questionnaire item about trader visits would collapse the distinction. Coordinated cleaning or collection arrangements must reflect the local pattern of repeated contacts.

Clinical evidence supports investigating the farm–market interface while preserving uncertainty about direction. In Pakistan, 133 H9N2 case farms were compared with 133 controls matched by month of sample submission. Direct sales to live-bird retail stalls were associated with case status. Controls were clinically classified, leaving uncertainty about unrecognized infection [25]. A separate Lahore study of 210 unvaccinated backyard chickens found higher odds of influenza antibodies near retail shops, adjusted odds ratio 6.9 (95% confidence interval 2.5–18.7) [26]. Antibodies establish prior exposure, and proximity can represent several contacts. The agreement strengthens the case for studying retail connections across production systems, without identifying a particular source or vehicle of infection.

Better facilities need not yield a detectable virological improvement. Biswas and colleagues compared ten FAO-assisted and 22 unassisted Bangladeshi live-bird markets in 2012. Several hygiene and waste-management practices were more common in assisted markets, but environmental H5N1 detection showed no clear difference, relative risk 1.10 (95% confidence interval 0.44–2.76) [27]. The wide interval allows materially lower or higher detection, and the observational comparison cannot isolate intervention effects. It provides an important counterweight to treating infrastructure completion as evidence of transmission control. Incoming infection pressure and the consistency of market routines should be evaluated alongside facilities.

Care seeking can precede official recognition of an event. In interviews with 70 Bangladeshi backyard raisers, 60 sought care from local providers and the others used home remedies alone. None described consulting government veterinary professionals. Distance and perceived service orientation mattered [28]. These historical accounts cannot estimate reporting rates for suspected influenza. They identify an existing contact through which unusual disease might be recognized and referred. The Rimi care-seeking and behaviorchange reports share a village research setting, so their observations should not be counted as independent regional replication.

Reporting also depends on its expected consequences. In Chitwan, 95 of 150 farmers identified whole-flock culling and 83 identified perceived inadequate compensation as barriers to reporting. Responses could overlap, and expectations about payment do not establish the legal entitlement or actual payment record [4]. Bangladeshi policy stakeholders described difficulty sustaining compensation after external funding ended [29]. Together these findings imply that clearer instructions alone cannot resolve financial uncertainty. A credible reporting arrangement requires accessible investigation and a response whose costs and support farmers can anticipate.

A household's ability to finance prevention depends on more than its average return. Longitudinal observation of 2,489 backyard poultry raisers in 115 Bangladeshi villages showed that birds contributed food and income with little cash expenditure [30]. A new housing or confinement requirement can add feed purchases and labor to that low-input system. Its value may also be understated if eggs consumed at home are ignored. Assessing affordability therefore requires the timing of

cash needs, who performs additional work, and whether the person responsible can authorize an investment. The evidence supports examining household authority directly rather than presuming a uniform division of decisions.

Testing whether precautions persist. The strongest conclusions concern the separation of knowledge, practice, and authority. Most infection-linked studies concern avian influenza. The Campylobacter comparisons extend the discussion to food-chain contamination, and egg production adds a livelihood outcome. They do not establish equal effectiveness against all poultry pathogens. Self-report, selective sampling, historical fieldwork, and scarce controlled follow-up further limit inference. Risk-weighted instruments can organize observations, but their weights and total scores are not themselves measured disease reductions [31]. Supplementary Table S2 preserves these distinctions so that disagreement is evaluated against the endpoint and design involved.

A household evaluation could follow one agreed precaution through hatching, seasonal changes, and caregiver absence. Repeated observations should distinguish access to housing, its condition, which birds actually use it, contamination in household spaces, bird losses, and additional labor. Comparing several communities per condition would help separate the intervention from local circumstances. Recording who proposes, finances, builds, and maintains a structure would test the authority explanation instead of assuming it. A measure that reduces one exposure while increasing losses that households cannot bear may be abandoned, so persistence and competing objectives should be assessed together.

A commercial evaluation could follow a buyer's route across successive collections. A negotiated loading procedure could be compared with that procedure plus cleaning equipment and adequate turnaround time. Repeated observation would establish whether the routine persists when schedules are crowded. Farm and market sampling would be interpreted with the interval between infection and detection, while costs and returns would be recorded separately for growers and traders. This would distinguish failure to perform a precaution from failure of a consistently performed precaution to protect. It would also identify whether the person expected to sustain the change receives enough benefit to continue it.

Conclusion. The pre-May 2022 evidence shows that understanding poultry disease, performing a precaution, and sustaining protection are separate achievements. Communication sometimes improved knowledge while observed practice changed little. Associations with infection or productivity identify useful priorities, but generally provide limited causal evidence. Household resources, credit, veterinary access, and trading relationships shape who can change consequential contacts. Evaluation should identify that person or organization and test whether a feasible precaution is repeated when flock composition, workload, or commercial pressures change.

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Daniel Sauvant. Упровадження біобезпеки у птахівництві Південної Азії

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Біобезпека у птахівництві залежить від здатності людей переривати контакти, через які поширюються збудники. Мета критичного наративного огляду — узагальнити опубліковані до травня 2022 року дані про знання птахівників, застосування профілактичних заходів і розподіл повноважень у виробничих та торговельних системах Південної Азії. Цільовий пошук і перевірка першоджерел дали змогу відібрати 27 емпіричних публікацій із семи країн. Окремо аналізували знання, доступність обладнання, повідомлені й спостережувані дії, виявлення збудників та продуктивність птиці. Відмінності вибірок, показників і методів оцінювання унеможливили обчислення єдиного регіонального рівня впровадження біобезпеки. Обізнаність про хвороби часто поєднувалася з браком практичних знань, обмеженим доступом до ветеринарної допомоги або фінансовими перешкодами. Окремі фермери не допускали використані яєчні лотки до пташника, водночас дозволяючи покупцеві заходити всередину. Після навчальних і комплексних програм іноді поліпшувалися знання та повідомлені практики, проте відсутність контрольних груп і тривалого спостереження обмежувала причинні висновки. У порівнянні ринків живої птиці Бангладеш поліпшені практики на підтриманих ринках не супроводжувалися чіткою відмінністю у виявленні H5N1 у довкіллі. Кредитні відносини, розподіл праці, звернення по допомогу та торгівля впливали на те, хто міг змінити небезпечний контакт. Оцінювання має встановлювати, чи повторюється захід за зміни складу стада, навантаження або умов збуту, та враховувати витрати й вигоди всіх учасників. Практичне значення огляду полягає в обґрунтуванні вибору між навчанням, матеріальною підтримкою та узгодженням торговельних процедур. Висновки характеризують історичну доказову базу й не є оцінкою сучасного стану біобезпеки в регіоні. Результати підтримують адресний підхід до конкретних шляхів передачі інфекції та потребують перевірки ефективності в різних виробничих умовах.

Ключові слова: *Біобезпека, птахівництво, Південна Азія, знання фермерів, профілактика хвороб.*