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Qualitative Risk Assessment of the Risk of Introduction and Transmission of H5N1 HPAI Virus for 1-km Buffer Zones Surrounding Compartmentalised Poultry Farms in Thailand

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Preface

Since its emergence, H5N1 HPAI has attracted considerable public and media attention because the viruses involved have been shown to be capable of producing fatal disease in humans. While there is fear that the virus may mutate into a strain capable of sustained human-to-human transmission, the greatest impact to date has been on the highly diverse poultry industries in affected countries. In response to this, HPAI control measures have so far focused on implementing prevention and eradication measures in poultry populations, with more than 175 million birds culled in Southeast Asia alone.

Until now, significantly less emphasis has been placed on assessing the efficacy of risk reduction measures, including and their effects on the livelihoods of smallholder farmers and their families. In order to improve local and global capacity for evidence-based decision making on the control of HPAI (and other diseases with epidemic potential), which inevitably has major social and economic impacts, the UK Department for International Development (DFID) has agreed to fund a collaborative, multi-disciplinary HPAI research project for Southeast Asia and Africa.

The specific purpose of the project is to aid decision makers in developing evidence-based, pro-poor HPAI control measures at national and international levels. These control measures should not only be cost-effective and efficient in reducing disease risk, but also protect and enhance livelihoods, particularly those of smallholder producers in developing countries, who are and will remain the majority of livestock producers in these countries for some time to come.

With the above in mind, this document aims to describe the process and results from a qualitative risk assessment conducted for Thailand in relation to the introduction and transmission of HPAI virus subtype H5N1 into the buffer zone surrounding compartmentalised poultry farms.

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Disclaimer

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Keywords

Avian Flu, Chickens, Ducks, Risk Assessment, Highly Pathogenic Avian Influenza, HPAI, Livelihoods, Markets, Market Shocks, Poultry, Poultry Production, Poverty, Smallholder Farms, Smallholders, Southeast Asia, Fighting Cocks, Compartmentalised Farms.

More information

For more information about the project please refer to www.hpai-research.net.

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Executive Summary

In Thailand, H5N1 infection was first reported on January 23, 2004 at a layer farm in Suphanburi province. Subsequently, several epidemic waves spread through Thailand, adversely affecting poultry farmers' livelihoods, commercial poultry production in general and human health, as well as tourism. In response to these epidemics, the Thai Department of Livestock Development (DLD) implemented various control measures, which encompassed stamping out of affected poultry flocks, pre-emptive culling of at-risk flocks, restricting poultry movements, banning free-range duck keeping, and improving bio-security and hygiene systems on poultry farms. Furthermore, DLD introduced a compartmentalisation system for commercial poultry enterprises. Implementation of these measures significantly reduced the incidence of HPAI outbreaks.

'Compartmentalised' poultry farms are mainly broiler production units belonging either to companies or to contract farmers. A key requirement for these farms is that specific disease surveillance and prevention activities (e.g. routine clinical surveillance and sampling of cloacal swabs) are carried out within a buffer zone of 1-kilometre (km) radius around the farm.

It is believed that compartmentalisation has had a significant impact in preventing further HPAI H5N1 epidemics in Thailand, much in contrast to other Mekong countries, which continue to experience small to medium scale outbreaks and minor epidemics.

In order to assess needs and possibilities for further HPAI risk mitigation in relation to poultry production within the buffer zones, DLD decided to conduct a formal risk assessment (RA) of HPAI virus introduction ('release') and spread in the 1km buffer zone. The RA was conducted by national risk assessors drawing on expertise from local scientists, field practitioners, and published as well as unpublished epidemiological knowledge.

A key advantage of this formal approach is that it transparently describes the relevant risk pathways and logic of the associated process of risk estimation. Due to the potentially large number of risk pathways to consider, information gaps, and to increase transparency of the process, a qualitative rather than quantitative approach was used.

Risk question and methodology

The principal risk question agreed upon by the risk assessment (RA) team was: "*What is the probability of introduction and transmission of H5N1 HPAIV into the 1-km buffer zone surrounding a compartmentalised (integrated) poultry farm in Thailand*?"

With respect to the identified risk question, the RA team identified seven pathways with the potential of introducing HPAIV subtype H5N1 into a buffer zone: (i) migratory birds, (ii) pests, (iii) free-ranging ducks, (iv) fomites, via humans, feeds, fertilizers and vehicles, (v) activities associated with poultry production sectors 2 and 3, (vi) activities associated with poultry production sector 4; and (vii) poultry products.

Data used in the RA were obtained from expert opinion workshops and the scientific literature. The DLD and KU organized four workshops to elicit expert opinion from veterinarians, farmers and researchers, and reviewed all locally available data while RVC reviewed relevant published scientific work.

The RA team applied six probability categories, adopted from the EFSA HPAI RA report 2006, to qualitatively estimate the risks associated with each pathway: Negligible, Very Low, Low, Medium, High and Very High. The level of uncertainty was also indicated in each step of a pathway using the following four categories, i.e. Low, Medium, High and Unknown.

The overall risk for each pathway was estimated by combining the probability of the presence of the virus at source and the probability of introducing the source into the buffer zone. The combination matrix was based on the principle of conditional probabilities where the probability of occurrence in the exposure and consequence pathway depends on the probability of occurrence in the preceding pathway, meaning an occurrence in the release pathway must precede an occurrence in the exposure. If the estimated risk of release is negligible, the combined risk across, release, exposure and consequence pathways will be assessed as being negligible.

Results

In the release pathways, the likelihoods for introducing the HPAIV subtype H5N1 into a buffer zone via wild birds, live poultry, free-ranging ducks, human and fertilizers were very low with uncertainty varying between pathways (Table I). Continuing on these risk pathways to the exposure and consequences, the probability of transmission of HPAIV subtype H5N1 within a buffer zone was considered very high for live poultry and medium for wild birds (Table II). However, the overall estimates of both risks were very low, due to the risk of release being very low (Table III).

Table I. Estimated risks and uncertainties for identified HPAIV introduction and release pathways.

Pathways for introduction and release of HPAI virus subtype H5N1 into a buffer zone	Risk	Uncertainty
wild birds	Very Low	Medium
live poultry	Very Low	High
free-ranging ducks	Very Low	Low
pests	Negligible	Medium
dogs and cats	Negligible	Medium
water	Negligible	Low
contaminated equipment	Negligible	Medium
feed	Negligible	Low
fertilizer	Very Low	Medium
poultry products	Negligible	High
humans	Very Low	Medium
vehicles	Negligible	High

Table II. Estimated risks with uncertainties for the exposure and consequence pathways.

Pathway for exposure to and transmission of HPAI virus subtype H5N1 within a buffer zone from	Risk	Uncertainty
infected wild birds to domestic poultry	Medium	Medium
introduced infected live poultry to domestic poultry	Very High	High
infected free-ranging ducks to backyard poultry	Very Low	Medium
contaminated fertilizer to domestic poultry	Very Low	Medium
infected or contaminated humans to domestic poultry	Low	High

Table III. Individual and combined risk estimates for introduction and transmission of HPAIV subtype H5N1 in 1-km buffer zones surrounding compartmentalised poultry farms in Thailand.

	Release		Exposure & Consequence		Overall risk	
Pathways	**Risk**	**Uncertainty**	**Risk**	**Uncertainty**	**Risk**	**Uncertainty**
wild birds	Very Low	Medium	Medium	Medium	Very Low	Medium
live poultry	Very Low	High	Very High	High	Very Low	High
free-ranging ducks	Very Low	Low	Very Low	Medium	Negligible	Medium
fertilizers	Very Low	Medium	Very Low	Medium	Negligible	Medium
humans	Very Low	Medium	Low	High	Negligible	High

Conclusions and recommendations

It is very encouraging that it was concluded that the overall risk for the key pathways was negligible for free-ranging ducks, fertilizer and humans, and very low for wild birds and live poultry. It needs to be recognised though that most of these estimates were associated with significant levels of uncertainty.

It is evident that the overall risk is only negligible to very low as a result of the negligible or very low risk of pathogen introduction (=release). It is important to monitor that risk level and to keep it negligible to very low, since the risk estimates for the exposure pathways indicate that introduction of the virus is likely to result in rapid spread.

The high level of uncertainty associated with many of the risk estimates, specifically for the pathways relating to live poultry and humans, indicate that there are significant knowledge gaps and that therefore the risk estimates need to be interpreted with caution. Targeted data collection should be initiated to fill some of the relevant knowledge gaps. The areas in particular need of data are the prevalence of HPAI in wild birds, the movement patterns of live poultry, particularly those of free-ranging ducks and fighting cocks.

The release pathways associated with live backyard poultry should be subjected to more detailed investigation. It was determined that they consist in fact of two separate pathways, one related to live backyard poultry trade and the other to fighting cock activity of backyard poultry farmers. Fighting cock activity in particular is likely to be associated with informal contacts and bird movements that may represent increased levels of risk for introduction of HPAI virus into a buffer zone. A quantitative risk assessment combined with targeted data collection should be conducted for these two specific pathways.

This risk assessment demonstrates how decision making in relation to disease control can be underpinned effectively by transparent presentation of data and qualitative risk estimates. Apart from defining risk pathways and estimating risks, this risk assessment compiled and documented the existing published literature and the local, unpublished epidemiological knowledge in relation to the defined pathways. It also showed how peer-reviewed information can be combined with expert opinion, while still being transparent about areas where scientific evidence is lacking.

Introduction

As part of the Department for International Development (DFID) funded Pro-poor HPAI Risk Reduction Project, a qualitative risk assessment was conducted for an agreed risk question related to avian influenza in Thailand. This activity was led by Kasetsart University (KU) and the Department of Livestock Development (DLD) base in Bangkok, Thailand, with support from the Royal Veterinary College (RVC) based in London, UK.

The risk assessment team first met on April 2008 to establish the risk question(s) and develop the associated risk pathway diagram(s). From April 2008 to August 2008, KU and DLD collected data through expert opinion workshops, review of unpublished literature and locally available data, while RVC reviewed all relevant published literature.

To assess the risks consistently, the risk assessment team used the following six qualitative probability categories, described in the EFSA report 2006 (Migratory Birds and their Possible Role in the Spread of Highly Pathogenic Avian Influenza). [Scientific report in Annex to The EFSA Journal 357, 1-46 (Table 1)].

Table 1. Interpretation of probability categories used in this risk assessment.

Probability Category	Interpretation
Negligible	Event is so rare that it does not merit to be considered
Very Low	Event is very rare but cannot be excluded
Low	Event is rare but does occur
Medium	Events occurs regularly
High	Event occurs very often
Very high	Event occurs almost certainly

The risks in the release and exposure pathways were estimated separately using the scales defined in Tables 5 and 6. The current data on HPAI subtype H5N1 in Thailand were used in the risk assessment process.

Table 2. Quantitative interpretation of qualitative risk categories in the release assessment for facilitation of communication and interpretation.

Risk	Frequency of occurrence	Prevalence (%)
Negligible	2 times per year	<=0.001
Very low	1 time per year	0.01
Low	3 times per year	0.1
Medium	1 time per month	1
High	1 time per week	10
Very high	Every day	>10

Table 3. Quantitative interpretation of qualitative risk categories in the exposure assessment for facilitation of communication and interpretation.

Risk	Probability of transmission to domestic poultry within a buffer zone given that HPAI virus subtype H5N1 has been introduced into the buffer zone
Negligible	<1%
Very low	5%
Low	25%
Medium	50%
High	75%
Very high	100%

The level of uncertainty for risk estimates was also indicated using the following 4 categories (Table 7). The first three categories were adopted from the EFSA report 2006 (Migratory Birds and their Possible Role in the Spread of Highly Pathogenic Avian Influenza; Scientific report in Annex to The EFSA Journal 357, 1-46). The last category was added for unknown data.

Table 4. Qualitative categories of uncertainty related to risk estimates.

Uncertainty Category	Interpretation
Low	There are solid and complete data available; strong evidence is provided in multiple references; authors report similar conclusions.
Medium	There are some but no complete data available; evidence is provided in small number of references; authors report conclusions that vary from one another.
High	There is scarce or no data available; evidence is not provided in references but rather in unpublished reports or based on observations, or personal communication; authors report conclusions that vary considerably between them.
Not Known	There is no data available, no reference, no personal communication, no experience.

Glossary and Definitions

Bantum: Poultry traded in village markets for decoration.

Buffer zone: An area of 1-kilometre width around a compartmentalized farm in which specific disease surveillance and prevention activities have been implemented (e.g. routine clinical surveillance and sampling of cloacal swabs). There are neither abattoirs nor live bird markets allowed within a buffer zone.

Compartmentalized farm: Co-operative or contract farms which have implemented the management and biosecurity system compliant with the OIE guidelines and the DLD requirements in order to improve the food security in production chain.

Duck keepers: Persons who take care of free-ranging ducks and move them from place to place. They are not necessarily the duck owners.

Egg trays or egg containers: Eggs (from ducks) can be traded either to pay the maintenance cost of the paddy field or to earn money for family support. They are carried on egg trays or egg container.

Farming systems and farm sectors: The poultry production system is classified into 4 sectors using the guidelines of FAO and DLD.

- Sector 1 = Industrial integrated systems with high level bio-security produce commercial birds/products to supply the domestic and international markets. Farms in this sector are certified against the criteria for compartmentalized farms defined by the DLD.

- Sector 2 = Commercial poultry production systems with moderate to high bio-security. Farms in this sector are certified against the standard farm criteria defined by the DLD.
- Sector 3 = Semi-commercial poultry production systems with low bio-security. For this report free-ranging ducks are not included in this sector.
- Sector 4 = Village or backyard production with minimal bio-security produces birds/products for local consumption.

Fighting cocks: Native poultry raised for cock fighting competitions.

Free-ranging ducks: Ducks are raised in flocks and freely moved from one geographical location (paddy rice field) to another by duck keepers. Free-ranging ducks are a category separate from poultry production sectors 1-4 defined above.

Pests: Rats, mosquitoes, flies and other possible vectors for AI transmission.

Manure: Poultry faeces and bedding collected from either the layer or broiler farms outside a buffer zone.

Non-processed poultry products: Eggs and dead chicken with feathers

Market: Open-air markets operating regularly for trade at a fixed location and time.

Resident birds: Wild birds resident in Thailand which may move across the country.

Unmilled rice: Non-processed rice

Live poultry: Domestic poultry including fighting cocks and backyard chickens, but excluding free-ranging ducks

Risk question used as the basis of the risk assessment

What is the probability of introduction and transmission of H5N1 HPAI infection into the 1-km buffer zone surrounding a compartmentalized (integrated) farm in Thailand?

Definition of Buffer Zone

A buffer zone is an area of 1 kilometre radius around a compartmentalized farm within which a defined set of surveillance, hygiene and disinfection activities have been implemented. The purpose (at least in theory) is to minimize the risk of avian influenza infection within the buffer zone.

According to the DLD regulations, poultry slaughterhouses are not allowed to be located within the buffer zone to prevent any movement of poultry across the zone. The clinical surveillance network in the buffer zone is strengthened so that it can rapidly respond to any poultry deaths, including more effective local communication and information exchange between the local and national level, etc.

For active surveillance within the buffer zone, cloacal swab samples for AI detection are taken at 3 month intervals and some compartmentalized farms may collect additional cloacal swab samples for testing. Poultry premises in the buffer zone are disinfected at 3-5 month intervals in accordance with the DLD's requirements for compartmentalization. There is variation in the population density, species and number of poultry among the buffer zones.

Based on the database of farm certification maintained by the DLD, there are currently 3 categories of compartmentalisation status: Firstly, a farm applying for the compartmentalization status. Secondly, a compartmentalized farm that has been certified with respect to its biosecurity system by the DLD and, lastly, a compartmentalized farm that has been certified with respect to its biosecurity system and accepted for inclusion in a 1-year disease monitoring DLD program. We included only the second and third categories of compartmentalized farms in this risk assessment.

Compartmentalized farms either belong to companies (company farms) or farmers (contract farms). There are differences with respect to geographical location and activities between company and contract farms. Company farms are large-scale farms and mostly located relatively distance from human settlements. This therefore results in a reduced risk of the AI transmission into their associated buffer zones. Additionally, some company farms have implemented their own disease surveillance and control activities within the buffer area to minimize the risks e.g. by performing additional cloacal swab sampling, removing poultry from the buffer zone during the high risk period, whereas these activities are rarely implemented by contract farms. These differences might affect the risks of AI transmission within the buffer zones. In this risk assessment, districts with a large number of company farms and contract farms were considered to minimize bias. In total, 4 districts (from 3 provinces) and 5 districts (from 5 provinces) were selected (Table 5). Relevant data was collected by interviewing local officers and farm owners.

Table 5. Number of contract and company farms included in the study by district.

District	Province	Number of contract farms	Number of company farms
Group 1: Company Farms			
Phatthanikhom	Lopburi	1	30
Chaibadan	Lopburi	2	20
Nakonchaisi	Nakonpathom	1	6
Phraphutthabat	Saraburi	1	2
Group 2: Contract Farms			
Mueang	Phetchabun	10	0
Banbueng	Chonburi	10	0
Nongmuang	Lopburi	10	0
Phanomsarakham	Chachoengsao	11	0
Kaengkhoi	Saraburi	16	0

Note: During the data collection period, 236 contract farms and 60 company farms were certified in accordance with the biosecurity standard specified by DLD, and categorised as Compartmentalised Farms.

Risk Pathways

The release, exposure and consequence pathways relevant for the specified risk question are described in the following sections.

Release Pathways

Seven risk factors were identified for the release of HPAI H5N1 into buffer zones around compartmentalised farms including (i) migratory birds, (ii) pests, (iii) free-ranging ducks, (iv) fomites (including humans, feeds, fertilizers and vehicles), (v) poultry sector 2&3 farms, (vi) poultry sector 4 farms and (vii) poultry products (Figure 1).

Exposure Pathways

The risk factors relevant for exposure of susceptible poultry within the buffer zones around compartmentalised farms were the presence of poultry sector 2 and 3 farms, backyard poultry population (sector 4), humans, free-ranging ducks and pets as the susceptible population within the buffer zone (Figure 2).

Consequence Pathways

Consequences of the introduction and transmission of the virus within the buffer zone were described at a farm and national level if there is an outbreak (Figure 3).

Period Covered by the Risk Assessment

The period of the assessment was seven months from January to July, 2008. There was no outbreak reported in Thailand during this period.

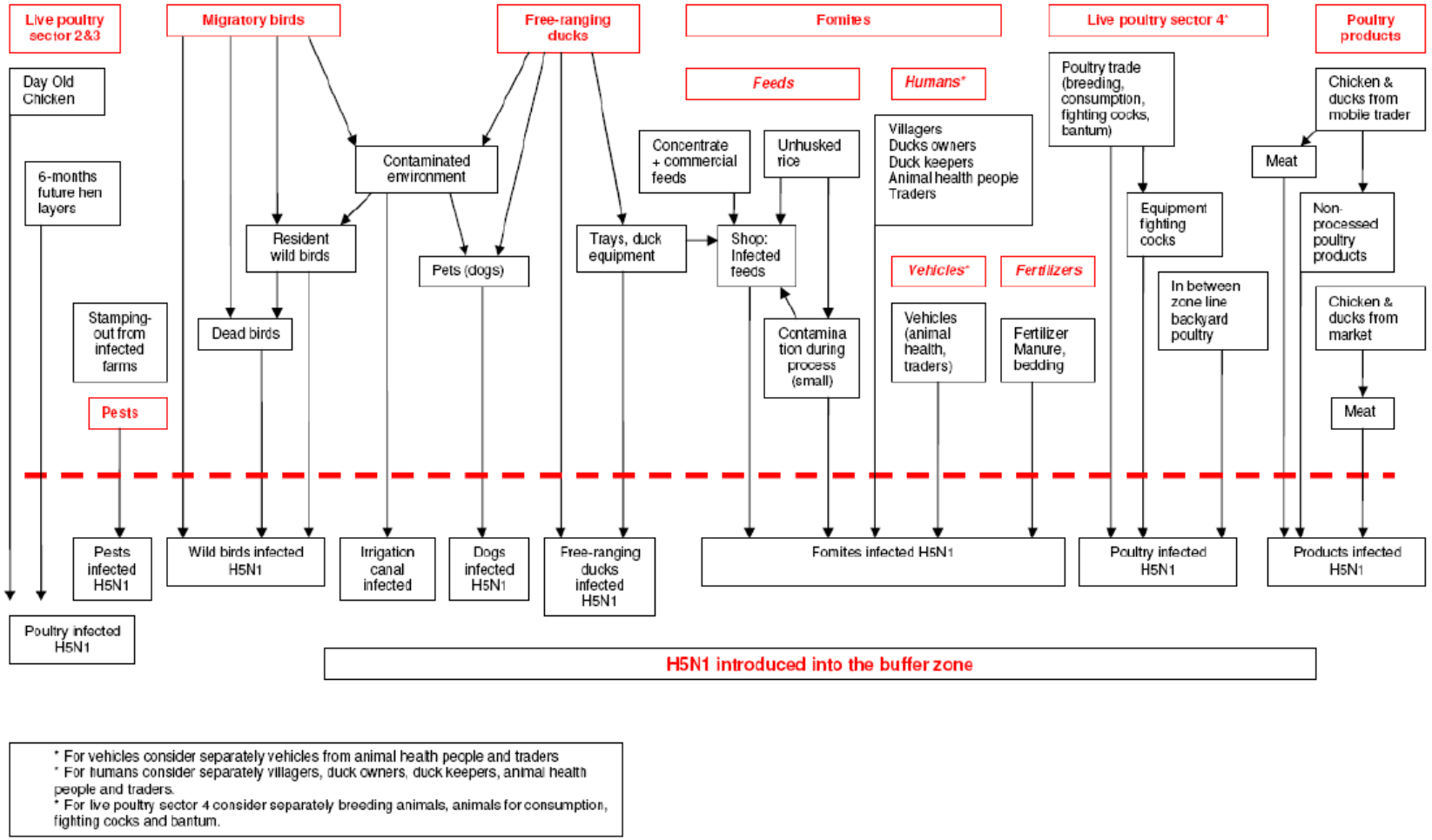

Figure 1. Diagram of release pathways of HPAIV H5N1 into buffer zones surrounding compartmentalised poultry farms in Thailand.

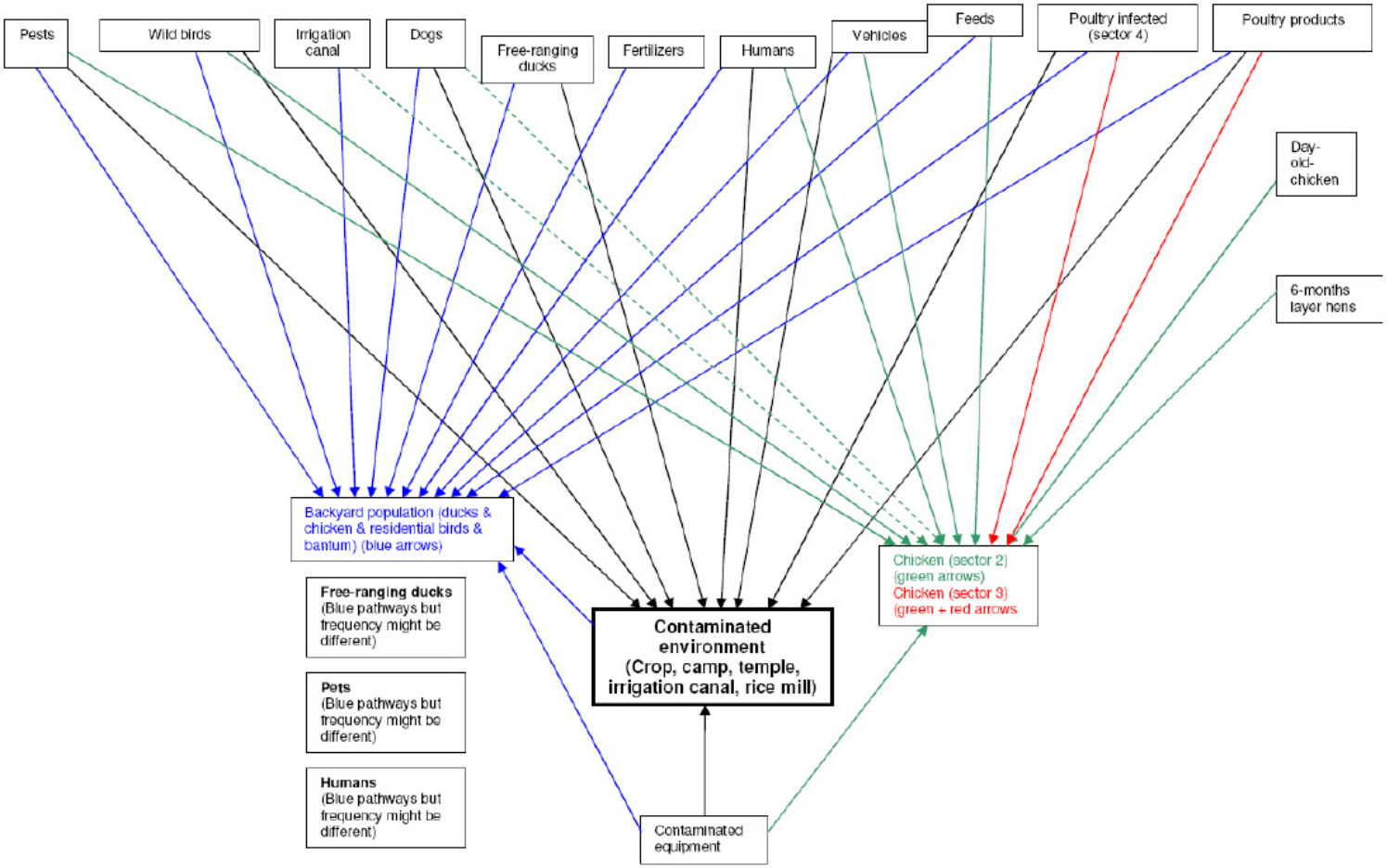

Figure 2. Diagram of exposure pathways for HPAIV H5N1 within buffer zones surrounding compartmentalised poultry farms in Thailand.

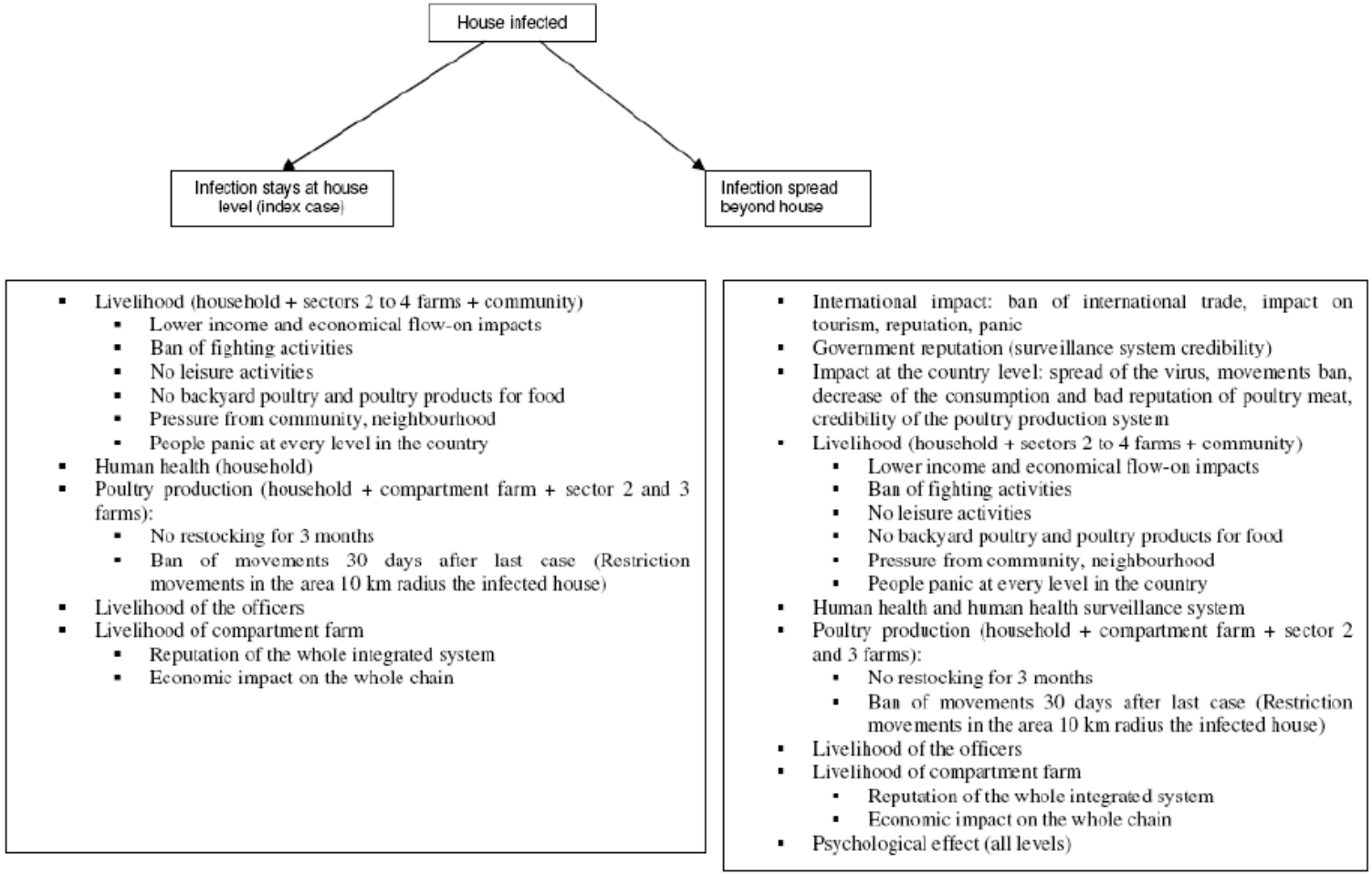

Figure 3. Diagram of consequence pathways for HPAIV H5N1 in buffer zones surrounding compartmentalised poultry farms in Thailand.

Data Needs and Data Collection

Data Needs

Data needed for the release, exposure and consequence assessment are summarized in Tables 6, 7, and 8.

Table 6. Data needed for the release assessment.

Release Assessment: 1. Always add the specificity and sensitivity of the tests used to assess the prevalence (in order to estimate the true prevalence); 2. Survival of virus in the environment means time/length of survival depending on the condition (humidity, temperature, etc).

Section of Release Assessment Pathway	Data Required
Wild birds	
Risk of migratory birds being infected with H5N1	Regions of origin – migration routes Season of migration Species of migration Species susceptible to H5N1 Carrier potentiality Case fatality rate Prevalence data in wild birds Abundance (distribution + density) of susceptible species
Risk of migratory birds contaminating resident wild birds	Species of resident wild birds Susceptibility of local resident wild birds to H5N1 Exposure of local wild birds (identifying area of concentration or mixing – aggregating sites, resting sites, and water bodies Virus survival in the environment
Risk of infected wild birds dead in the buffer zone	Case fatality rate Prevalence of infection in local resident wild birds
Free-ranging ducks	
Risk of free-ranging ducks being infected by H5N1	Prevalence of infection in free-ranging duck population Frequency of entry of free-ranging ducks in the buffer zone Hunting habits of dogs Frequency of dogs being in contact with ducks in the rice paddy fields
Risk of free-ranging duck industry contamination eggs trays and equipment	Prevalence of infection in free-ranging duck populations Contamination level of equipment and virus survival
Live poultry from sector 4	
Risk of live poultry being infected with H5N1	Species to be imported in the buffer zone: fighting cocks, animals for consumption, breeding animals, bantams Population data: prevalence of disease of infection in the populations Characterization of poultry husbandry and production systems in Thailand
Risk of equipment of fighting cocks being infected	Prevalence of infection in fighting cocks populations: contamination level of fighting cocks equipment and virus survival; frequency of movements in and out.

Section of Release Assessment Pathway	Data Required
Risk of resident backyard poultry being infected outside the buffer zone	Frequency of in between zone line movements of resident backyard poultry Prevalence of the disease in the backyard poultry outside the zone
Live poultry from sectors 2 and 3	
Risk of DOC being infected	Prevalence of the infection in DOC
Risk of 8 months future layer hens to be infected	Prevalence of the infection in 8 month hens future layers
Fresh poultry meat and other poultry products	
Risk of meat and visceral organs being infected with H5N1	Species to be imported into the buffer zone Population data: prevalence of disease infection in chickens and duck meat from mobile trades and prevalence of disease infection in chickens and ducks from markets Characterisation of poultry husbandry and production systems Survival of the virus in meat
Risk of eggs being contaminated with H5N1	Contamination level (chicken and ducks) Virus survival of eggs
Risk of un-feathered dead poultry being infected with H5N1	Survival of the virus in feathers
Feeds	
Risk of un-husked rice being contaminated	Prevalence of disease in poultry and wild birds that goes to the paddy fields
Risk of rice during the process (small rice mills) to be contaminated	Survival of virus in the processing of rice production: temperature, humidity, dry resistance Exposure to chickens, wild birds, pests, dogs and cats in rice mills Disease prevalence in chickens and wild birds Disease prevalence in pests, dogs and cats
Risk of feed from the manufacture industry and rice being infected in shop (packaging)	Biosecurity on bags of rice or feeds from the industry Condition of storage (place and time) Survival of virus
Equipment	
Cock fighting equipment	Population data: infection prevalence in fighting cocks Virus survival in equipment
Egg tray, mobile fences, spades; risk of egg trays being contaminated in a shop or contaminated from contact with ducks	Coming directly from the free-ranging flocks or coming from shops Prevalence of infection in free-ranging ducks Survival of virus in fomites, i.e. egg trays
Vehicles (cars, bikes, motorbikes, trucks)	
Risk of villagers' vehicles to carry H5N1	Origin of vehicles before entering the zone Frequency of journeys (villagers' habits) Survival of virus in fomites Awareness of not contaminating vehicles and associated biosecutiy measures

Section of Release Assessment Pathway	Data Required
Risk of health staff vehicles being contaminated and carrying virus	Origin of vehicles (other adjacent farms) Population data in the area Frequency of visits and survival of virus in fomites Awareness of not contaminating vehicles
Risk of trader vehicles being contaminated and carrying virus	Origin of vehicles (slaughterhouses, farms, markets) Population data in the area Frequency of visits and survival of virus in fomites Awareness of not contaminating vehicles and associated biosecurity measures applied
Fertilizers	
Risk of manure and bedding contamination with H5N1	Prevalence data in farms producing manure Survival in manure and bedding Environmental survival after spreading Existence of proper fertilizer processing
Humans	
Risk of humans for duck keepers carrying virus	Infection prevalence in ducks Frequency of visits Virus survival in environment (soil, human clothes)
Risk of humans for ducks owners carrying virus	Infection prevalence in ducks Frequency of visits Virus survival in environment (soil, human clothes)
Risk of humans for trade purpose carrying virus	Infection prevalence in the region Virus survival in environment (all what is carried by the trader, fomites, slaughterhouses) Frequency of visits, origin
Risk of villagers carrying virus	Frequency of movements to fighting areas and markets Infection prevalence in markets and fighting areas
Risk of humans for animal health purpose carrying virus	Prevalence of disease in farms Changing clothes, boots, cleaning/disinfection habits Virus survival on clothes, equipments, and shoes Awareness of animal health persons Frequency of visits
Environment	
Overall risks	Birds watering in the irrigation canal Infection frequency infection wild birds and free-ranging ducks Survival of virus in water (time, temperature, soil)
Other Animals (Mammals)	
Risk of dogs and cats to be infected (from free-ranging ducks or environment)	Hunting habits of dogs Frequency of dogs being in contact with ducks in rice paddy fields Susceptibility of dogs and cats
Risk of dogs and cats carrying dead birds infected	Mortality in wild and domestic birds Hunting habits of dogs Frequency of dogs being in contact with ducks in rice paddies
Risk of pests (i.e. rodents) being infected from stamping out infected farms	Disease prevalence in rodents Which distance can rodent run and density of farms in that area Pathogenesis in rodents (survival of infected animals)

Table 7. Data needed for the exposure assessment.

Exposure Assessment:

1. All data needed for direct exposures are specified and only supplementary information necessary for indirect exposure are needed;
2. The data needs are addressed for backyard poultry (sector 4). For sector 2, the same pathways should be considered, but fertilizers, free-ranging ducks, poultry products and poultry from small trade have to be removed, and day-old chicken and 6-month layer hens have to be added;
3. For sector 3, same pathways as sector 4 should be considered without fertilizers and free-ranging ducks pathways, but day-old chickens and 6-month laying hen pathways have to be added. A description of the poultry system in the country including frequency of presence of sector farms 2 and 3, and free-ranging ducks in buffer zones have to be described.

Section of Exposure Assessment Pathways	Data Required
Direct exposure of pests	Control measure effectiveness analysis Density of pests Virus shedding Length of survival of virus in dead pests Frequency of contacts between poultry and pests Behavior of poultry and pests
Indirect exposure of pests	Virus survival in the environment (crops) Frequency of contact between poultry and environment
Direct exposure of alive wild birds (migratory or resident)	Habitat and behavior data of wild birds Virus shedding Population numbers of migratory and residential wild birds Length of virus survival (in alive and dead wild birds) Frequency of contact between poultry and wild birds
Indirect exposure of wild bird	Virus survival in the environment (temple, crops, rice mills, canals) Frequency of contact between poultry and environment Virus stability in the environment (water, feces, soil) Climate data Poultry behavior (feeding) and use of surface water in poultry production Behavior of domestic poultry in terms of contact with irrigation canal
Direct exposure of irrigation canals	Virus survival in water Frequency of contact between water and poultry
Direct exposure of dogs	Density of dogs Virus shedding Frequency of contact between poultry and dogs Behavior of dogs
Indirect exposure of dogs	Virus survival in the environment (camps) Frequency of contact between poultry and environment
Direct exposure of free-ranging ducks	Sensitivity of surveillance systems Density of free-ranging systems Virus shedding Frequency of contact between poultry and ducks Behavior of poultry and ducks

Section of Exposure Assessment Pathways	Data Required
Indirect exposure of free-ranging ducks	Virus survival in the environment (crops, canals) Frequency of contact between poultry and environment
Direct exposure from humans	Disinfection process, special clothes, boots
Indirect exposure from humans	Virus stability in the environment (camps, lots)
Direct exposure from feeds	Transmissibility by ingestion
Direct exposure from vehicles	Disinfection process
Indirect exposure from vehicles	Virus stability in the environment (soils)
Direct exposure from fertilizers	Transmissibility by oral ingestion, aerosols, Frequency and quantity of spreading in lots, fields
Direct exposure of poultry	Sensitivity of the surveillance system Density of poultry Virus shedding Frequency of contacts between poultry and trade Behavior of poultry traders Consideration on breeding, fighting cocks, animal consumption, bantams
Indirect exposure of poultry	Virus survival in the environment (houses) Frequency of contact between poultry and poultry trade
Direct exposure of poultry products	Habits concerning cooking waste Survival and stability of virus in cooking waste (raw and cooked meat, eggs, visceral organs)
Indirect exposure of poultry products	Virus survival in cooking waste in the soil
Only for sector 2 and 3 farms	
Indirect exposure to DOC through equipment (DOC relevant only for layer farms)	Farm management regarding DOC and disinfection
Indirect exposure to 6-month future layer hens through equipment and premises	Farm management regarding 6-month layer hens Virus survival in the irrigation canal
Direct exposure to 6-month future layers because of sales to farmers	Quantity of laying hens sold to farmers

Table 8. Data needed for the consequence assessment.

Sections of consequence assessment pathways: Transmission to other households	Data needed	Magnitude of consequences
Risk the case stays in the index zone	Surveillance activity efficiency Efficacy of measures applied	At household level
Risk of index zone not detected: spread disease to households	Transmission parameter farm to farm; Density of buffer zones	At national, sub-district, district, and province levels

Data Collection

The expert opinion workshops

Data were obtained through four expert opinion workshops organized by the DLD and KU. DLD officers, poultry farmers and scientists with relevant expertise participated in these workshops (Table 9, Appendix I for the names of the individuals involved). During these workshops, participants were divided into groups for discussing questions presented in questionnaires produced by the risk assessment (RA) team.

KU and DLD also collated unpublished data from "The Monitoring and Surveillance Centre for Zoonotic Diseases on wildlife and exotic animals (Thailand)".

Table 9. Dates and stakeholder participant category of the expert opinion workshops.

Dates	Stakeholder participants	Number of participants
12th & 13th June 2008	DLD officers	15
23rd & 24th June 2008	Farmers	23
1st & 2nd July 2008	Farmers	22
22nd & 23rd July 2008	Scientists & company veterinarians	13

In this risk assessment document, data obtained through these workshops are presented as "Opinion provided by (name, year)".

Literature review

RVC summarised data from the published literature on virus survival (Appendix II).

Risk Estimation and Risk Combination

Combination Matrix

The matrix presented in Table 10 presents methods used for combining the qualitative risk estimates obtained from release and exposure assessment pathways into an overall risk estimate. Since the resulting overall risk is a conditional probability, it cannot be higher than the probability of release.

Table 10. Matrix for combining release and exposure risks.

		Exposure assessment					
		Very High	**High**	**Medium**	**Low**	**Very Low**	**Negligible**
Release assessment	**Very High**	Very High	High	medium	Low	Very low	Negligible
	High	High	Medium	Medium	Low	Very low	Negligible
	Medium	Medium	Medium	Medium	Low	Very low	Negligible
	Low	Low	Low	Low	Very low	Negligible	Negligible
	Very Low	Very Low	Very Low	Very Low	Negligible	Negligible	Negligible
	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

Release and Exposure Assessments

Wild birds

Release assessment (*The likelihood of the release of HPAI infected wild birds into a buffer zone*.)
Table 11 shows the species and presence of wild birds in a 1-km buffer zone area based on data collected during a farmer expert opinion workshops. Most of observed wild birds were Passeriformes *Passer domesticus* and *Streptopelia* spp.

During the AI outbreaks in Thailand, Passeriformes were the most frequently reported species, including mainly crows and magpies that are naturally susceptible to H5N1 infection. In Japan, crows were the predominantly reported species during the outbreak in 2003/2004[1], while the majority of reported species in South Korea were magpies[2].

Experimental study of HPAI infections in house sparrows (*Passer domesticus*) and European starlings (*Sturnus vulgaris*) showed that European starling were the most resistant species as there was neither reported morbidity nor viral shedding[3] while infected sparrows would shed the largest amount of virus [4].

Although Columbiformes are observed within 1-km buffer zone areas, this species appeared not to be susceptible to HPAI infection as they did not develop the disease during infection experiments with HPAIV H5N1 Chicken/97 strain[5]. However more recently, virus shedding following experimental infection with a more recent Thai strain has been reported in this species[4].

Some pigeons were experimentally found to be susceptible to infection with Indonesia 2003 strain of HPAI viruses[6, 7]. In 2007, another experimental infection study involving 187 pigeons did not result in

clinical disease symptoms. These results tend to support the hypothesis that pigeon are less susceptible to H5N1 infection[8].

With respect to Ciconiiformes, egret and herons were reported to be naturally susceptible but no data of *Ixobrychus* spp. is available[9].

Some ducks (wood ducks and teals) also have been reported in the buffer areas, but at a low frequency (Table 11). Wood ducks are susceptible to H5N1 infection and able to shed the virus[10, 11]. Some experimental data are available on common teal only (*Anas crecca*) indicating that this species can asymptomatically shed the virus[12], but these results have not been confirmed for ringed teals observed in Thailand.

Table 11. List of wild bird species observed in buffer zones by farmers and frequency of responses.

Common name	Scientific name	Order	No. responses 2nd workshop	No. responses 3rd workshop	Total	Frequency of response
House sparrow	*Passer domesticus*	Passeriformes	7	4	11	16.4%
Doves	*Streptopelia spp.*	Passeriformes	7	4	11	16.4%
Unidentified Bitterns	*Ixobrychus spp.*	Ciconiiformes	6	4	10	14.9%
Asian Pied Starling	*Sturnus contra*	Passeriformes	4	4	8	11.9%
Feral pigeon	*Columba livia*	Columbiformes	5	2	7	10.4%
Coucal	*Centropus spp.*	Cuculiformes	0	4	4	6.0%
Asian openbill storks	*Anastomus oscitans*	Cinoniiformes	3	1	4	6.0%
Tailor birds	*Orthotomus spp.*	Passeriformes	0	3	3	4.5%
Black Bulbul	*Hypsipetes leucocephalus*	Passeriformes	3	0	3	4.5%
Barred Buttonquail	*Turnix susci*	Charadriiformes	1	1	2	3.0%
Ringed Teal	*Callonetta leucophrys*	Anseriformes	1	0	1	1.5%
Wood duck	*Anas poecilorhyncha*	Anseriformes	1	0	1	1.5%
Water hern	*Amaurornis phoenicurus*	Gruiformes	1	0	1	1.5%
Streaked Weaver	*Ploceus manyar*	Passeriformes	0	1	1	1.5%
TOTAL			**39**	**28**	**67**	**100.0%**

Source: Farmers' workshops

If a wild bird becomes infected with HPAI virus and develops clinical disease, it is unlikely to be able to fly over long distances (Opinion provided by Songserm, 2008). It has been hypothesised that 50% of the bird population have immunity against various H subtypes.

Since the majority of the buffer zone areas (70%) are in highland areas, migratory birds are rarely found (Opinion provided by Wongnarkpet, 2008). Although seagulls were reported as migratory birds moving from Thailand to China and Cambodia, they were not observed in the buffer zones (Opinion provided by Suwanpakdee, 2008). Farmers observed only migratory bird species such as wood ducks and ringed teals, and one episode of dead birds within the buffer zones was reported (Opinion provided by farmers, 2008). Unfortunately, a confirmatory test for AI was not performed in this case. However, the sampling of healthy wild birds for AI detection performed by Mahidol University (Nakhon Pathom, Thailand) did not reveal positive results to H5N1 (Withawat, personal communication, 2008). The carcasses of wild birds collected by the National Park, Wildlife and Plant Conservation Department and submitted to a DLD laboratory were also found to be negative for AI virus. Additionally, local administrative organizations cooperated with the wild bird surveillance program by routine sampling of birds. If a dead wild bird is found, disinfectants are applied to sanitize the affected area.

Due to the majority of the buffer zones being horticulture areas, they are favourite habitats for the resident wild birds (Opinion provided by farmers, 2008). Some buffer zones are located in rice fields which are a favoured habitat for the Asian openbill stork. These birds may be no longer migrating unless they may move to another location to set up a new colony, but such a new location will usually be within 10 km distance (Opinion provided by Suwanpakdee, 2008). Moreover, egrets and Asian openbill storks share the habitat in rice fields, while resident wild birds live in the yard and trees near houses (Opinion provided by Suwanpakdee, 2008).

Although the frequency of presence of wild birds moving into a buffer zone is very high, the likelihood of those wild birds being infected with HPAI viruses is very low. Therefore, the probability of release of HPAI infected wild birds into a buffer zone is very low with medium uncertainty.

Frequency of wild birds moving into a buffer zone: Very High (low uncertainty)
HPAIV H5N1 prevalence in wild bird species likely to move into a buffer zone: Very Low (medium uncertainty)

The risk for the introduction of H5N1 HPAIV through wild birds into a buffer zone was estimated as **Very Low** with **Medium Uncertainty**.

Exposure assessment

In a buffer zone, sharing of feeding areas between wild birds and backyard chickens has been observed by farmers. From Table 11, Passeriformes, Columbiformes and Ciconiiformes were the predominately observed species of wild birds. Most of the backyard poultry in a buffer zone are free-ranging. High frequency of contact between poultry and wild birds was reported by farmers. However, if dead wild birds are found, disinfectants are used to clean up the area. This activity can reduce the risk for domestic poultry to become exposed to HPAI from dead wild birds. Besides, there is a low density of households in a buffer zone.

Experimental study of AI transmission showed that infected pigeons in contact with chickens never developed clinical signs[6]. This result was repeated in another study where 187 pigeons experimentally infected with H5N1 were placed amongst flocks of pathogen-free chickens. Pigeons did not show any evidence of clinical symptoms and all chickens remained healthy. These results tend to support the hypothesis that pigeons are less susceptible to H5N1 infection and thus are less likely to transmit the virus to chickens [8].

After experimental inoculation of pigeons, the birds were able to shed small amounts of H5N1 virus, from 5 to 16 days post-inoculation. Similar to the experiment performed in the Asian openbill storks, the birds died within 3 to 4 days post-inoculation, and shed the virus from the first to the fourth day (In press, National Research Council of Thailand).

Based on findings of a disease investigation of the DLD, it suggests the occurrence of the disease transmission between wild birds and backyard chicken. During the winter 2006/2007, the outbreak in South Korea was believed to be associated with transmission of infection from wild birds backyard chickens[13].

The risk of exposure and transmission of H5N1 HPAI virus to domestic poultry within a buffer zone through infected wild birds was assessed as **Medium** with **Medium Uncertainty**.

Live poultry

Release assessment

People living inside the buffer zone usually introduce live poultry only for genetic improvement, replacement of backyard chickens or if they are fighting cocks. Before the first epidemic wave in 2004, 50-60% of people brought live poultry into buffer zones without being aware of the origin of those birds (Opinion provided by Wongnarkpet, 2008). They bought the live poultry from the areas surrounding the HPAIV H5N1 outbreaks. After the implementation of extensive surveillance, monthly information of avian influenza was obtained within each buffer zone about disease characteristics, disease notification and poultry population size (Opinion provided by Wongnarkpet, 2008.

The frequency of disease notification and the poultry population size have decreased every year since the first HPAIV H5N1 outbreak. At present, there are no HPAIV HPAI outbreaks in and around any of the buffer zones. People living in the buffer zones bring live healthy poultry from outside the zone which may indicate that those live healthy poultry do not carry the virus (Opinion provided by DLD staff, 2008). In addition to the Thai government's HPAI disease control and surveillance scheme, the compartmentalized farmers bought some backyard chickens in the buffer areas which were destroyed when HPAIV H5N1 outbreaks occurred in the country. It reduces the number of potential reservoirs of HPAI in buffer areas during the outbreaks and thereby leading to a reduction of the risk of introducing AI virus into buffer zones (Opinion provided by DLD staff, 2008).

After the implementation of control measures and biosecurity systems in the poultry sector, it is less likely for farmers in a buffer zone to introduce HPAI infected live poultry into their buffer zone.

Frequency of introduction of live poultry: Medium (high uncertainty)
Prevalence of HPAI H5N1 in live poultry potentially introduced into buffer zones: Very Low (low uncertainty)

The risk for the introduction of H5N1 HPAIV into a buffer zone through live poultry was assessed as **Very Low** with **High Uncertainty**.

Exposure assessment

Most of the new birds are introduced into a buffer zone for genetic improvement and they are reared separately from existing poultry. New birds are quarantined prior to mixing with existing herds, particularly in case of fighting cocks, but introductions of new fighting cocks rarely occur. In sector 2 and 3, cloacal swab samples must be taken from new live poultry to determine their health status prior to introduction (Opinion provided by DLD staff, 2008). Introduced poultry are always mixed or restricted in the same area with backyard poultry in the households. However, confined cages are placed relatively close to the resident flocks; therefore birds belonging to the household are able to come into contact with the newly introduced birds.

Although tracheal swabs detect a larger amount of viruses than cloacal swabs, the viral transmission via respiratory route (direct contact) is thought to be less effective than the faecal route of the transmission (indirect contact) (Opinion provided by Songserm, 2008). When a chicken sneezes, the droplet will not travel further than 1 meter due to the hook shape of the chicken's beak (Opinion provided by Songserm, 2008). The oral-faecal route via drinking water is deemed to be a major route of infection for poultry within cages or houses (Opinion provided by Songserm, 2008).

Due to backyard chickens mostly being free-ranging (70-80%), they may expose to other birds. However, during an outbreak people tend to be more concerned about the biosecurity of their

chickens so they are more likely to keep their chickens safe (Opinion provided by Wongnarkpet, 2008).

Fighting cocks and pet birds are often kept individually, separated from other birds. It is then much easier for owners to keep their cage clean which will then minimize the risk of viral transmission (Opinion provided by farmers, 2008). Occasionally, fighting cocks are raised in individual cages located within a distance of 1.5m from each other in a location with potential access for other backyard poultry (Opinion provided by DLD staff, 2008). This would result in opportunities for viral transmission to other backyard poultry and fighting cocks.

The risk for the exposure and transmission of H5N1 HPAI virus to poultry in a buffer zone through introduced infected live poultry was assessed as **Very High** with **High Uncertainty**.

Free-ranging ducks

Release assessment

In most buffer zones, no ducks are being raised because the majority of buffer zones (70%) are located in highlands and the others are located in community area (Opinion provided by Wongnarkpet and Farmers, 2008).

Company farms have good collaboration with other poultry farmers in located within their buffer zone through company public relation campaigns. Being educated about avian influenza either through the government or the commercial farm's campaign, farmers will not allow free-ranging ducks within the buffer zone (Opinion provided by Wongnarkpet, 2008). However, some culled ducks were brought into buffer zones for consumption (Opinion provided by Farmers 2008). There are a small number of reports slaughterhouses with poor hygiene standard within buffer zones (Opinion provided by Wongnarkpet, 2008).

Ducks are known as a reservoir for HPAIV H5N1 because they do not exhibit clinical signs[14]. Subclinically infected ducks do not shed large amounts of virus into the environment (Opinion provided by Songserm, 2008). However, if they show clinical signs such as ataxia, respiratory distress and diarrhoea, the amount of virus shedding increases[14]. It has been speculated that HPAIV H5N1 prevalence in free-ranging ducks may vary ranging from very low to high, since these ducks are moved from place to place by their owners (Opinion provided by Songserm, 2008).

Infected ducks can shed virus for 5 to 10 days (mostly 7 days) before onset of clinical signs. The amount of virus shed is low[14], but increasing when they show clinical signs, mainly respiratory distress and nervous symptoms with ataxia.

Frequency of introduction of free-ranging ducks into a buffer zone: Very Low (low uncertainty)
Prevalence of H5N1 HPAIV in free-ranging ducks that may be introduced into a buffer zone: Very Low (medium uncertainty)

The risk for the introduction of H5N1 HPAIV into a buffer zone through free-ranging ducks is **Very Low** with **Low Uncertainty**.

Exposure assessment

Domestic poultry in the buffer zones are usually raised in other geographic locations than free-ranging ducks. Some duck owners have backyard chickens in the house area, so the backyard chickens potentially expose to the duck flocks.

The average flock size of ducks is approximately 2,000-5,000 birds/flock (Opinion provided by Farmers, 2008). Following the introduction of a DLD policy prescribing the use of a preliminary biosecurity housing system for free-ranging ducks, the number of free-ranging duck flocks and ducks per flock has decreased from 10,000 to 3,000 – 5,000 ducks/flock (Opinion provided by DLD staff, 2008). However, some duck owners smuggled their ducks to the rice fields near their farm housing. This led to increasing opportunity of contact between these ducks and backyard poultry when moving them back home (Opinion provided by DLD staff, 2008).

The risk for backyard poultry within a buffer zone to become exposed to and to become infected with H5N1 HPAIV from infected ducks is **Very Low** with **Medium Uncertainty.**

Pests (rats and mosquitoes)

Release assessment

Pests considered in the assessment are rats and mosquitoes that have feeding areas ranging over more than a 1 kilometre radius.

Rat species mostly found in poultry farms are the Norway rat (Opinion provided by Limtrajit, 2008). There is usually only one species of rats present in a farm at the same time. The Norway rat can wander 2 – 3 kilometres per night to seek for food (Opinion provided by Limtrajit, 2008). However, rats will not travel far unless is insufficient feed available locally or their habitats have become invaded by their predators or other rat species.

In some buffer zones, rats from rice paddy fields are caught by villagers for human consumption (Opinion provided by Farmers, 2008). Although rats may be brought into the buffer zones, they are healthy and therefore unlikely to carry viruses (Opinion provided by DLD staff, 2008). During the first period of the AI outbreak in Thailand (January – April 2004), H5N1 infected dead rats were found on outbreak farms (Opinion provided by DLD staff, 2008).

H5N1 viruses were isolated from mosquitoes trapped on an infected farm during the first wave of the AI outbreak in Thailand. The mosquitoes were found to be able to carry the viruses [15].

Frequency of introduction of pest species into a buffer zone: Very Low (medium uncertainty)
Prevalence of H5N1 HPAI virus in pest species likely to be introduced or moving into a buffer zone: Negligible (medium uncertainty)

The risk for the introduction of H5N1 HPAIV into a buffer zone through pest species is estimated as **Negligible** with **Medium Uncertainty**.

Note: The exposure pathway for pests will not be assessed as the release was estimated to be Negligible. Data collected are still presented for information.

Exposure assessment

Rats are nocturnal animals that search for food at night which is contrary to the feeding behaviour of backyard poultry (Opinion provided by Limtrajit, 2008). Moreover at night time, most of the backyard chickens sleep in trees. The probability of contact between rats and backyard chickens is low.

Viral shedding route of rats is mainly through the respiratory tract. Experimentally infected rats showed nervous signs, ataxia and died within 7 – 10 days following infection and died 2 days after onset of clinical signs (Opinion provided by Songserm, 2008). The virus was mostly detected and shed over a limited geographical area only during the clinical disease phase (Opinion provided by

Songserm, 2008). Habitats of rats are in dark, small and untidy areas which are less likely to be accessed by backyard poultry.

Mosquitoes have been found to feed on backyard chickens. However, it has not been shown that they could be a mechanical or a biological vector for transmission of H5N1 HPAIV[15].

Dogs and cats

Release assessment

Few dogs and cats are present in the buffer zone areas and they usually remain within their home territory (Opinion provided by Farmers, 2008). Dogs may hunt outside a buffer zone and bring back dead birds. This rarely occurs since dogs usually do roam far from their home territory (Opinion provided by Farmers, 2008).

In addition, DLD officers attempted to educate farmers to bury or burn dead carcasses. Therefore, dogs should have little access to dead poultry.

Although dogs may potentially become contaminated and carry the AI viruses in a buffer zone, the virus cannot survive in a dry environment such an animal's fur coat for extended periods of time (Opinion provided by Songserm, 2008). Moreover, dogs and cats are less likely to be a mechanical vector because they groom and clean themselves regularly (Opinion provided by Songserm, 2008).

An avian influenza serological survey of dogs in an outbreak area did not find any seroconversions, suggesting that dogs are less likely to transmit virus. Another study revealed that an infected cat was able to shed virus for 2 weeks without clinical signs [16].

Several studies found that dogs carried the virus or had antibodies against H5N1 HPAI viruses. Thai dogs could play an important role as sentinel animals since antibodies against H5N1 HPAI virus were found in their blood [17]. A study in Thailand showed that the virus was prevalent in 25 % of dogs in the country[18], and 2 dogs were also found positive in Bali[19].

A prevalence 25% of sero-positive against H5 in dogs was reported in Thailand during the outbreaks[18]. However, the cut off value for the serological test at 1:16 used in the study may have been too low, so that it produced false positives. Furthermore, the neutralization test is recommended as the test for monitoring of the disease in mammals rather than the hemagglutination inhibition (HI) test.

Felids have been found to be susceptible to H5N1 infection since 2003. Two tigers (*Panthera tigris*) and 2 leopards (*Panthera pardus*) died from H5N1 HPAIV infection in Thailand and, in 2004, 45 from 441 captive tigers also died from H5N1 HPAIV infection [20, 21].

In Germany, 3 cats became naturally infected by H5N1 Asian lineage HPAIV, most likely through exposure to infected whooping swan (*Cygnus cygnus*) in the same geographic area. Cats are considered to be at risk in areas with prevalent H5N1 HPAI viruses[22]. Test result from a dead cat in Germany were positive to H5N1 HPAI viruses in the same geographic area where tests from wild birds were also positive to the virus [23].

The frequency of dogs and cats entering a buffer zone: High (medium uncertainty)
The prevalence of H5N1 HPAIV infection in dogs and cats entering a buffer zone: Negligible (low uncertainty)

The risk for the introduction of H5N1 HPAIV through dogs and cats entering a buffer zone was estimated as **Negligible** with **Medium Uncertainty**.

Note: The exposure pathway for dogs and cats will not be assessed as the release was estimated as Negligible. Data collected are still presented for information.

Exposure assessment

Dogs and cats do not stay close to poultry. Backyard chickens do not directly come into contact with dogs and cats except when they are bitten by these animals or have been raised together since they were young (Opinion provided by Farmers, 2008).

In the early stage of infection, dogs and cats shed small amounts of virus via the respiratory route for 7 days post-infection. Dogs acquiring a large amount of viruses can show clinical signs within 7 days but they may survive (Opinion provided by Songserm, 2008). Cats become sick and die within a short time after infection. It is less likely that dogs and cats mechanically carry virus on their fur coat or noses because they often lick their mouth and noses when grooming themselves (Opinion provided by Songserm, 2008). The virus carried on dogs' and cats' fur cannot survive for a long time in the dry hair (Opinion provided by Songserm, 2008).

In an experimental study of AI infection in beagles the virus was inoculated intranasally. One of 4 inoculated dogs shed the viruses for 2-3 days[24].

Cats could be a source of AI transmission as cats excreted virus and showed clinical symptoms and lesions following experimental infection[25]. In Thailand, a fatal case of H5N1 was reported in a cat after it had eaten an infected pigeon carcass[26].

Cats can become infected with H5N1 HPAIV following oral contamination. After infection, all cats excreted the virus, which suggests they could be a source of transmission[27].

A recent study showed that experimentally infected dogs developed clinical symptoms but did not transmit the disease to either an in-contact dog or cat. Cats are considerably more susceptible than dogs. Although there are no reports of dead dogs, this does not exclude their potential implication in the epidemiology and transmission of the virus[19].

Water

Release assessment

Water was considered as a virus carrier medium. A disease investigation of AI in the first epidemic wave indicated water was a risk factor for disease transmission. Disease spread through water was hypothesised during the first outbreaks as people had disposed a large number of chicken carcasses into small public waterways (Opinion provided by DLD staff, 2008). Subsequent to the implementation of control measures and the education of farmers in 2007, the probability that people throw poultry carcasses into rivers should be very low now (Opinion provided by Wongnarkpet, 2008).

However, flooding can occur in the buffer zone via 2 mechanisms. The first possible source of flooding originates from a river in the mountains, with big amounts of water staying for a short time while the second occurs following heavy rain when the water remains stagnant for many days

(Opinion provided by Farmers, 2008). The dilution effect of the amount of water and the effect of the ultra-violet (UV) light tend to inactivate the virus, and the virus remains viable longer in stagnant compared with running water (Opinion provided by Nuanualsuwan, 2008).

The survey of the Monitoring and Surveillance Centre for Zoonotic Diseases in wild life and Exotic Animals (Thailand) found that the results of water samples from AI high risk areas in 2008 were all negative for H5N1 HPAI virus.

Data on virus survival in the environment were updated based on the 2006 EFSA Report (Migratory Birds and their Possible Role in the Spread of Highly Pathogenic Avian Influenza. Scientific report in Annex to The EFSA Journal 357, 1-46), and are provided in Appendix II.

The frequency of water entering a buffer zone: High (low uncertainty)
Prevalence of H5N1 HPAI virus in water: Negligible (low uncertainty)

The risk for the introduction of H5N1 HPAIV into a buffer zone through water was estimated as **Negligible** with **Low Uncertainty**.

Note: The exposure pathway for water will not be assessed as the release was estimated as Negligible. Data collected are still presented for information.

Exposure assessment
Ten percent (10%) of people are raising ducks in their house, especially near the buffer zone of contracted broiler farms. These ducks remain in the vicinity of the farmer's house, and there is therefore little opportunity for contact with public waterways (Opinion provided by Farmers, 2008). Backyard chickens obtain water from human leftovers. They can therefore not be exposed to the virus as humans always consume clean water (Opinion provided by Farmers, 2008).

Equipment

Release assessment
Fighting cock equipment: The DLD survey revealed that 10% of all buffer zones had fighting cocks and 7% of households in the buffer zones raised fighting cocks (Opinion provided by Wongnarkpet, 2008). Fighting cocks are always managed separate from other poultry. Cocks are raised individually and their equipment is not shared, which results in a low chance of equipment becoming contaminated with AI viruses (Opinions provided by Songserm and Wongnarkpet, 2008). The equipment is also less likely to become contaminated during a competition, as cock fighting activities only occasionally operate in a buffer zone (Opinion provided by Farmers, 2008). Farmers may take their fighting cocks outside buffer zones which possibly lead to a contamination of the equipment, but this could only occur if farmers take their cocks to fights at locations where there is an outbreak (Opinion provided by DLD staff, 2008).

Free-grazing duck equipment: The equipment for free-grazing duck management is potentially contaminated with avian influenza virus as a result for movement from place to place. Cages for transporting ducks on trucks may have a high chance of becoming contaminated when HPAI H5N1 infected ducks are transported, as farmers rarely clean or disinfect them (Opinion provided by Songserm, 2008). Although avian influenza virus will be killed by fermentation of the manure on the truck, the virus could survive for at least 7 days on the cage trays (Opinion provided by Songserm, 2008). However free-grazing duck egg trays are less likely to become contaminated. In an experimental study of contamination of egg trays with mixing 10^6 EID_{50} of HPAI H5N1 virus into faeces, virus could not be detected on the tray after 24 hours of the inoculation. If contaminated equipment are exposed to sunlight, heat, and dryness, the virus may become inactivated (Opinion provided by Nuanualsuwan, 2008).

Inactivation by solar radiation : A study of the expected inactivation of influenza A virus by solar ultraviolet radiation in several cities of the world during different times of the year reported that influenza A virions should remain infectious after being released from the host for several days during the winter "flu season" in many temperate-zone cities, with continued risk for re-aerosolization and human infection[28].

Survival on environmental surfaces: Both, influenza A & B viruses survived for 24-48 hours on hard, nonporous surfaces such as a stainless steel and plastic but the viruses survived for less than 8-12 hours on cloth, paper, and tissues[29]. Virus survived on hands for up to 5 min after transferring from the environmental surfaces. Measurable quantities of influenza A virus were transferred from stainless steel surfaces to hands for 24 hours and from tissues to hands for up to 15 min.

The frequency of introduction of poultry-associated equipment in a buffer zone: High (low uncertainty)
Prevalence of H5N1 HPAIV on poultry-associated equipment entering a buffer zone: Negligible (medium uncertainty)

The risk for the introduction of H5N1 HPAIV through poultry-associated equipment entering a buffer zone is estimated as **Negligible** with **Medium Uncertainty**.

Note: The exposure pathway for poultry-associated equipment will not be assessed as the release was estimated to be Negligible. Data collected are still presented for information.

Exposure assessment

A study of AI virus on chicken egg trays from markets did not find any positive result for AI, as H5N1 HPAI infected chicken would not lay eggs (Opinion provided by Songserm, 2008). There is a high probability of backyard chicken to become exposed to contaminated fighting cock equipment (e.g. bamboo cages) (Opinion provided by Songserm, 2008). Most farmers are less likely to disinfect their poultry equipment, but they usually clean the equipment with clean water and leave them to dry through sunlight (Opinion provided by Farmers, 2008)

Feed

Release assessment

The amount of feed grain brought into buffer zones is considerably lower since most farmers in the buffer zones feed their backyard poultry with by-products from their own horticulture activity (Opinion provided by Farmers, 2008). Most farmers (87%) feed their backyard poultry with commercial feed while other farmers use leftover human food (4%) or purchase unmilled rice (2%) and corn grains (7%) for feeding (Opinion provided by Wongnarkpet, 2008).

Generally, unmilled rice and corn are heated by the sunlight for at least 30 minutes. The temperature in the small grated heaps is sufficiently high to inactivate the virus. Although, in the worst case, a heap may become contaminated with faecal bird droppings, the virus would still become inactivated through the heat and UV light (Opinion provided by Researchers, 2008). On the other hand, commercial feeds are produced under quality control conditions involving temperature and pressures during the production process sufficient to kill the virus (Opinion provided by Researchers, 2008).

The frequency of introduction of feed into a buffer zone: High (low uncertainty)
Prevalence of H5N1 HPAI virus in feed entering a buffer zone: Negligible (low uncertainty)

The risk for the introduction of H5N1 HPAIV through feed entering a buffer zone was estimated as **Negligible** with **Low Uncertainty**.

Note: The exposure pathway for feed will not be assessed as the release was estimated as Negligible. Data collected are still presented for information.

Exposure assessment

Most of the backyard poultry move freely in and around the farmer's house areas seeking for feed either from the natural sources or purchased feed. Although domestic poultry can become exposed to the feed directly, the extent of this exposure is usually small. The frequency of feed purchase varies ranging from every 15 – 30 days to many months or a year (Opinion provided by Farmers, 2008). H5N1 HPAI virus might not be able to survive through such long time periods. Farmers may buy a large amount of commercial feed and store it in closed containers (Opinion provided by Farmers, 2008). Although few farmers keep the feed in original bags that are accessible to backyard chickens, the likelihood of commercial feed to become contaminated with HPAI virus is very low and backyard poultry are less likely to be fed with commercial feed (Opinion provided by Songserm, 2008).

Fertilizer

Release assessment

As there are a lot of horticultural crops in the buffer zones, a large amount of fertilizer has to be introduced into the buffer areas (range: 1-8 times per year) (Opinion provided by Farmers, 2008). Manure fertilizers used for vegetable and horticultural crops are mostly obtained from large animal farms, whereas litter from broiler farms has also been used as fertilizers, mostly sourced from compartmentalized farms. Some farmers in buffer zones obtain poultry litter from farms outside the buffer zones. This litter is relatively old, so that the amount of remaining viruses is likely to be very low. (Opinion provided by Wongnarkpet, 2008).

Poultry must be tested for HPAIV either before being slaughtered or during an occurrence of outbreak. If the result of HPAI testing is positive, all chicken, manure and other related material must be disposed of (Opinion provided by Farmers and DLD staffs, 2008). This will result in a low chance of releasing contaminated poultry litter and manure into buffer zones. The AIV survival in the core of the manure is very low because of low pH and high temperature resulting from the fermentation process in the faeces heap (Opinion provided by Songserm, 2008). Additionally, manure fertilizers are dried by the sunlight and stored for a certain period prior to the usage which decreases the AIV survival in the manure (Opinion provided by Farmers, 2008).

The frequency of manure fertilizer entering a buffer zone: Medium (low uncertainty)
Prevalence of H5N1 HPAIV in fertilizer entering a buffer zone: Very Low (medium uncertainty)

The risk for the introduction of H5N1 HPAIV through manure fertilizer entering a buffer zone was estimated as **Very Low** with **Medium Uncertainty**.

Exposure assessment

Poultry litter has been rarely used as fertilizer for vegetables and horticultural crops nearby the houses where backyard poultry are raised, as farmers prefer to use chemical fertilizers for their planting crops. Although the daily watering of plants may extend the period of virus survival, backyard poultry are less likely to seek for feed in such horticultural areas (Opinion provided by DLD

staff, 2008). Poultry faeces are the favourite habitat for flies, one of the potential mechanical vectors of H5N1 HPAI virus. Chickens sometimes dig in these faeces to find fly worms. However, it usually takes at least 7 days for fly worms to develop within poultry faeces. The HPAI virus can be destroyed by sunlight during such a period, resulting in a low chance of virus transmission (Opinion provided by DLD staff, 2008).

As horticulture areas are different from the habitat of backyard poultry, domestic poultry cannot access the location where fertilizer are stored nor become exposed to fertilizer that has been applied (Opinion provided by Farmers, 2008).

Farmers usually place poultry faeces into the sunlight for a certain period that inactivates the viruses. The H5N1 HPAI virus could survive in manure for 30 minutes in the sunlight at a temperature of 25-30^{o}C; in the shade, the virus may remain viable for 4 days (Songserm *et al.*, 2005).

The risk for the exposure and transmission of H5N1 HPAIV to poultry through fertilizer was assessed as **Very Low** with **Medium Uncertainty**.

Poultry meat and poultry products

Release assessment

Poultry meat: Most people living in the buffer zones consume their own backyard chicken. They occasionally purchase poultry meat from others, i.e. once a week (Opinion provided by Farmers, 2008). Fresh meat is introduced into the buffer zones either by vendor vans selling meat or people buying meat at the market (Opinion provided by Farmers, 2008).

During the first year of the H5N1 HPAI outbreak some poultry meat sold in fresh markets may have been contaminated with AI virus, since HPAI disease detection was not performed in poultry prior to slaughter, and half of the poultry slaughter houses were not certified (Opinion provided by DLD staff, 2008).

The DLD has initiated annual market surveys to test poultry meat samples for H5N1 HPAIV prior to the Chinese New Year Festival. So far, one positive sample has been detected (Opinion provided by DLD staff, 2008). HPAI virus has been detected in poultry meat samples from markets in areas where outbreaks of HPAI occurred (Opinion provided by Songserm, 2008).

The HPAI virus can survive in infected chilled duck meat for at least 231 days. After the viraemia, HPAI virus could be detected in ducks' heart and muscle tissues[14]. However, the pH in chicken meat remains above 6.5 which results in inactivation of AI virus on chicken meat surfaces, possibly up to 10^2 EID_{50} of AI viruses (Nuanualsuwan, 2008).

Eggs: Free-grazing duck eggs are cleaned before being distributed to the landowners (in a buffer zone) who can take more than 24 hours. The probability that AI virus survives on the egg shells is low (Opinion provided by Songserm, 2008).

The frequency of introduction of poultry meat into a buffer zone: High (low uncertainty)
Prevalence of H5N1 HPAIV in poultry meat entering a buffer zone: Negligible (high uncertainty)

The risk for the introduction of H5N1 HPAIV through poultry meat entering a buffer zone was estimated as **Negligible** with **High Uncertainty**.

Note: The exposure pathway for poultry meat and poultry products will not be assessed as the release was estimated as Negligible. Data collected are still presented for information.

Exposure assessment
The amount of AI virus in poultry meat is sufficiently large to infect backyard chicken. Backyard chickens are potentially exposed to H5N1 HPAIV contaminated poultry meat and products. People often dispose waste products by dropping them on the ground where they are directly accessible to backyard chicken. In general, they immediately run and eat the thrown food (Opinion provided by Farmers, 2008). Additionally, waste meat from cooking are placed in open bins accessible to backyard chicken (Opinion provided by Farmers, 2008).

Some households in buffer zones have water drains (Opinion provided by Farmers, 2008). Due to abundant organic materials in waste water, it creates a shield effect that enhances AIV stability. HPAIV might remain infectious for up to 12 hours in sewage (Opinion provided by Nuanualsuwan, 2008). However, if the waste water is on the ground, AIV will be inactivated by sunlight (UV irradiation) or dryness. HPAI virus can survive in waste water from 1 minute to 1 hour depending on the environmental conditions and areas (Opinion provided by Songserm, 2008).

Humans

Release assessment
Routinely showering can minimize the risk of humans becoming contaminated with AI viruses. Humans are potential mechanical vector for introduction of AI virus into a buffer zone, especially some professions associated with poultry production such as livestock volunteers, government officers, cockfighting men, traders, cloacal swab collectors or any person who works in close contact with poultry. They are considered to be the highest risk population (Opinion provided by Wongnarkpet and Songserm, 2008).

Samples from nasal cavities, eyes and foot were taken from people working in laboratories for HPAI diagnosis, but no HPAI positives were detected (Opinion provided by Songserm, 2008).

The frequency of introduction of people into a buffer zone: Very High (low uncertainty)
Prevalence of H5N1 HPAIV in people entering a buffer zone: Very Low (medium uncertainty)

The risk for the introduction of H5N1 HPAIV through humans into a buffer zone was estimated as **Very Low** with **Medium Uncertainty**.

Exposure assessment
Education about HPAI disease transmission is very important for poultry keepers so that they know how to protect themselves from and prevent them from spreading the disease (Opinion provided by Wongnarkpet and Songserm, 2008). Fighting cock owners can contribute to the spread of AI viruses, either directly or indirectly, to backyard chickens (Opinion provided by DLD staff, 2008). However, since the first HPAI outbreaks, poultry keepers have developed a better understanding of HPAI disease as a result of national information campaigns (Opinion provided by Wongnarkpet and Songserm, 2008).

The risk of exposure and transmission of H5N1 HPAIV to poultry through humans was estimated as **Low** with **High Uncertainty**.

Vehicles

Release assessment

Vehicles are considered to be potential mechanical vectors for the introduction of the AI virus into a buffer zone from fresh poultry meat markets. Personal vehicles (e.g. motorcycles and pick-up trucks) predominantly enter into or pass through a buffer zone (Opinion provided by DLD staff, 2008). Motorcycles can also become contaminated with AI virus at fighting cock arenas (Opinion provided by Songserm, 2008). Although some trucks carrying poultry litters and manure enter a buffer zone, these are cleaned and sprayed with disinfectants at the farm gate (Opinion from DLD staffs, 2008). However, a tractor may potentially introduce AI virus back into a buffer zone when it is hired for another task in an area experiencing an HPAI outbreak. Most of the tractors are rarely cleaned with chemical disinfectants as owners are concerned about the corrosive effects of disinfectants on their vehicles (Opinion provided by DLD staff, 2008).

In the environment of Thailand, HPAI virus can remain viable on vehicles for less than 2 hours (Opinion provided by Songserm, 2008). In HPAI infected farms, no HPAI virus was found in samples taken from wheels and trunk of vehicles. There is therefore likely to be a low opportunity of vehicles' wheels and trunk becoming a mechanical vector for HPAI virus (Songserm et al, unpublished). Although AI virus was isolated from a cage transporting free-ranging ducks on a truck and it was found that the virus could survive for a week, these trucks are less likely to enter into a buffer zone (Opinion provided by Songserm, 2008). Moreover, there are currently no reports of HPAI outbreaks in Thailand.

The frequency of introduction of vehicles in a buffer zone: Very High (low uncertainty)
Prevalence of H5N1 HPAIV contamination of vehicles entering a buffer zone: Negligible (low uncertainty)

The risk for the introduction of H5N1 HPAIV through vehicles entering a buffer zone was estimated as **Negligible** with **High Uncertainty**.

Note: The exposure pathway for vehicles will not be assessed as the release was estimated as Negligible. Data collected are still presented for information.

Exposure assessment

When a truck carrying free-ranging ducks enters a buffer zone, backyard poultry may jump on the truck while the truck is parked for loading of ducks that are raised outside the buffer zone.

Mostly, personal vehicles (e.g. motorcycles and pick-up trucks) are parked nearby the houses where there are backyard poultry. Therefore, chickens are more likely to come into contact with these vehicles especially motorcycles (Opinion provided by DLD staff and Farmers, 2008).

Overall Conclusions on the Release and Exposure Assessment

Conclusions on the Release Assessment

The release pathways for pest species, dogs and cats, equipment, feed, poultry products, water and vehicles were assessed as being **negligible** (Table 12). Therefore, no exposure assessment will be performed for these pathways.

Table 12. Estimated risks and associated uncertainties for the release assessment pathways.

Pathway for risk of introduction of HPAIV subtype H5N1 into a buffer zone through	Risk	Uncertainty
wild birds	Very Low	Medium
live poultry	Very Low	High
free-ranging ducks	Very Low	Low
pests	Negligible	Medium
dogs and cats	Negligible	Medium
water	Negligible	Low
contaminated equipment	Negligible	Medium
feed	Negligible	Low
fertilizer	Very Low	Medium
poultry products	Negligible	High
humans	Very Low	Medium
vehicles	Negligible	High

Conclusions on Exposure Assessment

When HPAI infected live poultry are introduced into a buffer zone, the risk of poultry within a buffer zone becoming exposed to H5N1 HPAIV infection and the risk of them becoming infected is very high with medium uncertainty (Table 16). The likelihoods for other exposure and consequence risk pathways including free-ranging ducks, fertilizers and human are low to very low.

Table 13. Estimated risks and associated uncertainties for exposure assessment.

Pathway for risk of exposure to and transmission of HPAI virus subtype H5N1 within a buffer zone from	Risk	Uncertainty
infected wild birds to domestic poultry	Medium	Medium
introduced infected live poultry to domestic poultry	Very High	High
infected ducks to backyard poultry	Very Low	Medium
contaminated fertilizer to domestic poultry	Very Low	Medium
infected or contaminated humans to domestic poultry	Low	High

Data on Consequences in Relation to Livelihood and Economics

Economic effects

When the occurrence of an HPAI outbreak is notified, various control measures are implemented rapidly. The outbreak can be limited within an affected location through restriction of poultry movement. These measures have a severe negative economic impact on compartmentalized farms. As compartmentalized farmers are not allowed to move their broilers out until 30 days after the date when the last case of AI has been identified in the affected area, compartmentalized farmers suffer revenue losses and incur additional expenditure for disinfectants. An outbreak also results in compensation having to be paid to backyard poultry farmers within the affected buffer zone. Regardless of the scale of an outbreak, the patterns and characteristics of its impact does not vary a lot, except for possibly the absolute magnitude of its impact. In a large outbreak of HPAI, poultry farmers are not allowed to move poultry off their premises for potentially long periods and continue to pay wages during the outbreak. The expenses are therefore higher than in a small outbreak of HPAI.

Moreover, enterprises in other poultry sectors and poultry product consumers are also adversely affected. The presence of HPAI infection results in a huge drop in the poultry market demand as most consumers are concerned about the safety of poultry consumption. This is likely to lead to further losses in poultry farmers' income.

Effects on society

Since the first occurrence of HPAIV in Thailand, many villagers have abandoned small-scale poultry production because having the stressful experience of outbreaks, especially fighting cock owners. As a result of the panic developing during an outbreak, villagers try to solve the problem by forcing other members of the community to stop raising chickens in the village.

Based on previous experience with the implemented control measures, people gradually lost confidence in the government's and poultry companies' ability to handle the HPAI outbreaks. As a consequence, affected people may have become less cooperative during subsequent implementation of control and preventive strategies. This adverse effect would have been much less frequent if the occurrence of HPAI outbreak had been controlled more quickly. However, since the introduction of compartmentalized farms, there have only been small numbers of HPAI outbreaks within buffer zones so that the aforementioned adverse effects have occurred much less frequently. This has lead to increased confidence in the implemented surveillance and biosecurity system.

Country level effects

If the measures implemented by the DLD cannot result in effective control of HPAI outbreaks, it will result in the perception that the standard of the national surveillance system and the veterinary service is poor.

Impact on professionals

The outbreaks of HPAI subtype H5N1 in Thailand have resulted in significant workload for the professionals involved, mostly governmental veterinarians, and resulted in re-structuring of the infrastructure, particularly the DLD for controlling the disease more efficiently. Budgets have been allocated to establish the on-going HPAI surveillance network and to fund the scientific research related to the HPAI infection. However, the promotion for the DLD officers is hindered. Some DLD

officers may not obtain rewards according to their performances so that they are less committed towards their assigned tasks. This may eventually lower the effectiveness of the on-going surveillance and control system for HPAI in Thailand.

Public health effects

The general public did develop a panic during the first outbreak of HPAI in Thailand, but since then the public perception in relation to the importance of HPAI risk has become less during subsequent outbreaks.

The impact of the presence of HPAI infection on the health of individuals depending depends on the magnitude of the outbreak. If it is of a huge magnitude, the individual person's health may be compromised due to stress, fatigue, common cold, and fever. Some people may develop psychological problems so that they require a medical consultant to relieve their stress.

Effects on the environment

The inappropriate disposal of poultry carcasses, either by burying or incineration, results in pollution of the environment. Also, over-use of chemicals may lead to increases in resistant strains of bacteria.

Conclusions and Recommendations

Conclusions

Table 14 presents the risk estimates for all risk pathways in this qualitative risk assessment. The likelihood of introducing H5N1 HPAI virus into a buffer zone via wild birds, live poultry, free-ranging ducks, fertilizer and human is very low to negligible with varying levels of uncertainty. Although the risk associated with pathways for live poultry and humans is very low or negligible, the associated uncertainties are very high.

It is very encouraging that it was concluded that the overall risk for the key pathways was negligible for free-ranging ducks, fertilizer and humans, and very low for wild birds and live poultry. It needs to be recognised though that most of these estimates were associated with significant levels of uncertainty.

It is evident that the overall risk is only negligible to very low as a result of the negligible or very low risk of pathogen introduction (=release). It is important to monitor that risk level and to keep it negligible to very low, since the risk estimates for the exposure pathways indicate that introduction of the virus is likely to result in rapid spread.

This risk assessment demonstrates how decision making in relation to disease control can be underpinned effectively by transparent presentation of data and qualitative risk estimates. Apart from defining risk pathways and estimating risks, this risk assessment compiled and documented the existing published literature and the local, unpublished epidemiological knowledge in relation to the defined pathways. It also showed how peer-reviewed information can be combined with expert opinion, while still being transparent about areas where scientific evidence is lacking.

Table 14. Individual and combined risk estimates for introduction and transmission of HPAIV subtype H5N1 in 1-km buffer zones surrounding compartmentalized poultry farms in Thailand.

	Release		Exposure & Consequence		Overall risk	
Pathways	**Risk**	**Uncertainty**	**Risk**	**Uncertainty**	**Risk**	**Uncertainty**
Wild Birds	Very Low	Medium	Medium	Medium	Very Low	Medium
Live Poultry	Very Low	High	Very High	High	Very Low	High
Free-Ranging Ducks	Very Low	Low	Very Low	Medium	Negligible	Medium
Fertilizers	Very Low	Medium	Very Low	Medium	Negligible	Medium
Humans	Very Low	Medium	Low	High	Negligible	High

Recommendations

The high level of uncertainty associated with many of the risk estimates, specifically for the pathways relating to live poultry and humans, indicate that there are significant knowledge gaps and that therefore the risk estimates need to be interpreted with caution. Targeted data collection should be initiated to fill some of the relevant knowledge gaps. The areas in particular need of data are the

prevalence of HPAI in wild birds, the movement patterns of live poultry, particularly those of free-ranging ducks and fighting cocks.

The release pathways associated with live backyard poultry should be subjected to more detailed investigation. It was determined that they consist in fact of two separate pathways, one related to live backyard poultry trade and the other to fighting cock activity of backyard poultry farmers. Fighting cock activity in particular is likely to be associated with informal contacts and bird movements that may represent increased levels of risk for introduction of HPAI virus into a buffer zone. A quantitative risk assessment combined with targeted data collection should be conducted for these two specific pathways.

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Appendix I - List of Individuals involved in risk assessment and workshops

Workshop with DLD veterinarians (12 - 13 May 2008)
APIWUT PAWANG
CHAMNAN WACSKAMA
SURAWAT SUEPSAKUL
SUPON CHANTOKOT
SOMPOD PAORPAMOT
EKARAT POONSRI
SUTHON RAOCHANANON
PICHAT NIYOMTHAI
SURACHAT CHUMRUNROT
CHEDTHAKRID DARAPHONG
AUSSAWIN SRITHAGAN
NURUMON WOOTIJIRATTIKAN
CHATSUDA CHUMKASEAN
PHANLOP LUKIN
Workshop with Farmers (23 - 24 June 2008)
SUWAJEE SAETEW
KADNAPAT SAETEW
SURAT RATTANAPISOPON
SUPAT SRIPONG
SAYAN ROTPITIKAN
KIM SAEAUE
SON THAMWIJIT
SOMCHAI THANPAN
WASAN BOCUNAN
SANTIPONG SONGSANGCHAN
TEE KAMPUNNOI
SOPI MONRAKSA
DEELOK DAOCHALADSAENGCHAI
CHARAM YAHATTA
AMNUI KALLAWAN
WAK SANGAUN
PANOM DUNGRAN
RATRI THIENGTHAM
BOONMA PINTOKTAN
SISUDA TATONG
KAMPOL TATONG
PITACK RATTANAPON
Workshop with Farmers (1 - 2 July 2008)
PARPIT BOONRANG
MAREE BUTYOJAN
SOMNAL CHAISUBIN
NONGNUT MINGKAN
ANOMA SAMREDEE
SOMKUN CHUSING
PON CHAIYO

BANCHA BOODKAL
WACHARIN CHUSING
SANWAN KANTHANU
KAR KANTHANU
LARB KANTHA
THAITIP TIPSUSI
SOMMAI RATCHNAT
SUTA MUMTA
BOORPIT NAKDEE
TAWATCHAI SUNTONG
PATCHAREE WICHANWAN
DAWAN TUNMARONG
TEM NUCHOM
KIN BOORPARK
JIRAWAN PAGJITA
Workshop with Researchers and cooperating company veterinarians (22 - 23 July 2008)
BORIPAT SIRIAROONRAT
THAWEESAK SONGSERM
SUPHACHAI NANNUALSUWAN
WITAWAT WIRIYARAT
SIRICHAI WONGNAKPET
SANIPA SURADITAT
BOONPROM ENKVETCHAKUL
ORAWAN FAKKHAM
TACHIT CHOTINAN
PANIPAN CHAIPANYA
NATTIKA AIMSUWAN
WASARAPONG
TRAYUT KIMMUN
Facilitators
SUWICHA KASEMSUWAN
NOPPAWAN BOAMEETOUP
CHAITHEP POOLKHET
MANUTCHAI WATTANAKUL
PATCHIMA SITTISARN
THITIWAN PATANASATIENKUL
TIPPAWAN PARAKGAMAWONGSA
KACHAIN WONGSATAPORNCHAI
THANOM NOIMAR
KAROON CHANACHAI
JAKAPOP CHANSAAD
WATCHARAPOL CHOTIYAPUTTA
SITH PREMASATHEINRA
SARAYA TAVORNPANICH
SUJIRA NGAOJAN

Appendix II - Summary of Knowledge about HPAI Virus Survival in the Environment

March 2008

By Clara Marce (Royal Veterinary College)

Stability in carcasses

- Thomas *et al.*, 07 [13]: Material = Chicken cooking meat (H5N1 strain A/chicken/Korea/ES/2003) / Parameters = 57 to 61°C / Time = 241.2 (321.1) to 33.1 (44.0) seconds (predicted D-values and upper limit of the 95% confidence interval for the Z-value) / Result = inactivation / Reference = Thomas *et al.*, 07 Prediction: cooking chicken meat according to current US time-temperature will inactivate Korean/03 in a heavily contaminated meat sample, with a large margin of safety.
- Senne *et al.*, 94 [11]: At the end of the first 10 days of composting, virus-isolation efforts showed that the HPAI virus had been inactivated.
- Tumpey *et al.*, 02 [14]: this paper reports the recovery of HPAI H5N1 virus from domestic duck meat.

Replication in feathers

- Yamamoto *et al.*, 08 [16]: this paper raise the possibility of feathers as sources of infection. They found that 2 different AI virus (H5N1) genotypes can replicate in the feather epidermal cells of domestic ducks and geese.

Stability in water

- Zarkov *et al.*, 06 [17]: Survival did not exceed 24 It at 9.34 pH, reached one week at the highest salinity and more than 2 weeks at close to tap water physical and chemical characteristics (H6N2 and A/duck/England/56 H11N6). Presence of living microorganisms in some waters further reduced AIV survival (with 12.5% in H6N2 and with 14.29% in A/Duck/England/56 H11N6 in the waters with microorganism count as small as 8.9*10^4 cells/ml). When microorganism count was high (6.64*10^6 cells/ml and 5.2*10^6 cells/ml), the period of survival was with 40% and 35.71% shorter.
- Brown *et al.*, 07 [2]: Virus (eight wild type low pathogenicity H5 and H7) were tested at 2 temperatures (17 and 28°C) and three salinity levels (0,15, and 30 parts per thousand sea salt). The wild-type H5 and H7 AIV persistence data to indicate the following: 1) that H5 and H7 AIV can persist for extended periods of time in water, with a duration of infectivity comparable to AIV of other subtypes; 2) that the persistence of H5 and H7 AIV is inversely proportional to temperature and salinity of water; 3) that a significant interaction exists between the effects of temperature and salinity on the persistence of AIV, with the effect of salinity more prominent at lower temperatures. Results form the 2 HPAI H5N1 viruses from Asia indicate that these viruses did not persist as long as the wild-type AIV.
- Rice *et al.*, 07 [8]: Free chlorine concentrations typically used in drinking water treatment -0.52-1.08 mg/L) are sufficient to inactivate the virus by >3 orders of magnitude (exposure time = 1 minute). (cf World Health Organization: Review of latest available evidence on risks to human health through potential transmission of avian influenza (H5N1) through water and sewage. WHO/SDE/WSH/06.1. Geneva: The Organization; 2006).
- Smith *et al.*, 04 [12]: influenza viruses can survive for days in water (especially true for cold water), and are well preserved when frozen in ice.

Stability in aerosols

- Schaffer *et al.*, 76 [10]: Influenza A virus, strain WSNH, propagated in bovine, human and chick embryo cell cultures and aerosolized from the cell culture medium, was maximally stable at low

relative humidity (RH), minimally stable at mid-range RH, and moderately stable at high RH. Polyhydroxy compounds exerted a protective effect on airborne stability.

- Lowen *et al.*, 07 [5]: (guinea pig model) aerosol spread of influenza virus is dependent upon both ambient relative humidity and temperature. Both cold and dry conditions favour transmission. For infected guinea pigs housed at 5°C, the duration of peak shedding was approximately 40h longer than that of animals housed at 20°C. They found that low relative humidities of 20%-35% were most favourable, while transmission was completely blocked at a high relative humidity of 80%. When guinea pigs were kept at 5°C, transmission occurred with greater frequency than at 20°C, while at 30°C, no transmission was detected. Suggestion: if transmission is not impaired at 30°C, this may suggest that contact-based spread predominates in the tropics, whereas aerosol transmission plays a larger role in temperate climates.
- Lowen *et al.*, 08 [6]: (guinea pig model) Lack of aerosol transmission at 30°C and at all humidities tested = transmission by the aerosol route is sensitive to RH and temperature. Conversely, transmission via the contact route was equally efficient at 30°C and 20°C = insensitive to RH and temperature. Precise results: transmission most efficient at a low temperature (5°C) and a low RH (20 to 35%) = conditions prevalent during winter months in the Northern and Southern hemispheres. Conversely, transmission via respiratory droplets failed to occur at either a high RH (80% RH and 20°C) or a high temperature (30°C and 35%RH).

Stability in manure

- Lu *et al.*, 03 [7]: The H7N2 AIV was effectively inactivated by field chicken manure in less than a week at an ambient temperature of 15-20°C. At a pH 2, heating at 56°C, and exposure to 70% ethanol or a specific disinfectant, the AIV infectivity was destroyed in less than 30 min.

Survival on environmental surfaces

- Bean *et al.*, 82 [1]: Both influenza A & B viruses survived 24-48 hours on hard, nonporous surfaces such as stainless steel and plastic but survived for less than 8-12 hours on cloth, paper, and tissues. Virus survived on hands for up to 5 min after transfer from the environmental surfaces. Measurable quantities of influenza A virus were transferred from stainless steel surfaces to hands for 24 hours and from tissues to hands for up to 15 min.

Inactivation by solar radiation

- Sagripanti & Lytle, 07 [9]: This study reports expected inactivation of influenza A virus by solar ultraviolet radiation in several cities of the world during different times of the year. The inactivation reported indicate that influenza A virions should remain infectious after release from the host for several days during the winter “flu season” in many temperate-zone cities, with continued risk for reaerosolization and human infection. Reminder: aerosolized influenza has been recovered from fomites and environmental surfaces and viable influenza virus has survived at least 48-72h on contaminated surfaces.

Other

- Greiner *et al.*, 07 [4]: Risk of human infection with H5N1 via preparation and consumption of poultry meat is negligible.
- Walther *et al.*, 04 [15]: high-virulence, high survival: mean percent mortality greater than or equal to 0.01% and mean survival time >10 days.

Table from EFSA report. Stability of different influenza viruses in various environmental materials and heat treated poultry products.

Material	Parameters	Time	Result***	Reference
Aerosol				
Aerosol, faeces	Low temperature, low humidity	not specified	prolonged infectivity	Schaffer et al., 1976
Aerosol (Influenza A virus, strain WSNH)	Different relative humidity (RH)	-	Maximally stable at low relative humidity	Schaffer et al., 1976
Aerosol spread	Relative humidity (RH) and temperature	-	Greater frequency transmission at 5 than 20°C, no transmission at 30°C; Low RH of 20-35% most favourable	Lowen et al., 2007
Aerosol spread	Relative humidity (RH) and temperature	-	Transmission via contact route equally efficient at 20 and 30°C(insensitive to RH and temperature) Transmission via respiratory droplets failed to occur at either a high RH (80%RH and 20°C) or a high temperature (30°C and 35%RH)	Lowen et al., 2008
Faeces				
Droppings of faeces (H5N2)	4°C	35 days	retained infectivity	Beard et al., 1984
Droppings of faeces (H5N2)	25°C	2 days	retained infectivity	Beard et al., 1984
Chicken manure (H5N2)	Ambient	105 days	retained infectivity	Fitchner, 1987
Chicken manure (H5N2)	not specified	44 days	retained infectivity	Utterback, 1984
Chicken manure (H7N2)	4°C	23 days*	retained infectivity	Lu et al., 2003

Material	Parameters	Time	Result***	Reference
Chicken manure (H7N2)	Ambient	19 days*	infectivity present, full inactivation at day 23	Lu et al., 2003
Chicken manure (H7N2)	37°C	14 days*	infectivity present, full inactivation at day 16	Lu et al., 2003
Chicken manure (H7N2)	15-20°C	-	Inactivation in less than a week	Lu et al., 2003
Chicken manure (H7N2)	56°C, pH=2, 70% ethanol or specific disinfectant	-	Infectivity destroyed in less than 30min	Lu et al., 2003
Chicken faeces (H5N1 HP/Asia)	32-35°C, sunlight exposure	30 mins	no infectivity retained	Songserm et al., 2005
Chicken faeces (H5N1 HP/Asia)	25-32°C, shade	4 days	no infectivity	Songserm et al., 2005
Water				
Lake water (H3N6)	0°C	>30 days	retained infectivity	Webster et al., 1978
Lake water (H3N6)	22°C	4 days	retained infectivity	Webster et al., 1978
Surface water, rice field (H5N1 HP/ Asia)	not specified	3 days	no infectivity retained	Songserm et al., 2005
Distilled water (five subtypes)	17°C	207 days*	retained infectivity	Stallknecht et al., 1990
Distilled water (five subtypes)	28°C	102 days*	retained infectivity	Stallknecht et al., 1990
Water (H6N2 and A/duck/England/56 H11N6)	9.34 pH / different salinities	24 It	End of survival	Zarkov et al., 2006
Water (H6N2 and A/duck/England/56 H11N6)	Presence of micro-organisms	-	Reduction of AIV survival	Zarkov et al., 2006
Water (8 wild type low pathogenicity H5 and H7)	2 temperatures (17 and 28°C) and 3 salinity levels (0,15 and 30 parts per thousand sea salt)	-	Persistence inversely temperature and proportional to salinity of water + interaction: salinity more prominent at lower temperatures	Brown et al., 2007
Water	Free chlorine concentrations(0.52-1.08 mg/l)	1 mins	Inactivation by >3 orders of magnitude	Rice et al., 2007
Water, ice	-	Days	Survival for days	Smith et al., 2004

Material	Parameters	Time	Result***	Reference
Environmental surfaces (Influenza A & B viruses)	-	-	24-48 hours survival on hard, non porous surfaces and less than 8-12 hours on cloth, paper and tissues; Survival on hands for up to 5 min	Bean et al., 1982
Heat-treated poultry products				
Meat	70°C	30 mins	full inactivation	AQIS, 1991
Meat	75°C	5 mins	full inactivation	AQIS, 1991
Meat	80°C	1 mins	full inactivation	AQIS, 1991
Meat	composting	10 days	inactivation	Senne et al., 1994
Meat (H5N1 HP/Asia)	70°C	3 mins	no infectivity retained	Songserm et al., 2005
Dried egg white (H7N2 LP, H5N2 HP)	54.4°C	15.2 days	full inactivation	Swayne and Beck, 2004
Dried egg white (H7N2 LP, H5N2 HP)	67°C	0.6 days	full inactivation	Swayne and Beck, 2004
Whole egg (H7N2 LP, H5N2 HP)	60°C	3 mins	full inactivation	Swayne and
Whole egg (H5N1 HP/Asia)	70°C	3 mins	no infectivity retained	Songserm et al., 2005
Chicken cooking meat (H5N1 strain A/chicken/Korea/ES/2003)	57 to 61°C	241.2 (321.2) to 33.1 (44.0) secs ***	inactivation	Thomas et al., 2007

* Measured in manure of SPF chickens; times were considerably shortened when “field manure“ was used (4 days at ambient temperature and 12 hours at 37°C).
** Estimates of linear regression models based on inactivation kinetics of 106.0 TCID50 ml-1
*** The results were based on in-vitro conditions and the risk of infection depends upon whether the minimal infectious dose is reached
**** Predicted D-values and upper limit of the 95% CI for the Z-value

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