IMPROVEMENT OF MANAGEMENT AND BIOSECURITY PRACTICES IN SMALLHOLDER POULTRY PRODUCERS

General concept

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Improvement of Management and Biosecurity Practices

in smallholder poultry producers

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List of Abbreviations and Definition of Terms

Biosecurity	Security from transmission of infectious diseases, parasites and pests to domesticated animals
Contagious	Infectious
Conducive	Contribute
Disease control	Methods to control a disease e.g. vaccination or treatment
Disease eradication	Methods to eradicate a disease e.g. elimination of selected organisms from a defined area
Disease prevention	Methods to exclude disease from a defined area e.g. vaccination is often used to prevent a disease from entering a geographical area
Disseminate	Spreading of information
Endemic	A situation where a disease is found permanently in a flock. Morbidity is high and mortality is low
Epidemic	A situation where a disease is progressing rapidly in a flock. Morbidity is high and mortality is high
Feral birds	Wild birds
HPAI	Highly Pathogenic Avian Influenza
Haemorrhage	Bleeding
Hatchery	Farm for hatching of chicks by the use of a hatching machine
Iatrogenic	Caused by the veterinarian e.g. abscesses due to injection
MHC	Major Histocompatibility Complex
Migratory birds	Feral birds with different habitats. Migration is typical in the autumn or spring
Mitigation	To moderate the severity of a disease
NGO	Non Governmental Organisation
OIE	World Organisation for Animal Health (www.oie.int)
Pandemic	World wide epidemic
Prophylactic vaccination	Prevention of a disease by vaccination
Poultry	Domesticated fowl descended from the red jungle fowl kept primarily for meat and eggs; including birds of the order *Galliformes,* e.g., the chicken, turkey, guinea fowl, pheasant, quail, and peacock; and natatorial (swimming) birds, e.g., the duck and goose
Ratites	Birds belonging to the ostrich family
Rearing	Breeding,
Remuneration	Financial compensation
Scavenging	Term used for birds finding their feed in the environment by their own
Sentinel birds	Disease naïve birds inserted into a flock to monitor the development of a vaccination programme
Stamping out	Method whereby all animals (birds) are killed due to a disease outbreak
WTO	World Trade Organisation

1 Executive Summary

- Worldwide there are many strains of avian influenza (AI) virus that cause varying amounts of clinical illness in poultry. AI viruses are classified into low pathogenic avian influenza (LPAI) which causes little or no clinical signs in infected birds, and highly pathogenic avian influenza (HPAI) which is a serious and often fatal disease in birds. LPAI may mutate into HPAI.
- Outbreaks of HPAI (H5N1) in South East Asia (SEA) in late 2003 to early 2004 were historically exceptional in their geographical scope, international spread and economic consequences for the agricultural sector. Twenty-three humans died and over 100 million birds died or were culled as a result.
- New outbreaks of HPAI (H5N1) occurred in June 2004 in SEA and spread into Europe and Africa by late 2005 and early 2006, causing deaths of humans and birds. To date (Jan. 2007) 163 humans have died globally.
- H5N1 is now endemic in SEA and epidemic in Europe and Africa. Other combinations of HxNx are probably endemic in most parts of the world among poultry and wild birds.
- It seems that migratory waterfowl are the natural reservoir for avian influenza therefore waterfowl should be separated from other poultry.
- Strategies to reduce the evolution of influenza and the emergence of pandemics include the separation of species, the development of new vaccine strategies, increased biosecurity at farm and market, better basic knowledge of the virus, its epidemiology and spread from farm to consumer.
- AI might be controlled by stamping-out procedures or vaccination, but with an endemic situation vaccination is the most cost effective method of control.
- Biosecurity is a mindset of actions taken to prevent disease outbreaks in a flock. State-of-the-art biosecurity has been developed for sector 1 and 2 farms. Transfer of basic biosecurity knowledge to sector 3 and 4 is possible.
- By applying simple biosecurity rules to sector 3 and 4 farms, disease outbreaks might be controlled or prevented.
- Restructuring of sector 4 farms and markets based on training of farmers and vendors is needed.
- More effective co-operation between scientists and veterinary and public health officials and livestock services is required to improve these goals.
- In the long term it is anticipated that survival of birds in sector 4 will improve the overall food security.

2 Introduction

2.1 Background

After the latest outbreaks of the highly pathogenic avian influenza (HPAI) in Southeast Asian countries in 2003, the disease has spread to an increasing number of regions and countries. In order to control the disease, culling of infected flocks has been one way of action leaving millions of small poultry producers behind with limited possibilities of income generating activities and in addition a decreased food security. To further control the spread of AI, restriction of the village poultry sector including the banning of complete production systems has been suggested. Alternatively, increased biosecurity and restructuring of the poultry sectors have been proposed as valid alternatives to culling and restriction.

In 2004 FAO/OIE defined four main poultry production sectors, numbered 1 to 4, with the sectors three and four representing small production systems in peri-urban areas and villages. The sector 3 comprises small scale, commercial farms involving mainly broilers, layers or ducks, while sector 4 includes backyard, indigenous and scavenging birds in mixed farming systems. Restructuring to improve biosecurity is considered especially important for sectors 3 and 4.

The objective of this literature review is to describe biosecurity and to cover options of improving biosecurity in sectors 3 and 4 while considering the possibilities of restructuring keeping in mind the special conditions of small poultry productions. Furthermore, the feasibility and cost of implementation and the potential impact on future contribution of small poultry production to food security is discussed. The target group is decision makers, professional poultry personnel and scientists.

2.2 Poultry for the Poor

For poor livestock keepers, free-ranging, scavenging poultry are especially important in providing nutrition for the family and for income generation{IAEA, 2002 30 /id;Network for Smallholder Development, 2006 69 /id}. In particular women and children are involved in the small-scale poultry production{Rushton, 1998 67 /id}. Some African households pay school fees from their backyard poultry micro-enterprises {IAEA, 2002 30 /id} while other may buy daily household needs. Avian influenza may therefore impact on the poor in a number of ways. Direct losses result from the death of their birds following outbreaks of the disease and additional losses from culling of birds. Compensation in developing countries is not always available and, if paid, is unlikely to represent the full market value of the birds, nor to compensate for future loss of earnings. Indirect losses may result in the development of malnutrition while lack of small cash to pay for school fees will damage the family's long term development. In the absence of outbreaks, fear of the disease may still damage local markets as consumers switch to other sources of animal protein.

Faced with these difficulties, the poor in developing countries have few options and extreme situations can provoke desperate reactions. Poor poultry owners in Vietnam, China, Laos, Nigeria and other countries have been hiding their birds from official culling teams, as compensation was considered inadequate. Also villagers have been arrested for feeding on culled birds retrieved from disposal pits. In these situations, human infection from avian flu is much more likely. Worldwide, over 270 persons have now been infected with HP H5N1 and 165 persons have died from the disease{WHO, 2006 31 /id}. Women and children are particularly vulnerable as they are often responsible for keeping, slaughtering and cooking of domestic poultry {IAEA, 2002 30 /id;Rushton, 1998 67 /id}.

2.3 Future Aspects of Keeping Poultry at Village Level

With the current epidemic situation of AI and a stamping-out policy to control the spread of AI {OIE, 2006 32 /id}, future aspects of keeping poultry at village level are not bright. However, for producers in countries not yet affected by AI as well as in countries infected with AI, there are some precautions that can be taken to protect their poultry {OIE, 2006 32 /id}. In general these precautions are termed biosecurity. In chapter 5 biosecurity will be dealt with in detail. Whilst migration of birds carrying avian flu is difficult to control, management of the flock and trade has played a significant role in the spread of the disease and may have contributed to the outbreaks in commercial farms as well as village flocks in many countries{Ducatez, 2006 2 /id}. Even for smallholders, it is important that any live birds bought at market should be kept quarantined from the existing flock until it is clear that no disease is present. However, at national level, there is a clear need for well thought out disease surveillance systems for sectors 3 and 4, pro-poor policies and public awareness campaigns. It is clear that ducks have played an important role in the evolution of the now dominating Z genotype of HPAI and the mixing of ducks and other domestic animals in the same backyard flocks pose large risks as duck often have been found to be silent carriers of HP H5N1 virus{Tumpey, 2003 27 /id;Tumpey, 2002 28 /id;Hulse-Post, 2005 29 /id;Webster, 2005 68 /id}. The circulation of human H3N2 influenza virus along with avian H9N2 virus among domestic pigs in south-eastern China further stress the immense importance of not mixing different species with each other {Peiris, 2001 24 /id}. To be able to continue backyard poultry production in developing countries the public awareness of biosecurity must increase and cost effective measures of biosecurity must be implemented without further delay at village level as well as in markets.

3 Background on Avian Influenza

3.1 The Spreading of Avian Influenza

The spread of AI has dominated the news, as outbreaks of the highly pathogenic H5N1 strain has spread first in East Asia, and subsequently across Asia and into Europe and Africa{Ducatez, 2006 2 /id;Ducatez, 2006 4 /id;Gilbert M, 2006 66 /id}. First isolated from geese in Guangdong in China in 1996 and then in south China in ducks the virus entered Hong Kong{Songserm, 2006 6 /id}. The first reported human cases of HP H5N1 avian influenza infections were in Hong Kong in 1997{Claas, 1998 7 /id;Suarez, 1998 9 /id;Subbarao, 1998 10 /id} where animal to human spread occurred at the live bird market. Several reappearances with other genotypes have occurred since in Hong Kong {Sims, 2003 11 /id}. In Vietnam similar avian influenza viruses have been in circulation since 2001{Nguyen, 2005 5 /id}. In 2002 a change in the virus occurred as dead wild aquatic birds appeared in Hong Kong{Ellis, 2004 12 /id;Sturm-Ramirez, 2004 13 /id}. This genotype has later spread all around east Asia and is now endemic in the area{Li, 2004 14 /id}. In Europe the first cases were reported in Turkey in October 2005 and from there it spread to Eastern Europe up to Denmark and Sweden in March 2006. Control of the disease was initiated and no outbreaks have been encountered since. In Africa the first cases were reported in February 2006, and by April, five African countries - Egypt, Nigeria, Niger, Cameroon and Burkina Faso - had confirmed the presence of HPAI. Control strategies have been planned in East Asia and to a large extent carried out. In West Africa countries have already begun to plan a regional control strategy, and elsewhere on the continent, governments are planning how poultry flocks can be protected and outbreaks controlled. But experts fear that Africa's poor human and animal health services, large backyard poultry population, and lack of resources to fight bird flu will make it an easy target for the disease. Nigeria was the first country to report the emergence of this HPAI{Ducatez, 2006 2 /id;Ducatez, 2006 4 /id}. From phylogenetic analyses of strains from these outbreaks it can be concluded that the February 2006 Nigerian outbreaks probably were caused by multiple introductions of the virus into the country{Ducatez, 2006 2 /id} rather than direct spread from farm to farm from one single introduction. As of September 2006 the situation is rather quiet, but few outbreaks have been reported from Southeast Asia. The relative role of migratory birds, markets and trading of poultry products (live and dead) are still not clear{Gilbert M, 2006 66 /id}.

3.2 The Disease in Birds

Avian influenza is an infectious disease of birds caused by type A strains of the influenza virus{Food and Agriculture Organization and World Organisation for Animal Health in collaboration with World Health Organization, 2005 88 /id}. While all birds are thought to be susceptible to infection with avian influenza viruses, many wild bird species carry these viruses with no apparent clinical signs{Stallknecht DE, 1988 35 /id}. Other bird species, including domestic poultry, develop disease when infected with avian influenza viruses{Alexander, 1978 54 /id}. In poultry, the viruses cause two distinctly different forms of disease – one common and mild, the other rare and highly lethal. In the mild form, signs of illness may be expressed only as ruffled feathers, reduced egg production, or mild effects on the respiratory system. Outbreaks can be so mild they escape detection unless regular testing for viruses is in place{FAO, 2006 33 /id}.

In contrast, the second and far less common highly pathogenic form is difficult to miss. First identified in Italy in 1878, highly pathogenic avian influenza is characterized by sudden onset of severe disease, rapid contagion, and a mortality rate that can approach 100% within 48 hours. In this form of the disease, the virus not only affects the respiratory tract, as in the mild form, but also invades multiple organs and tissues. The resulting massive internal haemorrhaging has earned it the lay name of "chicken Ebola".

All 16 HA (haemagluttinin) and 9 NA (neuraminidase) subtypes of influenza viruses are known to infect wild waterfowl, thus providing an extensive reservoir of influenza viruses perpetually circulating in bird populations. In wild birds, routine testing will nearly always find some influenza viruses. The vast majority of these viruses cause no harm.

To date, all outbreaks of the highly pathogenic form of avian influenza have been caused by viruses of the H5 and H7 subtypes. Highly pathogenic viruses possess a tell-tale genetic "trade mark" or signature – a distinctive set of basic amino acids in the cleavage site of the HA – that distinguishes them from all other avian influenza viruses and is associated with their exceptional virulence.

Not all virus strains of the H5 and H7 subtypes are highly pathogenic, but most are thought to have the potential to become so. Recent research has shown that H5 and H7 viruses of low pathogenicity can, after circulation for sometimes short periods in a poultry population, mutate into highly pathogenic viruses. Considerable circumstantial evidence has long suggested that wild waterfowl introduce avian influenza viruses, in their low pathogenic form, to poultry flocks, but do not carry or directly spread highly pathogenic viruses. This role may, however, have changed very recently: at least some species of migratory waterfowl are now thought to be capable of transporting the H5N1 virus in its highly pathogenic form and introducing it to new geographical areas located along their flight routes without themselves being clinically affected. It is important to understand that although AI viruses may persist within a population of birds for some months, individuals do not remain infected for much more than a month.

Apart from being highly contagious among poultry, avian influenza viruses are readily transmitted from farm to farm by the movement of live birds, animal health personnel and equipment, other people (especially when shoes and other clothing are contaminated), contaminated vehicles, equipment, feed, and cages. Highly pathogenic viruses can survive for long periods in the environment, especially when temperatures are low. For example, the highly pathogenic H5N1 virus can survive in bird faeces for at least 35 days at low temperature ($4^{o}C$). At a much higher temperature ($37^{o}C$), H5N1 viruses have been shown to survive, in faecal samples, for six days. The newer H5N1 viruses are primarily shed from the upper respiratory tract and for up to 17 days after infection{Hulse-Post, 2005 29 /id}.

The evolution of influenza is a continuing process involving viral and host factors{Webster, 2004 72 /id}. The increasing frequency of emergence of the highly pathogenic H5N1, H7N3 and H7N7 influenza viruses and the panzootic spread of H9N2 influenza virus, all of which can be potentially transmitted to humans, are of great concern{Webster, 2004 72 /id}.

3.3 Spread of Disease

The most common method of disease transmission is by contact of a susceptible animal with an infected animal. This can occur within the flock or from flock to flock by the introduction of new birds bought at a market or received as a gift.

Other methods of disease transmission include{Food and Agriculture Organization and World Organisation for Animal Health in collaboration with World Health Organization, 2005 88 /id}:

- Aerosol spread can spread respiratory diseases over long as well as short distances.
- Rodents, domestic and other wild animals can spread diseases such as Salmonella and other diseases.
- Migratory birds can transmit disease by direct contact or indirect by dropping of faeces, nasal discharge onto material to be introduced into a susceptible flock (litter, feed, vehicles, other materials)
- Flies, mosquitoes and ticks can transmit a wide variety of diseases (viral, bacterial and parasitic) when they are endemic within a production area.
- Feed, vehicles, visitors and other inputs are all capable of transmitting disease to the flock. Any litter, manure on boots or clothing coming from an unknown source could be a threat.
- Likewise equipment such as egg trays, crates etc. may spread the disease.

3.4 The Role of Migratory Birds

The role of migratory birds in the spread of highly pathogenic avian influenza is not fully understood {Food and Agriculture Organization and World Organisation for Animal Health in collaboration with World Health Organization, 2005 88 /id;Gilbert M, 2006 66 /id}. Wild waterfowl are considered the natural reservoir of all influenza A viruses{Hulse-Post, 2005 29 /id}. They have probably carried influenza viruses, with no apparent harm, for centuries. They are known to be infected by and transport viruses of the H5 and H7 subtypes in the low pathogenic form. This is a concern as many of these birds are migratory and travel over long distances across international borders. A simplistic model of flyways is given in Figure 1. Wild birds have been shown to introduce novel influenza gene segments into a population, that when reassorted with existing viruses can generate a dissimilar virus with different antigenic and other biological characteristics.

The influenza viruses are easily spread by fomites and survive and spread well in water. Furthermore, certain species of ducks are able to carry influenza viruses without exhibiting any clinical symptoms of disease. Juvenile ducks have the highest rates of infection and shedding. High titres of virus occur in late-summer, when birds leave their northern breeding areas, although these titres decrease as birds continue southwards{FAO, 2006 33 /id}.

Considerable circumstantial evidence suggests that migratory birds can introduce low pathogenic H5 and H7 viruses to poultry flocks, which then mutate to the highly pathogenic form {WHO, 2006 31 /id}. Recent surveillance studies in Europe have shown that several influenza A viruses of subtypes H5 and H7 could be isolated from dead wild birds. These contained virus isolates that are closely related to isolates recovered from each of the recorded H5 and H7 HPAI outbreaks in Europe since 1997. To date, extensive testing of clinically normal migratory birds in the infected countries has not yielded any HPAI H5N1 viruses.

Recent events have suggested that some migratory bird species have carried the H5N1 virus in its highly pathogenic form and have been responsible for introducing infection into new areas that lie along their migratory routes. This was particularly so in the case of the 2006 introductions of infection into Europe. The spread of the HPAI H5N1 virus in relation to species-specific flyways of Anatidae species (ducks, geese, and swans) and climate has been shown by Gilbert and co-workers{Gilbert M, 2006 66 /id}. They concluded that the spread of HPAI H5N1 virus from Russia and Kazakhstan to the Black Sea basin was consistent in space and time with the hypothesis that birds in the Anatidae family have seeded the virus along their autumn migration routes.

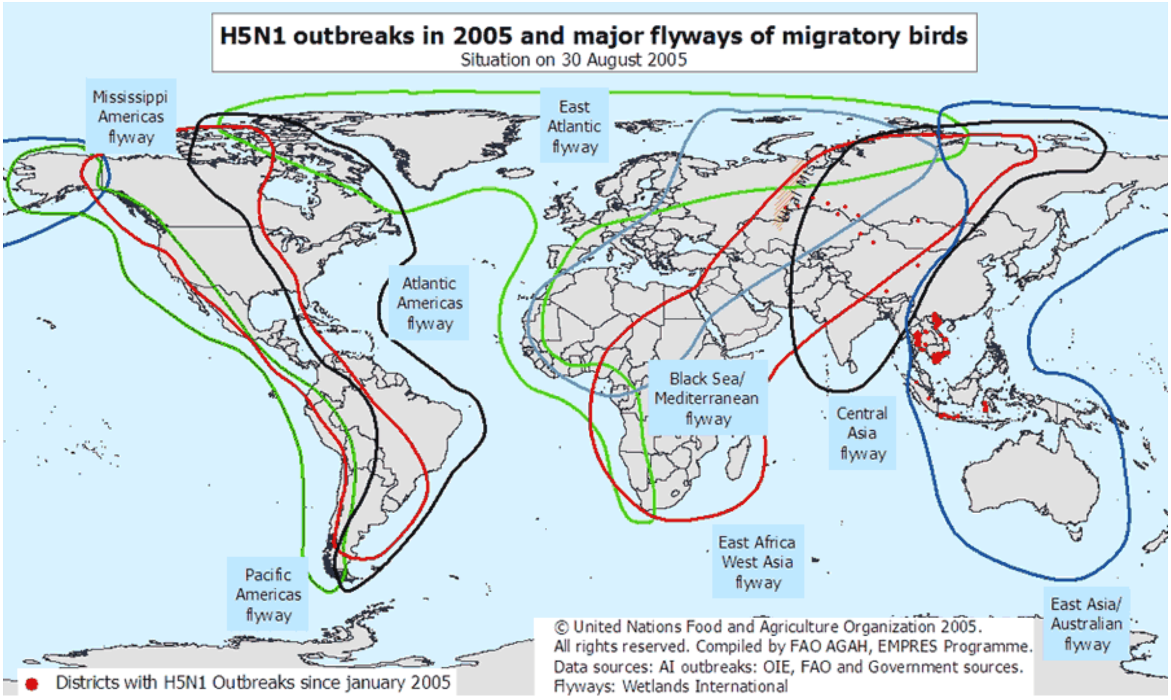

Figure 1 H5N1 Outbreaks in 2005 and Major Flyways of Migratory Birds{FAO, 2006 33 /id;Gilbert M, 2006 66 /id}

Evidence supporting this changed role began to emerge in mid-2005 and has since been strengthened. The die-off of more than 6000 migratory birds, infected with the highly pathogenic H5N1 virus that began at the Qinghai Lake nature reserve in central China in late April 2005 was highly unusual and probably unprecedented. Prior to that event, wild bird deaths from highly pathogenic avian influenza viruses were rare, usually occurring as isolated cases found within the flight distance of a poultry outbreak. The events in Hong Kong suggested that a change was taking place{Sims, 2003 11 /id}. Scientific studies comparing viruses from different outbreaks in birds have found that viruses from the most recently affected countries, all of which lie along migratory routes, are almost identical to viruses recovered from dead migratory birds at Qinghai Lake. Viruses from Turkey's first two human cases, which were fatal, were also virtually identical to viruses from Qinghai Lake.

Anatidae (ducks, geese and swans) is a group of water birds that is ecologically dependent on wetlands for at least some aspects of their annual cycle. Anatidae species use a wide range of wetlands, from the high arctic tundra, rivers and estuaries, freshwater or saline lakes, and ponds or swamps to coastal lagoons and inter-tidal coastal areas such as mud-flats, bays and the open sea. They also utilise man-made wetlands such as rice fields and other agricultural areas. Many of the Anatidae populations migrate between wetlands in the northern breeding areas and southern non-breeding areas and in doing so, regularly cross the borders of two or more countries.

Southward migration for the northern-breeding Anatidae starts in July and increases throughout the following months. Most birds would have reached their winter range sometime between November and December. The migration takes them north to reproduction areas at the end of winter, beginning of spring. The winter of 2003-2004 when most of the outbreaks in South East Asia occurred, was when migratory bird densities in South East Asia were at their peak. This appears to implicate wild birds as a possible source for the infection. However, the pattern of the HPAI outbreaks does not coincide with migratory pathway of wild birds for all countries. It is important to note that, if introduced by migratory birds alone, outbreaks of avian influenza would also be expected to have occurred for example-in Taiwan Province of China (POC) and the Philippines, or even at the extreme range of the flyway in parts of eastern Australia and New Zealand, if shore birds are shown to be reservoirs (Shore birds belong to the classification order Charadiformes and are not Anatidae).

Many duck species identified to carry avian influenza viruses, winter in large numbers in Taiwan POC and the Philippines as well as in areas in Southern Asia. Migrating birds also tend to bypass mainland China, where numerous HPAI outbreaks have occurred, in favour of travelling down the coastline or across western China to avoid the Himalayan Mountains. Furthermore, the timing of the Indonesian and Malaysian outbreaks occurred outside the times when migratory birds would have been present in the countries. Therefore, unexplained factors other than shedding of AI viruses by migratory wild birds could possibly be at play in the dissemination of AI viruses.

Molecular characterisations of Indonesian viruses indicate that all are derived form a single introduction. It is also known that movement of poultry and fighting cocks occur from mainland SE Asia to Indonesia{Smith, 2006 37 /id}.

As the avian influenza virus H5N1 swept from Asia across Russia to Europe, Nigeria was the first country in Africa to report the emergence of this highly pathogenic virus. H5N1 sequences in poultry from two different farms in Lagos state were analysed and it seems that three H5N1 lineages were independently introduced through routes that could coincide with the flight paths of migratory birds, although independent trade imports cannot be excluded{Ducatez, 2006 4 /id;Ducatez, 2006 2 /id}.

Detailed information on migratory water bird species and their population size, migratory routes, important congregation and mixing sites and main areas of interaction with locally migrant and peri-domesticated birds are needed to understand the potential role that wild birds may play in the spread of HPAI. This information is also needed to implement risk assessments, surveillance programs, and early warning systems{FAO, 2006 33 /id}.

3.5 The Epidemic Situation

The outbreaks of reassorted Z genotype of highly pathogenic H5N1 avian influenza that began in Southeast Asia in mid-2003 and have now spread to a few parts of Europe, are the largest and most severe on record. To date, nine Asian countries have reported outbreaks: the Republic of Korea, Vietnam, Japan, Thailand, Cambodia, the Lao People's Democratic Republic, Indonesia, China, and Malaysia. Of these, Japan, the Republic of Korea, and Malaysia have controlled their outbreaks and are now considered free of the disease. Elsewhere in Asia, the virus has become endemic in several of the initially affected countries.

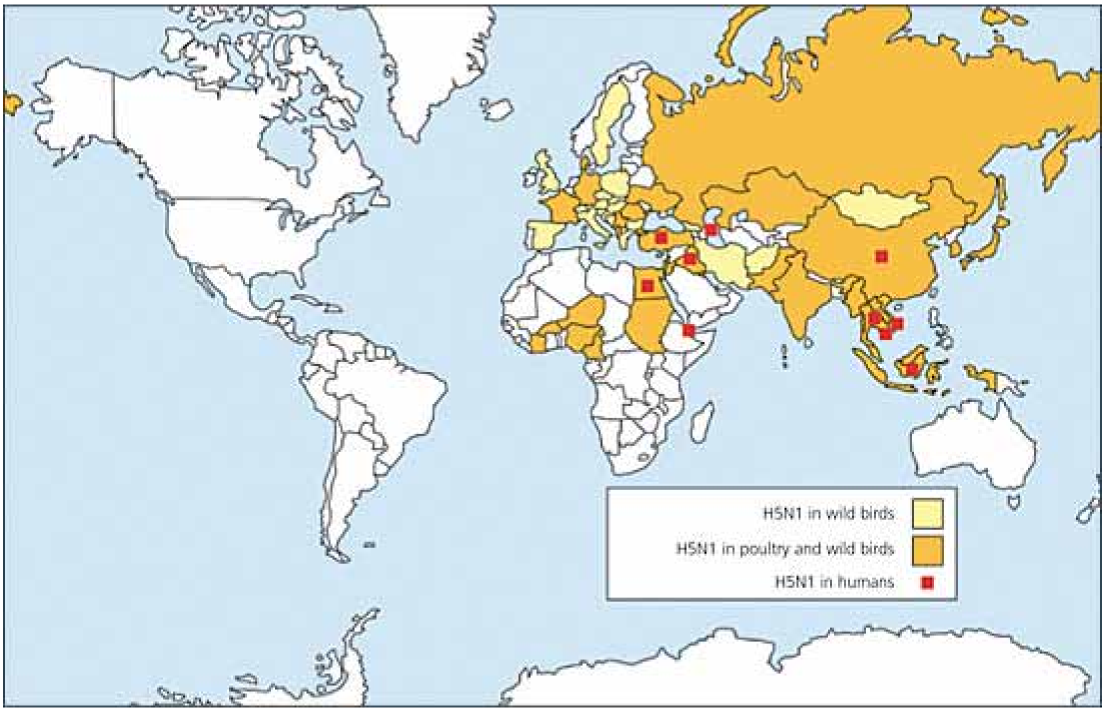

Figure 2 Countries with Confirmed Cases of Avian Influenza (H5N1) as of July 2006 (www.pandemicflu.gov)

In late July 2005, the virus spread geographically beyond its original focus in Asia to affect poultry and wild birds in the Russian Federation and adjacent parts of Kazakhstan. Almost simultaneously, Mongolia reported detection of the highly pathogenic virus in wild birds. In October 2005, the virus was reported in Turkey, Romania, and Croatia. In early December 2005, Ukraine reported its first outbreak in domestic birds. Most of these newer outbreaks were detected and reported quickly. Further spread of the virus along the migratory routes of wild waterfowl is, however, anticipated (Figure 1). Moreover, bird migration is a recurring event. Countries that lie along the flight pathways of birds migrating from central Asia may face a persistent risk of introduction or re-introduction of the virus to domestic poultry flocks.

Prior to the present situation, outbreaks of highly pathogenic avian influenza in poultry were considered rare. Excluding the current outbreaks caused by the H5N1 virus, only 24 outbreaks of highly pathogenic avian influenza have been recorded worldwide since 1959. Of these, 14 occurred in the past decade. The majority have shown limited geographical spread, a few remained confined to a single farm or flock, and only one spread internationally. All of the larger outbreaks were costly for the agricultural sector and difficult to control.

3.6 The Endemic Situation

The first isolation of influenza virus from wild birds was in 1961 in South Africa, but systematic investigations of free-living birds did not begin until the 1975. These investigations revealed a pool of influenza viruses in the wild bird population. Mainly in waterfowl, Order *Anseriformes*, a large number of influenza viruses were identified. In the surveys listed by Stallknecht and Shane (1988) a total of 21,318 samples from all species resulted in the isolation of 2,317 (10.9%) viruses{Stallknecht DE, 1988 35 /id}. Of these samples 14,303 were from birds of the Order Anseriformes and yielded 2,173 (15.2%) isolates. The next highest isolation rates were 2.9% and 2.2% from the *Passeriformes* and *Charadriiformes* and the overall isolation rate from all birds other than ducks and geese was 2.1%.

The first isolates from caged birds were recorded in 1975. The isolates were mainly of H3 or H4 subtypes. The majority of influenza viruses from caged birds come from passerine species. Psittacine species are rarely infected unlike Newcastle disease.

Since 1959 outbreaks of HPAI have been reported 17 times in poultry.

At the end of the 19th and early 20th centuries avian influenza was often reported in chickens and in several countries this disease was probably endemic. However, in the second half of the 20th century reports of influenza infections of chickens have been rare compared to infections of other domestic poultry despite the much higher populations of chickens. In poultry, infections with influenza viruses of H9N2 subtype appeared in 1994-99. Outbreaks occurred in Italy in 1994, South Africa in 1995, Germany in 1995-96, Korea in 1996 and Ireland in 1997. And since 1997, H9N2 virus has been reported in Iran, Saudi Arabia, Pakistan{Naeem, 2006 83 /id;Bano, 2003 84 /id;Naeem, 2003 85 /id;Naeem, 1999 86 /id;Naeem, 1995 87 /id}, China and other Asian countries. H7 and H5 subtypes were isolated from outbreaks in poultry flocks in Pakistan{Naeem, 2006 83 /id;Bano, 2003 84 /id;Naeem, 2003 85 /id;Naeem, 1999 86 /id;Naeem, 1995 87 /id}.

Eight HPAI outbreaks in backyard poultry flocks infected with H5N2 virus were reported in Italy in 1997/78. Outbreaks of H5N1 HPAI occurred on three farms in Hong Kong during March-May 1997 with 70-100% mortalities and subsequent spread to live bird markets.

Since 1963, most of the major turkey-producing countries have had disease problems associated with influenza infections. In the USA in California and Minnesota, where turkey farms are heavily concentrated and situated on migratory waterfowl flyways, influenza virus infections have been seen regularly, but in other countries outbreaks in turkeys have been usually restricted to one or two isolated incidents in the years recorded. Despite the greater prevalence of influenza viruses in turkeys, of the 17 reported isolations of HPAI since 1959 only five were apparently primarily from turkeys.

The status of commercial ducks in most countries is poorly understood or has not been investigated. When surveillance of commercial ducks has been undertaken, enormous pools of virus and many subtype combinations have been detected. In the 2004 outbreak of H5N1 influenza in Thailand, domestic duck flocks were recognised as carriers of the H5N1 influenza virus{Songserm, 2006 6 /id}. No influenza viruses were detected in ducks raised in confinement with high biosecurity. However, H5N1 influenza virus was prevalent in free-ranging (grazing) ducks and backyard ducks{Antarasena, 2006 73 /id;Hulse-Post, 2005 29 /id}.

Testing of ostriches and other ratites during the 1990s has resulted in the regular isolation of influenza viruses. The following influenza subtypes were isolated from ratites: H3N2, H4N2, H4N6, H5N2, H5N9, H7N1, H7N3, H9N2, H10N4 and H10N7. None of these subtypes were virulent for chickens.

Pheasants, geese and other birds are reared under semi-wild (free-range) conditions in a number of countries. Isolations of influenza viruses have been reported from muscovy ducks (*Cairinia moschata*), mallard ducks (*Anas platyrhyncos*), pheasants (*Phasianus* spp.), Japanese quail (*Coturnix coturnix japonica*), chukars (*Alectoris chukar*), guinea fowl (*Numida meleagris*), and various types of geese{Humberd, 2006 78 /id}.

HPAI H5N1 has become endemic in various countries in South East Asia{Smith, 2006 37 /id}. The endemic situation has influenced the control strategies in favour of vaccination programmes instead of culling as it has happened in Vietnam{Oshitani, 2006 39 /id}.

3.7 Other Animal Species Affected by Avian Influenza

Until recently, it was thought that pigs were required as intermediate hosts for the transmission of avian influenza viruses to humans{Shoham, 2006 79 /id}. This hypothesis was based on three suppositions:

- Pigs are generally more susceptible to avian influenza viruses than humans.
- Pigs are the single animal species with receptors preferred by both avian (alpha 2-3 linked sialic acid to galactose) and human (alpha 2-6 linked sialic acid) influenza viruses, which supports their role as "mixing vessels" for reassortment between human and avian viruses. In addition, influenza viruses from aquatic birds can adapt to "human" receptors in the pig.
- Genetic reassortment between avian and human influenza viruses, which is an important mechanism for the emergence of new pandemic human strains, frequently occurs in pigs in nature{Capua, 2002 16 /id}.

However, the respective HPAI viruses have spread directly from infected poultry to both humans and pigs, and pigs did not serve as an intermediate host between birds and humans. Fortunately, it is unlikely that these viruses would spread widely in the human population, unless mutations or genetic reassortment would occur. In theory such genetic changes might occur in the pig. However, it is currently impossible to analyse the risk of the pig in the introduction of new avian influenza strains in the human population, because the basic questions about the replication and pathogenesis of such viruses in swine are still unanswered{van Reeth, 2006 41 /id}. Furthermore, although the present H5N1 virus has an unusual broad host range, swine appear not to be infected easily.

Although avian influenza has been reported in cats and dogs these do not appear to be involved in the epidemiology of HPAI.

3.8 The Disease in Humans and its Importance for Further Spread

Influenza viruses are normally highly species-specific, meaning that viruses that infect an individual species (humans, certain species of birds, pigs, horses, and seals) stay in that species, and only rarely cause infection in other species{Capua, 2002 64 /id;Capua, 2004 63 /id;Capua, 2004 62 /id}. Since 1959, instances of human infection with an avian influenza virus have been documented in 10 occasions. Of the hundreds of strains of avian influenza A viruses, only four are known to have caused human infections namely H5N1, H7N3, H7N7, and H9N2. In general, human infection with these viruses has resulted in mild symptoms and very little severe illness, with only one exception: the HPAI H5N1 virus. The H5N1 virus is presently of great concern for human health for two main reasons. First, the H5N1 virus has caused a number of human cases of severe disease with a high mortality rate (Table 1). Furthermore, it has crossed the species barrier to infect humans{Subbarao, 1998 10 /id}. Another implication for human health is the risk that the H5N1 virus will develop the characteristics it needs to start another human influenza pandemic vis-à-vis the Spanish Flu. The virus has met all prerequisites for the start of a pandemic except the ability to spread efficiently among humans{De Jong, 1997 8 /id}. While H5N1 is presently the virus of greatest concern, the possibility that other avian influenza viruses, known to infect humans, might cause a pandemic cannot be ruled out{WHO, 2006 31 /id;Suarez, 1998 9 /id}.

The virus can improve its transmissibility among humans by two principal mechanisms. The first is a reassortment event (virus shift), in which genetic material is exchanged between human and avian viruses during co-infection of a human or pig. Reassortment could result in a fully transmissible pandemic virus, announced by a sudden surge of cases with explosive spread. The second mechanism is a more gradual process of adaptive mutation (virus drift), whereby the capability of the virus to bind to human cells increases during subsequent infections of humans. Adaptive mutation, expressed initially as small clusters of human cases with some evidence of human-to-human transmission, would probably give the world some time to take defensive action, if detected sufficiently early{WHO, 2006 31 /id}.

To date no reports exist on transmission of the virus from diseased humans to birds, except as passive carriers. Viruses isolated from humans could upon experimental inoculation replicate in ducks. Viruses were also transmitted to contact ducks, whom shed virus at high titres{Hulse-Post, 2005 29 /id}. However, the passive transmission of virus from humans back to birds is likely to occur through markets or movement of equipment{Webster RG, 2006 46 /id}.

Table 1 Human cases of Avian Influenza as of July 2006

Period	Subtype	Site	Cases (lab confirmed)	Deaths (lab confirmed)	Source of infection	Human to human transmission
1997	H5N1	Hong Kong SAR	18	6	Chicken Ducks Geese	Yes
1999	H9N2	Hong Kong SAR	2	0	Chicken	Possible
2002	H7N2	Virginia, USA	1	0	Chicken	No
2003	H5N1	China Hong Kong SAR Vietnam	1 2 3	1 1 3	unknown Chicken Poultry	No No No
2003	H7N2	New York, USA	1	0	Unknown	No
2003	H7N7	Netherlands, Belgium, Germany	89	1	Chicken	Yes*
2003	H9N2	Hong Kong SAR	1	0	Chicken	No
2004	H5N1	Thailand Vietnam	17 29	12 20	Poultry	Possible Possible
2004	H7N3	Canada	2	0	Poultry	No
2005	H5N1	Cambodia China Indonesia Thailand Vietnam	4 8 19 5 61	4 5 12 2 19	Poultry	No No No No Possible
2006	H5N1	Azerbaijan Cambodia China Djibouti Egypt Indonesia Iraq Thailand Turkey	8 2 12 1 15 53 3 3 12	5 2 8 0 6 43 2 3 4	Poultry Wild Birds	No No No No No Possible No No No
2006	H7N3	United Kingdom	1	0	Poultry	No

*Evidence of conjunctivitis in three cases within families

3.9 Genetic Resistance

Natural resistance to diseases is likely to have developed within populations of indigenous poultry breeds through generations of exposure to pathogens occurring in the local environment. Selection for genotypes associated with disease resistance can be a useful addition to disease control programmes and particularly one gene complex, the Major Histocompatibility Complex (MHC), has been investigated thoroughly for its role in disease resistance{Li, 2006 74 /id;Pinard-van der Laan MH, 2004 75 /id;Lakshmanan, 1997 76

/id;Kaufman, 1996 77 /id}. The MHC has been shown to be involved in the genetic control of resistance to several viral diseases, including: Marek's disease; Rous sarcoma virus and avian leucosis. The MHC has furthermore been found to be associated with fowl cholera and salmonellosis. Compared with indigenous breeds, high levels of selection for a few economically important traits (i.e. egg production and weight gain) have in general decreased the genetic diversity in commercial breeds. In contrast, indigenous breeds show high levels of phenotypic variability and increased fitness under natural conditions. The MHC is the most polymorphic gene cluster known, and it is very likely that infectious diseases have been the main selection force{Li, 2006 74 /id;Pinard-van der Laan MH, 2004 75 /id;Lakshmanan, 1997 76 /id;Kaufman, 1996 77 /id}. It is therefore likely, that a considerable risk to poultry production might develop if local genetic resources associated with disease resistance are lost through stamping out policies and subsequently introduction of exotic breeds. Any livestock industry, large or small, needs genetic diversity on which it can draw to cope with whatever challenges the future holds, changes in disease, climate or market preference. Unfortunately, the commercial poultry industries tend to become reliant on a narrow genetic base. In the short term they get the most production but they, and the future of their industry, ultimately depend on the much greater genetic diversity that so often lies in the hands of the small-scale producers.

In relation to AI, genetic resistance exhibits an interesting aspect if it is possible to select for disease resistance against AI. For future re-stocking programmes, this could be a way to improve biosecurity in sectors 3 and 4. However, far more research is needed to document the possibilities of developing an AI-resistant chicken line{Li, 2006 80 /id;Bean, 1989 81 /id}.

4 Current Organization of Poultry Production

4.1 Poultry Production Systems

Several production systems exist in developed and developing countries, but two broad distinctions can be made between the traditional village and backyard system and the modern commercial system. The commercial system is based on a highly specialised breeding system controlled by five major companies. The breeding output is aimed at either egg production (up to 320 eggs/year/hen) for consumption or meat production (acquired body weight for broiler approximately 2 kg in 40 days). In contrast the village based system is based on indigenous chickens with a formal breeding strategy. The output is low and might be either eggs (up to 100 eggs/year/hen) or meat (acquired body weight for broiler approximately 1 kg in 100 days).

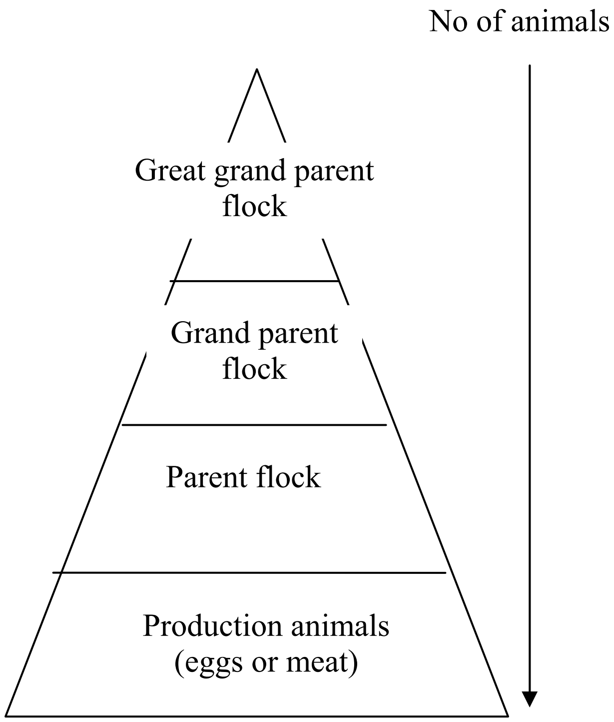

Figure 3 Production Pyramid for Commercial Poultry Production (sectors 1 - 3)

In rural areas, far from cities and markets, the predominant production system is a scavenging system with very few inputs provided by the owner, who will typically be a woman or children. At the opposite end of a continuum with several types of sub-systems; poultry production may constitute a complex, integrated system with thousands of commercially bred birds, highly dependent on the world market for inputs and outputs. The owner will typically be a man. The situation in Thailand illustrates the point. The large, industrial scale producers focus on export, the country being the World's fourth largest exporter of poultry meat before the H5N1 outbreak. However, these exporters depend on import of grand parent or parent stock and other inputs. On the other hand in Thailand it is still more than 90% of those who keep poultry that are categorized as small farmers with native chickens, ducks, fighting cocks and quails and 36% of the chicken population is classified as "native" and kept by small farmers.

For analytical purposes four main production systems (sectors) have been characterised by FAO and OIE:

- Sector 1: Industrial Integrated System
- Sector 2: Commercial Production System
- Sector 3: Small-Scale Commercial Production System
- Sector 4: The Village or Backyard System

4.2 Industrial Integrated System – Sector 1

The Industrial Integrated System is typically a breeding farm an export of products out of the country of breeding material, feed, expertise and other inputs. It keeps the breeding stock (great grand parents, grand parents and parents) and occasionally only the parent stock. Especially the exporting companies will maintain a high level of biosecurity and their farms are typically part of an integrated production enterprise with clearly defined and implemented standard operating procedures for biosecurity. It typically employs its own veterinary staff.

Although the definition of sector 1 is quite clear, the size of the farms may vary. In industrialised countries a sector 1 farm may contain more than 500.000 birds. In Vietnam farms with more than 2001 birds are classified as industrial, while in Indonesia the farms may have 20,000 to 500,000 birds. On the African continent Sector 1 farms are only found in Egypt, South Africa and Nigeria. On world scale only 6 companies are keeping great grand parents.

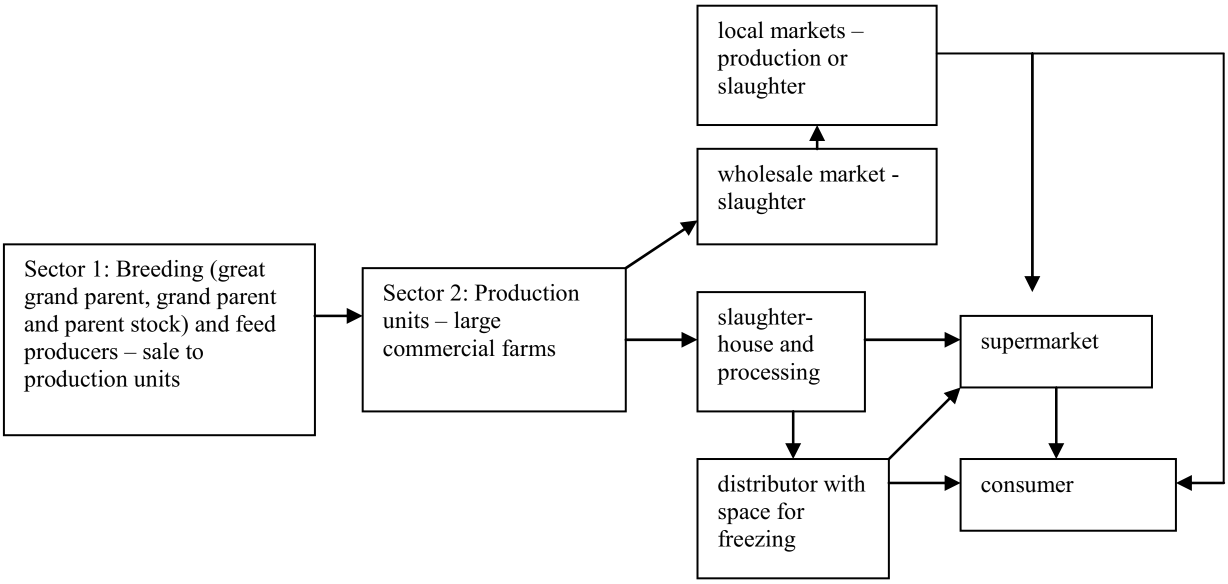

Figure 4 Industrial Integrated System – Sector 1

4.3 Commercial Production System – Sector 2

Sector 2 is a commercial poultry production system that may produce meat or eggs with moderate to high biosecurity. The birds are purchased from breeding companies. The products are sold commercially in urban and rural areas. The farms keep their birds indoors continuously, strictly preventing contact with other poultry or wildlife.

As for sector 1 farms, also sector 2 farms may vary greatly in size. In industrialised countries a sector 2 farm may contain more than 500.000 birds. In Vietnam the farms included in this category had 100 to 2.000 birds, while they had from 5.000 to 10.000 in Indonesia. On the African continent Sector 2 farms are found in a number of countries but mainly Egypt, Nigeria and South Africa. Most commonly day-old chicks are imported from breeding companies in Europe.

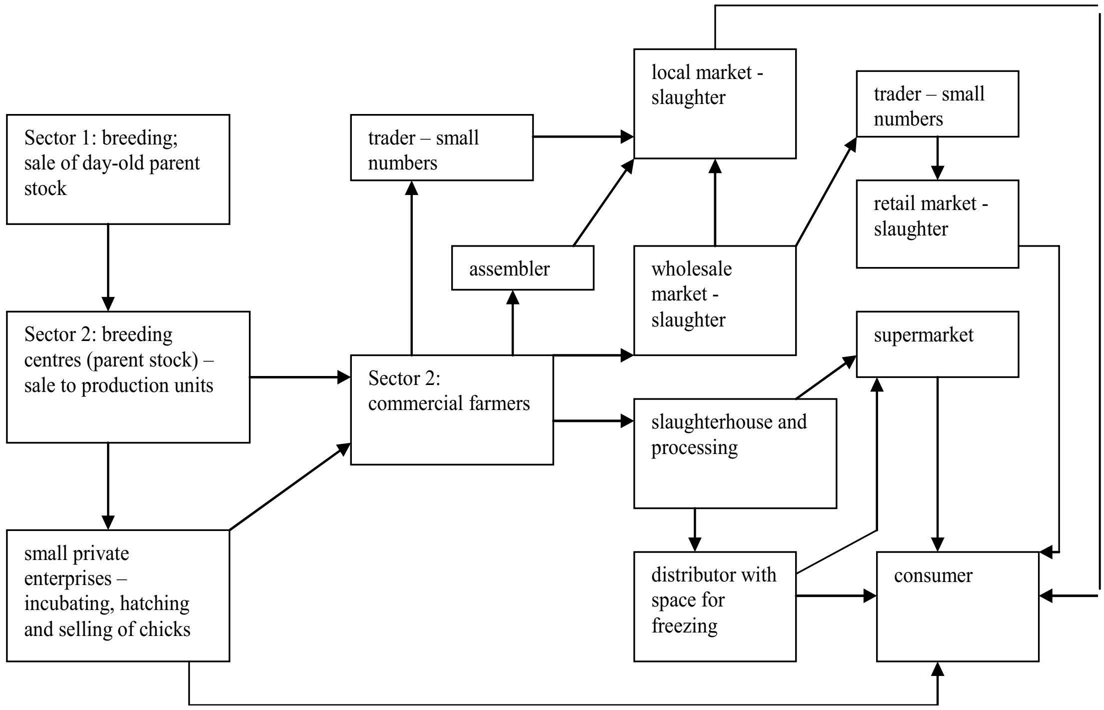

Figure 5 Commercial Production System – Sector 2

4.4 Small-Scale Commercial Production System - Sector 3

This production system has many similarities to sector 2, but the units are smaller and the level of biosecurity is lower. It may be a caged layer farm with birds in open sheds; a farm with poultry spending time outside the shed or a farm producing chickens and waterfowls. The products are sold in live markets in urban and rural areas. Men mainly undertake this production type. In Vietnam the size of the farms ranges from 50 to 150 birds, while the number is from 500 to 10,000 in Indonesia. The commercial farms in Lao PDR and Cambodia tend to fall in this category. Furthermore, integrated farming systems constitute a large part of the production systems in Sector 3. In Africa sector 3 farms are mainly found in peri-urban and urban areas, whereas they are found in rural areas in Asia.

Sector 3 production systems may be divided into Sector 3A systems where the production system is characterised by being a small scale commercial production system consisting of either layers, broilers, ducks, geese or quails. In the less frequent Sector 3B systems the production is characterised by being integrated production systems with free-ranging animals in large out-door runs. The organic farming system developing in Europe is an example of sector 3B farms with high numbers of animals with free access to out-door areas.

For both Sectors 3A and 3B investments are large and veterinary and animal husbandry services form an integrated part of the production.

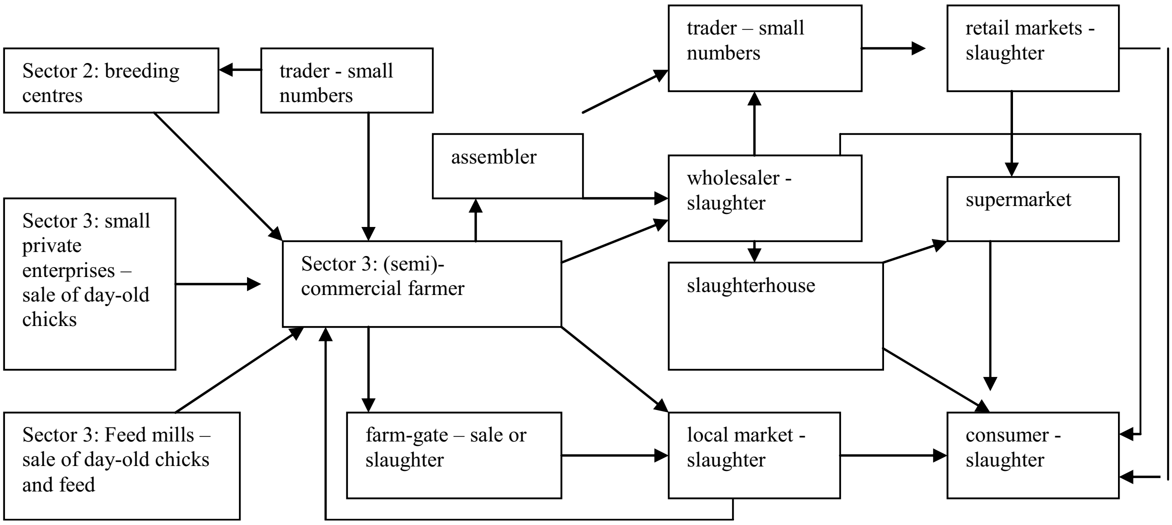

Figure 6 Small-Scale Commercial Production System - Sector 3

4.5 The Village or Backyard System - Sector 4

This production system is the most widespread in Asia, Africa and South America and it is undertaken by millions of households. Many of the households belong to the poorest in the countries. It is mainly women and children, who are responsible for the daily management of the poultry and they are also frequently the owners and decision-makers. The exact number of women and their families who rely on poultry as a component of their farming system is difficult to find, but it is probably 60 % to 80 % of the rural households in most developing countries which keep poultry. Sector 4 production systems are also found in peri-urban and urban areas. The finding of producers in villages and towns makes it very difficult to make an estimate of the number of people who deal with poultry one way or another.

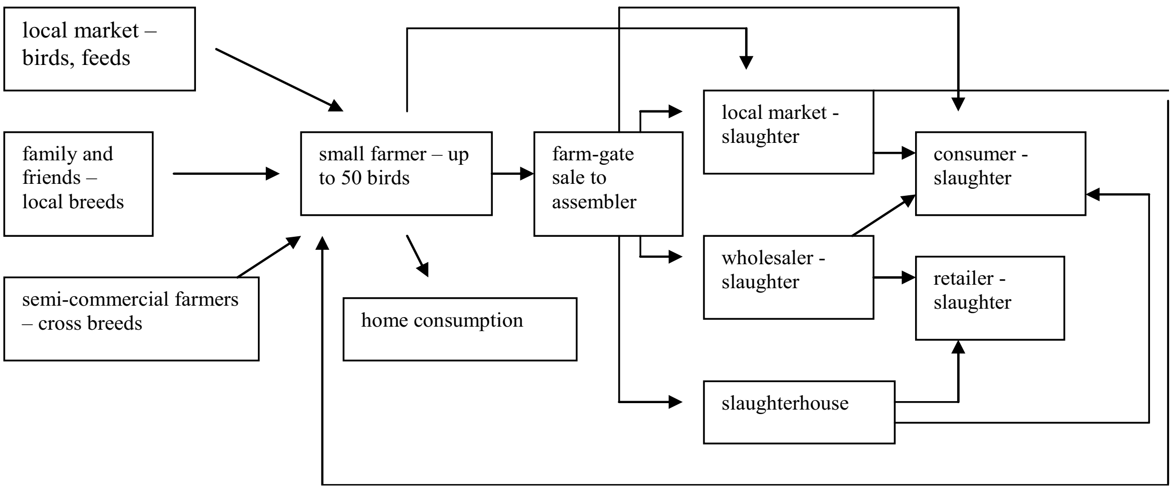

Figure 7 The Village or Backyard System - Sector 4

The poultry and their women managers can be viewed as a sub-system within a larger production system common to many villages, which is known as an integrated or mixed farming system and often praised for its efficiency in coping as the several types of animal and plant productions help to minimize risk, while enhancing resource utilization. However, the frequent and often close contact between the various species of animals and humans living on the same farm provide a very conducive environment for the spread of diseases including H5N1 and possible reassortment of the virus.

Sector 4 does not produce many eggs for sale. The reasons are many, but in some regions farmers prefer to produce young chickens for sale. Other reasons are that as high mortality among chicks and adult birds, most eggs go for reproduction and not human consumption or sale. Village poultry production systems are characterized by a mixing of species and ages categories.

Sector 4 can be further "broken" into 2 sub-sectors. Sector 4A which is characterised by a very basic system with scavenging indigenous poultry, no cross breeds, rather meet production than egg production and part of a mixed farming system. Sector 4B, which is characterised by the use of improved breeds, slightly improved management and input of additional services such as vaccinations and other investments.

Sectors 4A and 4B are the most numerous with millions of producers. In many developing countries more than 80-90% of the poultry producing households belong to Sectors 4A and 4B.

In Sector 4 production systems the chickens might be kept together with other animal species such as ducks, fish, pigs, cattle and buffaloes. There may be regular contact between birds and people as the poultry frequently scavenge and move in and out of the farmers' houses{FAO, 1992 42 /id}.

4.6 Duck Systems

Duck farming is common in Asia{Khanum J, 2005 43 /id}. In terms of numbers the ducks represent 10 – 15% of the poultry in the village and backyard system. The duck production systems can be divided into two broad systems. One is the few ducks that mix with the chicken (seen in Africa) and other animals year round on the small farms, but data on the exact number of farms that keep ducks in this manner are not available. In these production systems Muscovy ducks are common. The other system with much larger flocks that may run into thousands of ducks is typically found around larger water bodies and rice paddies in low laying areas such as the Mekong Delta of Vietnam. In these large flocks other duck types than Muscovy are used. One sub-system of these larger flocks is cyclical and very mobile as ducks are herded after the rice harvest to clean the fields for lost grain. In contrast with the village and backyard poultry system around the homestead, which is controlled by women, men control the specialised and mobile system with large numbers of ducks. These systems have received scant research attention, whether economic, social or biological.

In many countries duck production systems are usually differentiated into three systems combining a spatial aspect (free ranging, semi-confined and confined), as well as an economic criteria (low scale, semi-commercial, commercial){Edan M, 2006 44 /id}. In the Mekong Delta, the duck production systems vary considerably depending on their location (rural, urban and peri-urban). They comprise three main systems as follows:

- Scavenging systems: scavenging, free ranging within the farm and the village (garden, home or village pond); daily herding in rice-fields, dikes, rivers, canals and tidal areas (beyond the farm); seasonal transhumant supervised ranging (beyond the locality);
- Integrated duck production systems: rice-fish-duck; fish-duck-pigs (or other domestic species);
- Confined systems: semi-commercial and commercial farms (meat and egg production); duck-fish combination in enclosures or floating cage in ponds/canals/rivers

Duck husbandry systems may be further divided into sub-systems depending on local conditions. Scavenging systems can be either full scavenging or semi-scavenging, where ducks are confined at night in enclosures or pens. Ducks in the Mekong Delta are mostly raised on small-scaled farms.

Another classification has been proposed by the FAO and other agencies, differentiating systems according to economic criteria. Over the past years, poultry production units have been given numbered levels according to their production scale. The levels are:

- Industrial integrated system with broilers, layers and breeder farms, potentially for exportation
- Medium commercial poultry production system (broilers/layers/ducks)
- Medium to small commercial poultry production system (broilers/layers)
- Village or backyard production in mixed farming system (ducks, pigs, etc.)

The village or backyard production in mixed farming systems is mainly found in Sub-Saharan Africa whereas the more intensive production systems are found in Asia.

Recent data from Thailand where a study of 4 different duck rearing systems revealed that ducks raised in closed houses with high biosecurity did not have any influenza antibodies contrary to ducks raised in open houses, free-ranging ducks and backyard ducks were H5N1 influenza virus was prevalent {Songserm, 2006 6 /id}. Also, results from analyses of sera from live bird markets in Vietnam during 2001 revealed that ducks were prominent carriers of different avian influenza viruses with a prevalence of 30%{Nguyen, 2005 5 /id}. Since October 2005 the practice of raising ducks in open fields and moving grazing ducks from one region to another is forbidden in Thailand{Songserm, 2006 6 /id}.

4.7 Integrated Production Systems

The expression ‘integrated’ can have two meanings in the context of the production systems{FAO, 1992 42 /id}. In one case, it is applied to large commercial farms that under the umbrella of the same enterprise undertake various production and processing tasks such as feed processing, production of day-old chicks, broiler production, slaughtering and sales. In the other case (predominantly systems 3 and 4) it is applied to a situation where chickens are kept together with other animal species such as ducks, fish, pigs, cattle and buffaloes. There may be regular contact between birds and people as the poultry frequently scavenge and move in and out of the farmers' houses.

4.8 Differences in Production Systems and Their Densities

In general poultry production systems are more sophisticated the more developed a country is. This means that in the poorest countries in Africa mainly sector 4 production systems exists whereas in Asia a mixture of production systems co-exists{Rushton, 2006 70 /id;IAEA, 2002 30 /id}.

The exact number of farmers and their families who rely on poultry as a part of their farming system is difficult to estimate. But a number of studies have shown that about 60-80% of the farmers in developing countries keep poultry one way or another {IAEA, 2002 30 /id;FAO, 2006 33 /id}. From a development point is probably closer to 80% of the farmers in Africa and closer to 70-80% in Asia.

Another factor of importance is the human -poultry density which varies between the countries. For example Cambodia and Lao PDR have relatively low poultry densities in comparison to the Viet Nam and Thailand. The number of domestic birds per person is highest in Thailand and lowest in Cambodia and the proportion of species other than chickens is highest in Viet Nam and Cambodia. Ducks are particularly important in these countries{Rushton, 2006 70 /id}. In Africa the population densities are low compared to SEA. However, Nigeria and Egypt have high urban human and poultry densities.

The population densities of poultry, pigs and humans, are likely factors affecting the evolution of the virus. Highly concentrated poultry and pig farming, in conjunction with traditional live animal or 'wet' markets, provide optimal conditions for increased mutation, reassortment and recombination of influenza viruses{Webster, 2004 72 /id}.

4.9 Marketing of Poultry Products in Sectors 1 and 2

As seen the marketing of poultry products in Sectors 1 and 2 follows strict rules given by authorities and producers. The level of biosecurity is extremely high and seldom disease problems are spread through these channels. However, considering the flock sizes there is a potential high risk of multiplication and propagation of the virus if it has entered the farm or flock.

4.10 Marketing of Poultry Products in Sectors 3 and 4

4.10.1 Traditional Village Markets

In sectors 3 and 4 the majority of products are sold through traditional village markets. Here mainly live birds are for sale. Eggs are rarely sold, as they are seen as a potential live animal, and thus they should not be eaten (killed). Cocks and hens are sold at highly variable prices depending on factors such as demand (high during festivals), size (seldom weight), plumage (high price for white-feathered birds), or other external characteristics. Cocks usually fetch higher prices at the market than hens. Local birds fetch higher prices than imported improved breeds, although they are smaller. Also local eggs may fetch higher prices, despite their smaller size. Taste and texture of meat are major reasons for the higher price of local products.

The marketing of live birds in traditional bird markets is a high-risk event. Furthermore, birds on sale might be brought back to the household at the end of the day thus exposing the home flock for an even greater risk of attracting any disease including avian influenza.

Live-animal markets (wet markets) provide a source of vertebrate and invertebrate animals for customers in tropical and subtropical regions of the world. Wet markets sell live poultry, fish, reptiles, and mammals of every kind. Live-poultry markets (mostly chicken, pigeon, quail, ducks, geese, and a wide range of exotic wild-caught and farm-raised fowl) are usually separated from markets selling fish or red-meat animals, but the stalls can be near each other with no physical separation. Despite the widespread availability of affordable refrigeration, many Asian people prefer live animals for fresh produce. Wet markets are widespread in Asian countries and in countries where Asian people have migrated{Webster RG, 2006 46 /id}. Live-poultry markets were the source of the H5N1 bird-influenza virus that transmitted to and killed six of 18 people in Hong Kong{Sims, 2003 11 /id}.

At the market especially the mixing of live pet birds and domestic poultry, both waterfowl and land-based birds, increases the risk to unacceptable heights. Ducks have on several occasions been found as the major silent shedder of HPAI virus {Nguyen, 2005 5 /id;Songserm, 2006 6 /id}. Restrictions on the movement of live poultry, both within and between countries, are another important control measure. It is a key issue to prevent the mixing of species in these wet markets to control spread of disease. However, wet markets are deeply incorporated into traditional marketing and are thought to be a cornerstone in local economy in South East Asia{Goldman A, 1999 47 /id}.

The logistics of recommended control measures are most straightforward when applied to large commercial farms, where birds are housed indoors, usually under strictly controlled sanitary conditions, in large numbers. Control is far more difficult under poultry production systems in which most birds are raised in small backyard flocks scattered throughout rural or peri-urban areas. In countries where AI is endemic it can be questioned if live bird markets at all should be allowed. To reduce the risk with traditional village markets in areas not affected by AI, but close to currently infected areas, ducks or other waterfowls as well as pet birds should be kept separated both in place and time from poultry if live bird markets at all should be allowed.

In general live markets are poorly regulated and hygienic measurements are not carried out at all.

4.10.2 Live Birds

Birds infected with AI excrete virus particles through nasal discharges and faeces{FAO, 2006 33 /id}. The sale of live birds therefore poses an enormous risk for spreading of HPAI and infection of humans. There are no differences in the risk of spreading of HPAI whether the birds are young or old. Ducks pose a much larger risk than other birds as they can shed virus for >4 weeks post infection without showing apparent clinical signs{Songserm, 2006 6 /id}.

Also wild or caged wild birds have been identified to excrete AI virus and must be seen as a potential transmitter of AI{Alexander, 2000 51 /id;Humberd, 2006 78 /id}.

In addition to wild and domesticated birds including poultry, the whole concept of transport, carriers, vehicles, bicycles, containers and cages can possibly transfer AI virus or other disease agents passively to susceptible animals and humans if proper disinfection has not been carried out.

4.10.3 Other Animals

At live animal markets, poultry, game, pigs, fish and ruminants are transported alive to the market and often killed after purchase. Live markets are popular as they allow the purchaser to inspect the animal before having them killed in order to be sure the meat is fresh (and healthy). Apart from domesticated animals, also wild animals such as turtles, frogs, privet cats, cats, wild fowl, monkeys, dogs and others are brought to the market. The combination of a wide variety of species in a confined area increases immensely the risk of disease spreading.

4.10.4 Eggs

AI virus have been isolated from commercial eggs during an outbreak {Cappucci, 1985 26 /id}. AI virus is probably easily killed by heating despite the lack of thorough investigations. The marketing of eggs for consumption from healthy birds should possibly be continued also in HPAI endemic areas, if eggs are not eaten raw but thoroughly cooked. Eggshells must be safely disposed and not reused in animal production. Fertilised eggs for breeding should be disinfected before incubation or exported.

4.10.5 Meat

In developed countries poultry meat is sold chilled or frozen at the butcher or at the supermarket. Fresh and frozen poultry meats from healthy birds pose a small risk of spreading HPAI. The risk of contracting influenza from eating well-done chicken meat is close to nil. However, dressing of an infected slaughtered chicken poses a high risk for infection of the person. Undercooked chicken meat pose a threat from common food pathogens like Campylobacter and Salmonella and should under no circumstances be eaten. There is absolutely no necessity to stop eating or locally trading chicken meat from healthy chickens in areas not affected by HPAI but it is wise to safely dispose of the packaging materials and other waste. Internationally, HPAI is a notifiable disease and as such rigorous restrictions are implied to exportation of poultry and poultry products. AI virus have been isolated from duck meat{Tumpey, 2002 28 /id} and it can be recommended that all poultry meat in areas affected by HPAI should be well done at consumption and not served medium or rare.

The disposal of offal from slaughtering at the market calls for implementation of safe procedures of waste disposal. Also the disposal of manure from the markets must be reconsidered. Other material used at the slaughtering such as knifes, cloths, plates, tables should be cleaned after and between carcasses.

4.11 Relation between Husbandry Practices and Spread of HPAI

In poor areas people live close to their animals and it is not uncommon to house domestic animals indoors during night to protect them from predators{IAEA, 2002 30 /id;Ducatez, 2006 2 /id}. Further, many ducks go out on paddy fields to eat during the day where they possibly get in contact with other waterfowls or their faeces. At evening they return to the house and mix with the other poultry{Khanum J, 2005 43 /id;Edan M, 2006 44 /id;Songserm, 2006 6 /id}. This close mixing of multiple species of waterfowl and land-based birds with pigs and humans is creating the ideal environment for the genetic reassortment foregoing an influenza pandemic. To break the direct contact between waterfowl and land-based birds and between birds and pigs as well as keeping the animals out of human housings and children play areas must have high priority in the preventive work to stop both the current spread of HPAI and reduce the risk of a pandemic. Indirect interspecies contact via unwise disposal of waste and carcasses and the use of fresh manure on fields must also be stopped.

5 Principles of Biosecurity

5.1 Definition of Biosecurity

The broad meaning of biosecurity literally means the "safety of living things or the freedom of concern for sickness or disease". A second definition is "the management of risks posed by organisms to the economy, environment and people's health through exclusion, mitigation, adaptation, control, and eradication{Anon, 2001 45 /id}. Another definition of biosecurity is "security from transmission of infectious diseases, parasites and pests to a production unit (Figure 8).

Biosecurity is in practical terms a "mindset" or "philosophy" that must be developed by the producers in order to prevent the entry of disease to the flock. It is an approach to animal husbandry that has a focus on maintaining or improving the health status of their animals and preventing the introduction of new disease pathogens by assessing all possible risks to animal health{Anon, 2001 45 /id}. It is essentially keeping the bird separate from the infections.

Additionally, biosecurity is a tool to help minimize the effect of infections and decrease the impact of disease. Sometimes it may not be critical to diagnose the disease agent involved in a problem, but to analyse what is wrong with the biosecurity programme. Biosecurity should be viewed as part of the solution, potentially reducing the dependency on extensive testing and medications.

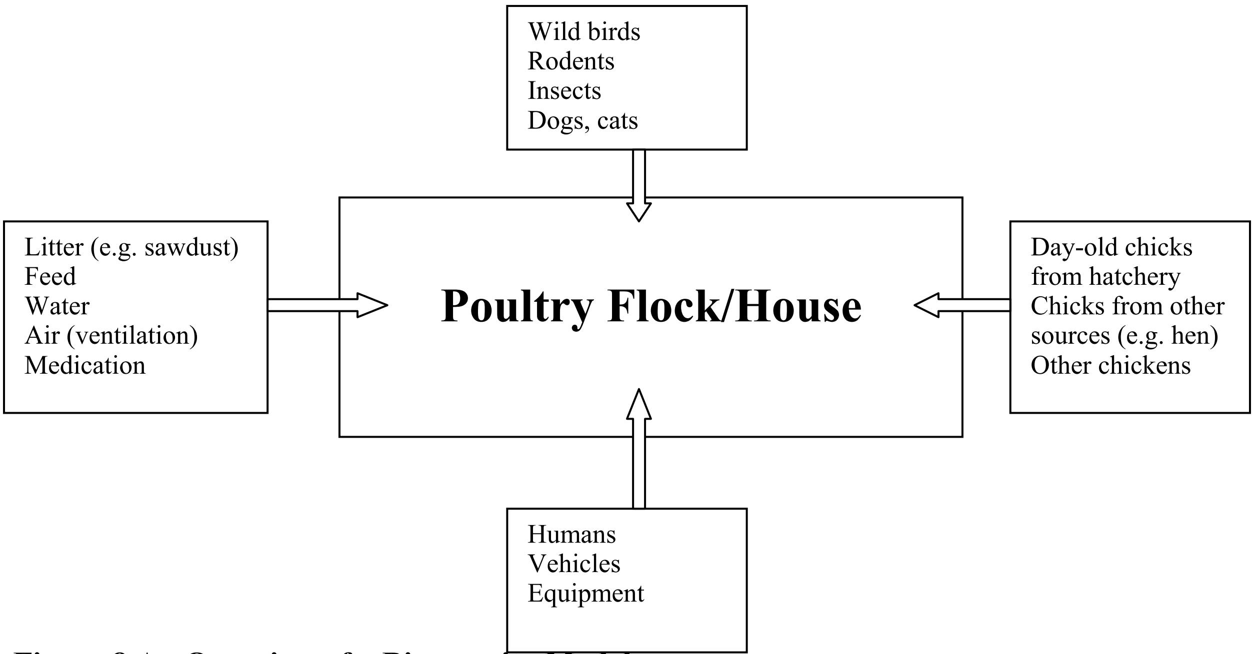

Figure 8 An Overview of a Biosecurity Model

The biosecurity mindset must ultimately maintain itself as tangible measures (e.g., practical issues such as locks on gates, visitors, showers, disinfection points, policies, protocols, quarantine rules etc. and also biological issues such as vaccination programmes and other preventive treatments). The positive relation between husbandry practices and spread of any disease has been demonstrated many times and is from a historic point of view the reason behind the development of industrial poultry farming. The poultry industries (sectors 1 and 2) have had biosecurity protocols in place for many years and with good effect. The effective biosecurity protocols allow large-scale intensive production to occur on a single site.

5.2 State-of-the-Art Biosecurity

5.2.1 Management of the Flock

As such, biosecurity is primarily a management-implemented system. Initial design of a biosecurity system should include expert input from veterinarians and farm managers (flock owner), but implementation and follow-through is accomplished by every person involved in the production process, with ultimate responsibility resting with the farm manager. Farm managers should continually evaluate all areas of operation under their direction. Changes in protocols and procedures must be assessed for risk of introduction of pathogens. A complete biosecurity program includes proper design, training of staff, system-wide monitoring, and constant updating.

The concept of creating microbiological barriers to prevent pathogen transmission is the basis of biosecurity. It is good if the effectiveness of the barrier can be monitored. Monitoring can either be qualitative (for example, the presence or absence of a specific bacteria) or quantitative (for example, bacterial surface counts or detection of antibodies). Monitoring of surface bacterial counts in hatchery and on farm after cleanout are typical examples of monitoring biosecurity effectiveness.

Pathogens can be roughly broken into two classes; those with vertical transmission and those with only horizontal transmission. The independence of the day-old chick from its mother after hatch allows poultry production to completely separate generations and stop horizontal transmission of pathogens between generations. This gives the poultry industry a great advantage over other animal industries. A managed system of egg hygiene, handling and hatchery operation is needed to stop movement of pathogens between generations by horizontal transmission. Only true vertical infections will come through a hatchery with a good biosecurity programme.

It is important to understand in the objectives of a biosecurity programme that control of all infections may not be practical. For example, the installation of filters on incoming air is not practical in most situations. Also all biosecurity barriers need to be equally effective; otherwise the expense of implementing heat treatment of feed will potentially have no impact, due to a weak link in the system.

The advantages of biosecurity include the setting up of a sustainable production system that does not depend on routine administration of antibiotics. This capital cost may look considerable if your current farm base is a multi-age site but if the ultimate aim is kept in mind during planning for future expansion, single-age may be possible. The only way to convince the owners or management of the value of single age site is to make the talk in terms of money. What savings can be made with a new farm organization? Savings on antibiotics, vaccines, liveability and expected improvement in performance needs to be quantified and compared to capital costs.

In operations that are currently infected with an undesirable infection there will need to be a plan to eliminate or control that infection. The usual method is to accurately classify all flocks into infected (dirty) and uninfected (clean) and then put extra controls to stop the infection from moving between dirty flocks to clean flocks. This may involve more intensive monitoring of clean flocks, barriers between clean and dirty flocks and where appropriate, strategic medication or vaccination of dirty flocks to decrease the number of pathogens in these flocks and decrease the likelihood of horizontal transmission. Good quality laboratory testing is needed.

Biosecurity systems also need to be able to cope with breakdowns in biosecurity. Again the clean/dirty principle can be applied. Traceability at this stage becomes very important for containment of the problem and working out the probable source of the problem.

Staff training on biosecurity is needed. This includes production staff, management staff (including the owner) and trades people. Staff having contact with birds at work should not be allowed to own birds at home and be discouraged from contact with other birds. Training and auditing is needed on cleaning and disinfection of sites.

5.2.2 Control of Incoming Animals

Initially, biosecurity begins with the physical layout of the farm and the production cycle. Production sites should be isolated from other production facilities so that if problems occur, spread is minimised. Sites with feed mills', breeders, broilers, rendering plants, slaughterhouses and hatcheries offer some economies in organisation but make the implementation of effective biosecurity very difficult.

"All in - all out" strategies effectively stop the carry over of fragile pathogens on a site. Modernised facilities and effective cleaning and disinfection further enhance this effect. Placing flocks of single-ages helps to control disease problems by reducing bird to bird passage from vaccine strains.

The sourcing of stock from flocks with known health status is important. Most broiler breeder stock is supplied free of infections known to cause problems by vertical transmission (*M. gallisepticum* and *M. synoviae* infection confirmed by a routine monitoring programmes, free of exogenous avian leucosis virus infection and free of *Salmonella pullorum*, *S. gallinarum*, *S. typhimurium* and *S. enteritidis*). The stock should be delivered with maternal antibodies for REO-virus, chicken anemia virus, avian encephalomyelitis and infectious bursal disease and have been vaccinated with an effective Marek's vaccine at the hatchery.

However, effectiveness of geographic isolation can be undone by contact from flocks in the rest of the operation. Feed delivery, bird transport and egg collection should be a biosecure process. Sharing of equipment and staff between farms should be avoided, but if it occurs, efforts should be to organise the process in a biosecure way. Management practices like spiking (introduction of new males into an older flock) and thinning of broiler flocks (partial depletion) need to be conducted with biosecure methods. Transport crates need to be washed and disinfected after use, and appropriate personnel should conduct auditing on a regular basis.

5.2.3 Control of In- and Out-going Material

Cleaning and disinfection are important parts of a biosecurity programme. Cleaning is the most important aspect; the physical removal of contamination. Litter and other contaminated material needs to be removed from the farm to maximise the effectiveness of "All in - All out" strategies.

It is important to verify control points where flow of pathogens could be reversed in the production process, and implement barriers to prevent back-flow of pathogens (washing of egg trolleys, trays, crates, transport etc).

The distances between farms to prevent transmission of airborne infections is not known and is influenced by climate, wind direction and the actual pathogen under consideration. *Mycoplasma synoviae* appears to be more infectious between farms by airborne route that *M. gallisepticum*. Certainly flocks should be more than 400 m and preferably over 2 km apart. The size of the infected source flock (and receiving flock) also influences the risk of contamination. Large infected flocks 500m from a site are more risky than 5 backyard chickens at the same distance. Two kilometres is recommended as a minimum distance from parent stock flocks.

Live vaccines should be free from contamination especially with avian leucosis virus, reticulo entothelial virus, egg drop syndrome virus (EDS-76) and their efficacy should be proven. This is a responsibility in most countries of government authorities but contamination can still occur. Suspected problems need to be investigated by independent laboratories. Breeding stock is very valuable and saving money on vaccines is not always advisable.

Iatrogenic problems with administration of vaccines need to be prevented by further training. Sterile technique in the making up and administration is important. Contamination during vaccination procedures in the hatchery can cause problems like mortality and femoral head necrosis

Feed should be manufactured in a hygienic way and kept biosecure until delivery to the birds. Heat treatment in a pelleting process is a good way to minimize microbiological hazards from feed. All raw materials entering the mill should be monitored for salmonella during quarantine and measures to reduce the level in the feed ingredients should be taken. From feed raw materials identified salmonella strains should be checked for epidemiological connections to salmonella strains isolated from the breeder and broiler flocks and products in order to continuously re-evaluate the risk assessment.

New litter needs to be considered as a source of infection. It should not be stored on the floor or outside. It should be covered or kept in plastic bags. Many poultry integrations have wood shavings made specially and bagged for use rather than obtaining sawdust as a by-product. Rice hulls and other materials are also used for litter. Litter will always pose a risk for introduction of disease into a flock, especially if the origin is unknown.

5.2.4 Control of Other Animals

Rodent control and the exclusion of wild birds also require consideration. Making the shed unattractive to rodents and wild birds is the first step. Feed (and stored litter) should not be accessible to rodents or wild birds, the sheds should be well maintained. Other animals should not be allowed in the sheds.

6 Policies for Development of Veterinary Services

Veterinary services have a central role to play in the control and eradication of an epidemic disease such as HPAI{Food and Agriculture Organization and World Organisation for Animal Health in collaboration with World Health Organization, 2005 88 /id}. However, today the level of services available to farmers varies enormously from country to country. As an example in some developing countries only 3% of the farmers have access to veterinary/livestock services. A survey in Tanzania among village farmers indicated that the lack of veterinary services not only limits the possibilities for farmers to keep livestock, but also limits the possibilities of expanding existing livestock production due to high mortality rates.

FAO and OIE believe that the concept of veterinarians as professionals who are only concerned with animal diseases should be broadened to include areas of activity that focus on public health outcomes, the control of risks along the food chain, as well as the welfare of animals{Food and Agriculture Organization and World Organisation for Animal Health in collaboration with World Health Organization, 2005 88 /id}. FAO and OIE also consider Veterinary Services to be a Global Public Good and their bringing into line with international standards (in terms of legislation, structure, organisation, resources, capacities, the role of the private sector and paraprofessionals) as a public investment priority. The official agreement signed by the OIE and the World Bank in 2001 supports this view{OIE, 2006 32 /id}.

Sanitary standards related to animal health (including zoonoses) and animal welfare should be developed and steps must be taken to improve the capacity of official Veterinary Services to rapidly detect, diagnose and control animal diseases. Furthermore, to be able to support access of animals and their products to national, regional and international markets, Veterinary Services, especially in developing and in transition countries, need to improve their ability to collect and rapidly disseminate national data on animal diseases{OIE, 2006 32 /id}.

The Veterinary Services of developing and transition countries are in urgent need of the necessary resources and capacities that will enable their countries to benefit more fully from the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) while at the same time provide greater protection for animal health, animal welfare and public health and reduce the risks linked to zoonoses. In order to achieve this objective, Member Countries must aim to comply with OIE standards on the quality and evaluation of Veterinary Services, which have already been adopted by the International Committee and are published in the Terrestrial Animal Health Code. The OIE, with the support of IICA (Interamerican Institute for Cooperation in Agriculture) have developed a tool (PVS) aimed at facilitating the process of evaluating national Veterinary Services{OIE, 2006 32 /id}.

A number of initiatives have been taken to support Veterinary Services{OIE, 2006 32 /id}:

- The Memorandum of Understanding signed with the World Bank in 2001 as well as the 'Development Grant Fund' signed at the beginning of 2006 were important steps forward in strengthening the capacity of interested developing countries to meet the common objectives of the two signing organisations, in particular by supporting both public and private Veterinary Services. This event was also an important step for the recognition of the public and private components of national Veterinary Services as a 'Global Public Good'.

- The Standard and Trade Development Facility (STDF) which came in direct response to the demand to tailor capacity assistance to the needs of developing and in transition countries, and not to merely provide 'generic' assistance. At the WTO Ministerial meeting in Doha, this became one of the major issues and it resulted in substantial commitments made by the WTO, the World Bank, the OIE, FAO and WHO to respond with focused technical assistance. More specifically, the OIE submitted three different projects to the STDF which were all adopted for a total amount of around US$ 500,000. They address:
- the training of trainers to support FAO/OIE national representatives (Delegates) and national Veterinary Services
- a new tool for the evaluation of Veterinary Services' compliance with FAO/OIE international standards on quality
- the strengthening of Veterinary Services in Africa.

Several projects designed to support the Veterinary Services of developing countries to meet FAO and OIE international standards are in progress, for example:

- Specific activities for the benefit of the OIE Regional Representations, in order to strengthen Member Countries' capacity building
- National seminars intended for east European countries and carried out in association with the European Union (Programme for 2005-2008)
- A global programme called 'Ensuring good governance to address emerging and re-emerging animal disease threats' which was presented and endorsed at the international conferences on avian influenza held in Geneva (November 2005) and in Beijing (January 2006).

National Veterinary Services should always operate based on scientific principles and be technically independent and immune from external pressures. Efforts to strengthen official veterinary services require the active participation and investment on the part of both the public and the private sectors{OIE, 2006 32 /id}.

The responsibilities of the Veterinary Services of developing countries should be extended to the entire production chain of animal foodstuffs, "from stable to table", in particular to foster dialogue with all levels of the sector and to avoid conflicts of interest between consumers and producers. The creation of new structures, in particular institutional authorities responsible for risk assessment, can be decided only if these national priorities have already been met.

Food safety is a legitimate concern for consumers and has become a priority issue, particularly for developed countries, in the context of trade globalisation and the agreements governing them. This concern has been exacerbated by world food crises, which were heavily publicised in the news in the latter half of the 1990s and in early 2000. Any system for ensuring food safety must be based on a risk assessment that integrates the various links in the 'stable to table' chain. This system must encourage appropriate risk management in the form of clear regulations, stemming from a consultative and concerted approach that is nationally applicable and internationally recognised. This means that the Veterinary Services of many developing countries must integrate into their current activities issues relating to food-borne diseases transmitted by animals, whether or not the dangers identified are pathogenic for the said animals{OIE, 2006 32 /id}.

In line with each country's specific conditions, it should be envisaged delegating the official Veterinary Services' activities to private veterinarians, within a contractual framework, in particular through a 'sanitary mandate' or any equivalent system. In order to achieve this, the appropriate provisions must be made to facilitate the establishment and maintenance of private veterinarians in rural areas, in particular through a policy for providing them with a satisfactory income. For a permanent health surveillance network to be sustained, in compliance with OIE standards, which relies in particular on contracted veterinarians, supported where necessary by non-veterinary auxiliaries, the public service missions of such agents should be recognised, specifically by remunerating such veterinarians from public funds{OIE, 2006 32 /id}.

The role of health auxiliaries in the countries concerned should be recognised, defined and controlled; such agents should be supervised by veterinarians, who themselves come under the authority of the official Veterinary Services when carrying out public service missions. The Veterinary Services must be encouraged to organise and recognise the different players in the animal health and veterinary public health field, based on an analysis of their environment, in particular by creating national organisations to represent private veterinarians, by drafting a Veterinary Code of Professional Conduct on a regional level and by setting up livestock producers' organisations, as close as possible to the field, united under a national association. Such livestock producers' associations participate in solving in particular the problem of sustaining projects involving health auxiliaries{OIE, 2006 32 /id}.

The following identified steps needs to be supported by politicians{OIE, 2006 32 /id}:

- Control AI at source in birds
- Improve veterinary services, emergency preparedness plans and control campaigns including culling, vaccination and compensation
- Improve animal husbandry services
- Assist countries to control avian influenza in animal populations
- Surveillance – internationally, nationally, regionally and locally
- Strengthen early detection and rapid response systems for animal and human influenza
- Build and strengthen laboratory capacity including field laboratories
- Rapid containment or vaccination
- Support and training for the investigation of animal and human cases and clusters, and planning and testing rapid containment activities
- Pandemic preparedness
- Build and test national pandemic preparedness plans, conduct a global pandemic response exercise, strengthen the capacity of health systems, training of clinicians and health managers
- Integrated country plans
- Develop integrated national plans across all sectors to provide the basis for coordinated technical and financial support
- Communications and training of farmers

To support all of the above, factual and transparent communications, in particular risk communication, is vital.

7 Options to Limit Spread of HPAI in the Poultry Sector

7.1 General Considerations on Biosecurity

From a biosecurity point of view, village poultry producers (sectors 3 and 4) need to be concerned about two major types of disease. Most producers in Sectors 1 and 2 are very familiar with the so-called "production limiting diseases", which include most of the respiratory diseases and many types of enteritis. The other major types of diseases are the epidemic or named diseases such as Newcastle disease or avian influenza. The introduction of disease into a flock is usually of non-intentional nature or lack of knowledge and therefore all poultry can be affected by a loss of biosecurity from one day to another. Of these two groups of diseases Newcastle and avian influenza are the most important to control in sectors 3 and 4.

Biosecurity is a key issue in stopping the spread of avian influenza or any other disease{Agronomes et Vétérinaires Sans Frontier (VSF-CICDA), 2005 25 /id}. Using principles of biosecurity is vital in protecting birds from any disease. Avian influenza as well as many other diseases is mostly spread by direct bird-to-bird contact or by indirect spread through contaminated feed, water, equipment and, clothing etc. Basically this is what good management is: Taking steps to ensure good hygiene and increasing the standards of cleanliness as well as containment to reduce the risk of introducing disease into a flock irrespective of the flock size.

Biosecurity is common sense and must not always be expensive. A thorough check on flows into or out from the flock will reveal critical control points where even cheap actions can improve biosecurity immensely. By improving biosecurity with the aim of stopping avian influenza the benefit is a reduced risk of contracting other contagious diseases as well.

For small-scale poultry production, biosecurity is a dual concept; consisting of various simple measures both to keep the infections away from poultry and additionally keeping the poultry away from the infections.

In some branches of bird production biosecurity measures might be difficult to imply, like where ducks scavenge paddy fields or when breeding mallard ducks where you rely on in-flying wild drakes for mating. If it is not possible to apply biosecurity measures to some branches of bird production then it must be discussed to prohibit them or at least secure that they are separated from all other animal production.

7.2 Culling – Stamping-out

Culling of infected animals has to date been an effective and preferred method of HPAI control. More than 100 million domestic chickens in nine Asian countries infected by avian influenza have been culled since December 2005{OIE, 2006 32 /id;FAO, 2006 33 /id}. However, out breaks are seen in domestic flocks, but they are not the source of avian influenza. Here ducks are probably the true silent carriers of HPAI. Culling flocks may limit the spread but will not stop a new virus from appearing{GRAIN, 2006 55 /id}.

There have been calls for the culling of wild birds and animals. However, it is not easy to be sure which wild bird or animal is the original source of a virus. Eradication of a particular species may have other effects - proliferation of pests that were controlled by that species for example.

If culling fails or proves impracticable as in village flocks, vaccination of poultry in a high-risk area can be used as a supplementary emergency measure, provided quality-assured vaccines are used and recommendations from FAO and OIE are strictly followed{OIE, 2006 32 /id;Food and Agriculture Organization and World Organisation for Animal Health in collaboration with World Health Organization, 2005 88 /id}. The use of poor quality vaccines or vaccines that poorly match the circulating virus strain may accelerate mutation of the virus. Poor quality animal vaccines may also pose a risk for human health, as they may allow infected birds to shed virus while still appearing to be disease-free.

Apart from being difficult to control, outbreaks in backyard flocks are associated with a heightened risk of human exposure and infection. These birds usually roam freely as they scavenge for food and often mingle with wild birds or share water sources with them. Such situations create abundant opportunities for human exposure to the virus, especially when birds enter households or are brought into households during adverse weather, or when they share areas where children play or sleep. Poverty exacerbates the problem: in situations where a prime source of food and income cannot be wasted, households frequently consume poultry when deaths or signs of illness appear in flocks. This practice carries a high risk of exposure to the virus during slaughtering, defeathering, butchering, and preparation of poultry meat for cooking, but has proved difficult to change. Moreover, as deaths of birds in backyard flocks are common, especially under adverse weather conditions, owners may not interpret deaths or signs of illness in a flock as a signal of avian influenza and a reason to alert the authorities. This tendency may help explain why outbreaks in some rural areas have smouldered undetected for months. The frequent absence of compensation to farmers for destroyed birds further works against the spontaneous reporting of outbreaks and may encourage owners to hide their birds during culling operations. More contact between veterinarians and villagers is needed with village based training (training of farmers) to explain the severity of the disease and the need for improved management of village flocks. This must be combined with a prompt system for laboratory diagnosis of HPAI at local level.

7.3 Vaccination

7.3.1 Options for Vaccination

When an outbreak of AI occurs in an area with a high population density in which the application of rigorous biosecurity measures is incompatible with the modern rearing systems, vaccination should be considered as a first option to control the spread of infection. The expected results of the implementation of a vaccination policy on the dynamics of infection are primarily those of reducing susceptibility to infection (i.e. a higher dose of virus is necessary for establishing productive infection) and reducing the amount of virus shed into the environment. This association between a higher infective dose needed to establish infection and less virus contaminating the environment represents a valuable aid to the eradication of infection{OIE, 2006 32 /id}.

Clearly, the efficacy of an emergency vaccination programme is inversely correlated to the time span between the diagnosis in the index case and the implementation of mass vaccination. For this reason, it is imperative that if emergency vaccination is to be considered as a possible option in a given country, vaccine banks must be available in the framework of national contingency plans{OIE, 2006 32 /id}.

It is extremely difficult to establish fixed rules for the control of infectious diseases in animal populations because due to the unpredictable number of variables involved. There are several crucial steps that must be carried out if AI represents a risk. First, the index case must be identified promptly. This does not represent a problem if the virus is of high pathogenicity, but it can be a serious concern if the virus if of low pathogenicity. For this reason countries or areas at risk of infection should implement specific surveillance systems to detect infection with LPAI as soon as it appears. Secondly, a timely assessment of whether there has been spread to the industrial poultry population in the area must be performed. This is a crucial evaluation that must be made available by epidemiologist to decision makers{OIE, 2006 32 /id}.

Once an AI outbreak has been identified, eradication measures based on stamping out or controlled marketing of slaughterbirds on infected farms must be enforced. The choice between these two options must be taken bearing in mind the pathogenicity and transmissibility of the virus, the density of poultry farms around the affected premises, the economic value of the affected birds, and the logistics of carrying out a slaughter/stamping-out policy. In Italy, a stamping-out policy was generally applied to LPAI-infected young meat-birds, breeders and layers, while controlled marketing was applied to older meat-birds approaching slaughter age. This strategy enabled the restriction periods to be reduced (i.e. if infected young turkeys, breeders or layers were kept on the farms, the restriction period could be several months) and hence facilitated faster restocking{OIE, 2006 32 /id}.

Restriction measures on the movement of live poultry, vehicles and staff must also be imposed in the areas at risk.

Finally, if vaccination is the proposed strategy, vaccine banks should be available for immediate use and a contingency plan must be enforced. A territorial strategy must also be implemented. It must include restriction measures and an ongoing set of adequate controls that enable public authorities to establish whether or not the virus is circulating in the vaccinated population and to assess the efficacy of the vaccination programme{OIE, 2006 32 /id}.

7.3.2 Vaccination Strategies

To successfully control the spread of HPAI with vaccination programmes, the necessity of developing methods to distinguish between antibodies acquired by natural infection or from vaccination arises. Such a program has indeed been developed for avian influenza. The DIVA strategy (Differentiating Infected from Vaccinated Animals) based on the use of a heterologous neuraminidase to distinguish vaccinated animals from naturally infected{Capua, 2003 22 /id}. Other vaccines available are the ordinary inactivated homologous vaccine with the same H and N antigens as the strain in the outbreak. Advantage is that it is readily available at a low cost. It is however not possible to differentiate between vaccinated and infected birds serologically but require the use of unvaccinated sentinel birds left in the flock, which is rather unpractical at least in small scale poultry production. The third alternative is to use a recombinant vaccine based on a fowlpox virus vector. This vaccine can only be used for day-old chicks as the vaccinee needs to be naïve to fowl pox in order for the vaccine to function.

It can be considered that reduction of viral shedding from rural poultry so that the amount of virus shed is insufficient to infect a human being combined with stamping out strategies is the best way to control the spread of virus among rural poultry {Capua, 2006 17 /id}. To prepare a vaccine strategy applicable to all situations arising world wide is however not possible. Vaccine strategies need to be modified from country to country and with time. An exit strategy (when to stop vaccinating) must always be formulated. If vaccination is used in such a way that it is possible to distinguish between vaccinated and infected animals, then vaccination as such should not be a hindrance to export.

It is also necessary to find a way to transport antigens to be used for the proficiency testing of diagnostic laboratories without causing any risk of accidental spread of HPAI virus. This has recently been addressed by Spackman and Suarez who suggests the use of phenolic disinfectants to inactivate live virus{Spackman, 2005 23 /id}.

The use of fowlpox virus for vaccination of all day old chicks combined with culling of all ducks in the area would be one way to combat virus shedding in rural areas also applicable in developing countries.

7.4 Financial Consequences of Stamping-out in Relation to Vaccination and Management Improvements

Stamping out is an effective method to eradicate infectious diseases. It is however a costly method that is not always effective in highly populated areas, as it has to be followed by a quarantine period with biosecurity measures and subsequently restocking of the poultry population. If not followed by increases in biosecurity depopulation (stamping-out) can be a never-ending story. In Hong Kong the entire population of domestic poultry was successfully killed after the outbreak in 1997 and this genotype of avian influenza has not appeared again. Otherwise culling has not been a success story mainly due to deficiencies in early warning systems, illegal movements of birds and incomplete control over restocking. In highly populated areas where the HPAI is endemic as now among poultry in Asia, culling without applying very strict measures of biosecurity when repopulating will have to be carefully considered against the trading advantages of rapid eradication as costs can be extremely high accounted in money but also in ethical aspects. Successful use of culling methods for HPAI eradication requires a good early warning system including laboratories of adequate quality and capacity as a prompt diagnosis of the index case is a prerequisite for rapid eradication.

The direct costs involved in a stamping-out campaign would include the actual process of killing the birds and safe disposal of the carcasses (mainly labour cost), education of the culling team, compensation to the farmers, lost labour time for the farmers, lost income from not having an ongoing production and restocking. Indirectly costs in relation to loss of food security, lack of pretty cash to pay for daily needs in the family, loss of tourism etc.

Even when vaccination is considered a valid option it is not possible to lay down general conditions for vaccination programmes that can be applied worldwide {Capua, 2006 17 /id}.

8 Improvement of Management and Biosecurity to Limit the Spread of HPAI in Sectors 3 and 4

8.1 General Considerations

In general it can be said that the poultry production, which occurs in sectors 3 and 4, needs to be up-graded in terms of improved management and biosecurity. When planning for improvement of management and biosecurity to limit the spread of HPAI the following issues needs to be taken into consideration:

- The production system
- The mixing of species must be avoided
- The routes of spreading the virus (bird-bird contact, other animals, equipment, humans, trading etc)
- The disease in the birds and it's diagnosis
- The disease status i.e. epidemic or endemic
- Available services for the farmers and traders
- The public knowledge on basic principles of biosecurity must increase

Societal service to small scale operators must at least provide diagnostic service in case of fatalities as well as a surveillance system for early detection. Free technical and veterinary service for the restocking schemes must be supplied.

Societal preparedness in case of an outbreak must be planned and contingency plans including decision-making patterns under different scenarios should be formulated.

Financial support in case of culling needs to be carefully considered and at least meat market prices of healthy culled stock.

A possibility for emergency vaccination must be prepared in advance.

The sale of live birds poses an enormous risk for spread of HPAI. Measures to control movement of live birds in and out of the farm and the market are needed.

8.2 Veterinary Services

Especially for sector 4 producers the veterinary services are generally not present. A need for up-grading of the veterinary services is envisaged{OIE, 2006 32 /id}. This should involve training of veterinary staff, and civil society organisations, NGOs and local government to not only educate the farmers on the dangers of avian influenza and importance of improving biosecurity at farm level and market level, but also to spread the message on the need for rapid reporting of suspected cases.

8.3 Livestock Services

Only a small number of the farmers have received formal training in farming practices and management of livestock. A need of up-grading of farmer's knowledge on management is generally needed.

8.4 Options for Limiting the Spread of HPAI in Sector 3

8.4.1 At Farm Level

For sector 3A operators the best option to keep AI out of a flock is an improved level of biosecurity. This means applying an "all-in all-out" system with a certified biosecurity system applied at all levels from fertilised eggs, day-old chicks, housings and staff, feed sources and transport companies.

Also for sector 3B operators the level of biosecurity is a key feature in protecting the flock from infection with HPAI. Although an "all-in-all-out" principle might not be possible more control of the birds coming into the flock would improve the level of biosecurity. If AI is spread with migratory birds it is impossible to avoid the spreading of AI from migratory birds to domestic poultry if the biosecurity level is low like when keeping free-ranging chickens or free roaming ducks in paddy fields.

To be able to keep free-ranging poultry production as in Sectors 3 some changes in habits and a good deal of preparatory work is necessary:

Possible options for improved biosecurity:

- Increased level of management
- Develop a plan for biosecurity
- For sector 3B farms discuss the size of the flock
- Avoided mixing of species
- Marketing channels (in and out of the flock) must be adapted to the restructuring
- The local knowledge on basic principles of biosecurity must increase this includes training of operators/farmers
- Veterinary services to sector 3 farmers must at least provide diagnostic service in case of fatalities as well as a surveillance system for early detection.
- Free technical and veterinary service for the restocking schemes must be supplied
- Societal preparedness in case of an outbreak must be planned and contingency plans including decision-making patterns under different scenarios should be formulated
- Financial support in case of culling needs to be carefully considered and at least meat market prices of healthy culled stock

8.4.2 Applicability of Biosecurity in Sector 3 at Market Level

The majority of products from sector 3 farms are sold in live markets in urban or rural areas, which increases the risk of spreading a pathogen. Needs for changing of habits in relation to hygiene is foreseen:

- Sectioning of markets in time and place to avoid mixing of species
- With time change from live markets to the use of slaughterhouse and marketing of chilled or frozen meat
- Improvement of hygiene
- Proper disposal of waste
- Disinfection of material leaving markets going back to the farm
- Unsold animals should remain at market and not return to the farm ("Live in – dead out" principles)
- Licence to sell (includes adequate education)

8.5 Options for Limiting the Spread of HPAI in Sector 4

8.5.1 Applicability of Biosecurity Principles in Sector 4 at Farm Level

The biosecurity principles developed in sector 1 and 2 can in brief be adopted to sector 4 by these 4 simple principles (Table 3):
- Principle 1 Good management - Always keep the birds healthy and in a good condition
- Principle 2 Containment - Keep birds in a closed environment
- Principle 3 Improve hygiene – Use disinfectants at your farm
- Principle 4 Control entries - Do not allow visitors

Table 2 Biosecurity Levels

High biosecurity	A	Birds are always kept in a closed building
	B	Birds have access to a fenced park
	C	Birds are left free in the farm yard
	D	Birds are left free in and outside the farm yard
Low biosecurity	E	Birds go to the fields and come back

Adopted from FAO's Guide for veterinary paraprofessionals in Vietnam Prevention and control of Avian Flu in small scale poultry {Agronomes et Vétérinaires Sans Frontier (VSF-CICDA), 2005 25 /id}.

Table 3 Simple Biosecurity Principles for Sector 4{Agronomes et Vétérinaires Sans Frontier (VSF-CICDA), 2005 25 /id}

Principle	Description
Principle 1	**Good management - animals in good body condition have a better immune system and thus resistance to disease causing agents is better. The farmer should:** • ensure access to clean water and adequate food in a protected area away from wild birds • let the poultry have access to separate housing depending on age group • give the poultry de-worming and vaccinations • keep sick birds away from the flock • cull old or sick birds • report sick or dead birds immediately to the veterinary authorities (or local equivalent) • not insert new birds in the flock without a 2-week quarantine period in a house far from the flock • ensure good sanitation for the new-hatched chicks in a separate housing system • keep the chickens separated from pigs, pigeons, domestic ducks, geese, and wild birds • if returning from the market with unsold poultry, keep them separated from other animals, especially younger poultry
Principle 2	**Containment. Ideally, poultry should be kept in a closed area (Biosecurity level A and B in Table 2)** • If the birds are allowed into the farmyard, keep the ground clean daily and feed the animals indoors • Keep species separated from each other, do not mix chickens with pigs, pigeons, geese or ducks • Keep dogs, cats, rodents and children out of the poultry area • If a pond is necessary, keep the pond fenced
Principle 3	**Improve hygiene and use disinfectants regularly at the farm. The farmer should** • not borrow equipment or vehicles from other farms • wash pens and cages coming from outside • wash the cages and other forms of container and means of transport thoroughly when coming back from the market • keep pens, cages, other forms of container, the farmyard and equipment clean, washing thoroughly at least once a week. Apply lime wash if possible • not leave dead animals lying around • not throw dead animals into rivers, lakes or other bodies of water • leave disposal of bird carcasses to the veterinary authorities (or local equivalent) and help only if they ask • not eat the carcass of a dead bird • not sell the carcass of a dead bird • get rid of carcasses safely by burning them or burying them deeply enough that dogs, cats and other scavengers cannot reach them • burn or bury feathers and other waste away from your farmyard • allow manure to decompose for several weeks before applying it on fields
Principle 4	**Control all entries to the farm and the poultry** • Allow only one person to take care of the birds • Do not allow visitors into the bird quarters without complete change of clothes and shoes • Keep the number of visitors to your farm down to a minimum • Keep all means of transport outside your farm as far as possible

Principle	Description
	• If transport must enter, wash the wheels at the farm entrance • When anybody (including you and your family) enters the farm, wash the bottoms of shoes or change shoes at farm entrance • Always quarantine new birds (keep them separated from other birds for a 2-week period) • Control entry of feed and equipment • avoid entry of other animals and rodents to the farm area • Always start work in the clean area and move towards the dirty area • Wash hands after handling birds and when moving birds between housings

8.5.2 Market Level

The market might pose the biggest risk of spreading avian influenza and other diseases. The following steps are needed to improve biosecurity in village markets{FAO, 2006 33 /id}:

- Report sick or dead birds immediately to the veterinary authorities (or local equivalent)
- Do not leave dead animals lying around
- Do not throw dead animals into rivers, lakes or other bodies of water
- If you have a plastic bag, place the carcass in the bag; if you do not, take the carcass away from the rest of the flock and out of reach of children and others
- Leave disposal of bird carcasses to the veterinary authorities (or local equivalent) and help only if
- If there are no veterinary authorities (or local equivalent), seek help from your local community to dispose of carcasses
- Do not eat the carcass of a dead bird
- Do not sell the carcass of a dead bird
- Get rid of carcasses safely by burning them or burying them deeply enough that dogs, cats and other scavengers cannot reach them
- Burn or bury feathers and other waste away from your farmyard
- Allow manure to decompose for several weeks before applying it on fields
- Only sell healthy birds - do not trade poultry that look sick
- Do not trade birds of unknown origin (only trade birds that are certificated/ from a trusted source)
- If you notice poultry on a farm that seem to be affected with avian flu, report it to the veterinarian authorities (or local equivalent)
- Try to adopt all in/all out management: sell all animals at the same time and buy animals in one batch
- Respect poultry movement bans: this will help control the disease and lead to lifting of the ban
- Collaborate with the veterinarian authorities: this will help resumption of the poultry trade
- Do not enter a farm with any means of transport: leave it at the entrance to the farm
- Take your shoes off at the entrance to the farm and ask the farmer to provide you with other shoes. If this is not possible, ask the farmer to help you clean the soles of your shoes

8.6 Cost of Implementation

8.6.1 General Issues

The economic costs of H5N1 have mostly been related to domestic bird deaths, the culling of domestic birds to prevent disease spread, and the costs to governments for avian flu preparedness and prevention. Typically, countries shoulder the burden of economic losses solely, but the benefits from destroying the infected birds are felt at an international scale. Many argue that the international community should contribute aid to help offset the financial costs associated with avian influenza. Not one country can protect itself against an influenza pandemic, but the actions one country takes to mitigate its spread can have important implications for the global community. Further costs related to the control of disease and implementation of biosecurity at all levels are foreseen:

At farm level the following costs should be included:

- Training of trainers
- Training of farmers
- Vaccination
- Building of housing and fences
- Loss of unsold animals
- Implementation of other biosecurity measures

At market level the following costs are foreseen:

- Training of trainers
- Training of staff
- Rebuilding of market
- Plan for waste disposal
- Loss of unsold animals
- Implementation of biosecurity measures

Requirements for implementation of the above raised points can not take place without acceptance and understanding in the society, staff to train and willingness for funding from the international community. However, further field surveys are needed to estimate the real costs involved in implementing biosecurity at village level.

8.7 Information to the Public

As an effect of increased globalisation, animal diseases, in particular those transmissible to man, have an immediate global economic and social impact. This fact, dramatically illustrated by the current avian influenza epizootic in South-East Asia and Eastern Europe, clearly demonstrates the crucial importance of the national Veterinary Services (VS) for the prevention, early detection and response for the efficient control of animal diseases. Public information campaigns by the VS are needed to ensure public knowledge on the disease.

Complying with this mission for the VS presupposes the existence of appropriate governance and legislation and of an official system to control their quality and reliability- an obvious weakness in many developing and in transition countries.

OIE has therefore developed a project aiming at strengthening the VS in those countries facing the greatest animal health threats and to bring them into line with OIE international standards already adopted by the same countries. Based on the evaluation of the VS and subsequent actions at the global, regional and national levels, the project will have a significant beneficial impact on the targeted countries as well as the international community as a whole, not only in the fields of agriculture, food security and production, and food safety, but also for the local and global prevention of emerging and re-emerging diseases of veterinary and public health importance{OIE, 2006 32 /id}.

8.8 Potential Impact of HPAI on Future Food Security

Food security is defined as access by all people at all times to enough food for an active, healthy life, and at a minimum includes the following: 1) the ready availability of nutritionally adequate and safe foods and 2) the assured ability to acquire personally acceptable foods in a socially acceptable way{Campbell, 1991 65 /id}. Potential consequences of food insecurity include hunger, malnutrition and (either directly or indirectly) negative effects on health and quality of life. Food insecurity will therefore exists whenever food security is limited or uncertain. The measurement of food insecurity at the household or individual level involves the measurement of those quantitative, qualitative, psychological and social or normative constructs that are central to the experience of food insecurity, qualified by their involuntariness and periodicity{Campbell, 1991 65 /id}. Outbreaks of avian influenza - with a mortality up to 100% in affected poultry flocks - will constitute an enormous risk factor for food insecurity and will potentially affect all households relying on poultry products for consumption or sale. In addition to AI outbreaks also culling of flocks will in reality develop food insecurity as disease outbreak, especially if compensation is not given.

On the other side, improvement of farm structure, infrastructure and improvement of biosecurity will improve food security as it can be anticipated that the overall mortality (which is up to 80% in Sector 4 flocks) will decrease{IAEA, 2002 30 /id}.

9 Discussion and Conclusion

Lessons about control of avian flu can be learnt from Asian countries, as they have already had to deal with the impacts of the disease. Open communication between researchers and risk managers not only in each country but also on a worldwide basis is mandatory to stop further spreading of HP AI. For each country, there are important considerations that have to be taken into account, which will decide how effectively the disease is reported and then dealt with. For instance, is there a plan to provide compensation to those who have lost their birds? Is it better to vaccinate or kill infected poultry? Can biosecurity measures developed for sectors 1 and 2 be adopted by sectors 3 and 4? These questions can be answered through the sharing of experiences.

To reduce the risk of a new human pandemic it appears logical to reduce circulating virus and to avoid contacts at risk. Contacts at risk occurs mainly between villagers and rural chicken/fighting cooks in developing countries {Capua, 2006 17 /id} but also industrial flocks in sectors 1 and 2 pose a risk in multiplication of the virus. Small scale poultry production is a major bringer of high quality protein and wealth to poor rural citizens in developing countries. To stamp out and ban a large part of the small scale and back yard poultry production because the risk of a pandemic would be devastating to several years of successful help to developing countries as well as destroy a genetic recourse of rural local poultry of unknown value. Prophylactic vaccination is a much more ethical approach that ideally should result in preventing the index case or reducing the number of secondary outbreaks {Capua, 2006 17 /id}. Prophylactic vaccination must be used with great knowledge and only in countries/areas/compartments really at high risk. The choice of vaccine is crucial to the outcome {Capua, 2006 17 /id}. The knowledge worldwide to cope with this task is available but resources remains to be allocated to developing countries to obtain a cost effective and still ethical way of controlling HPAI to the benefit of the entire society.

Avian influenza virus has existed in feral and domesticated birds for years. The first recordings were in 1959, but the disease has occurred earlier than that (i.e. the Spanish flu). It is unlikely that culling of birds will prevent the presence HPAI and development of new HPAI strains in the future.

Biosecurity is based on the simple idea that disease cannot occur if the pathogen that causes the disease is not present at the right time. Horizontal transmission is easier to prevent, and should be the focus of an effective biosecurity program. Vertically transmitted infections can give us more problems but the control or eradication of these infections is the primary responsibility of the primary breeders. Veterinarians in the poultry industry have the responsibility to make sure that infections are not introduced into stock from vaccines (general biosecurity and the use of suitable quality vaccines).

This struggle to exclude pathogens is the responsibility of everyone involved in the production process: from the feed miller to the company electrician, from the veterinarian to the egg collectors, from the crate wash operators to the truck drivers. Training to make staff understand biosecurity and documentation of biosecurity protocols is essential. Critical review of these processes by everyone involved and external audit is needed continuously.

Finally, the rewards of a sound management and biosecurity system are a poultry production system well protected against known and unknown health threats, lowered risk of evolving resistance to current medication, and a sustainable production system. Furthermore, an improved level of management and biosecurity in sectors 3 and 4 will without doubt improve food security in developing countries.

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