Logistical Study in Hyogo Prefecture on Disposal of Poultry Carcasses Infected with Highly Pathogenic Avian Influenza Virus to Prevent Infection Spreading to Other Flocks

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ABSTRACT. Establishment of a disposal plan for carcasses in advance is important for prevention of epidemics. A disposal plan for contaminated goods such as poultry carcasses infected with highly pathogenic avian influenza (HPAI) virus was studied in Hyogo Prefecture, Japan. We investigated all poultry farms with over 1,000 birds for their locations, species and numbers of birds, structure and size of poultry facilities and land spaces of the farms. Moreover, we judged whether they could dispose of all the carcasses at their farms. In 2005, 5.5 million layers and 2.7 million broilers were being kept. If HPAI had broken out, 44.0% of the farmers could bury all the carcasses, and 65.6% could compost them at their farms. However, 23.4% could not dispose of them except by burning them at incineration facilities. We decided to choose burning first for rapid disposal as long as the virus was not a pandemic type.

KEY WORDS: avian disease, epidemiology, influenza.

In January 2004, highly pathogenic avian influenza (HPAI) caused by a subtype H5N1 virus (HPAI H5N1) broke out after an interval of 79 years, and large-scale preventive measures for epidemics were executed in Japan [5]. Preventive measures are executed in order to contain HPAI on poultry farms to prevent the spread of HPAI virus around the country. The first preventive measure that poultry farmers have to execute is to kill birds that the HPAI virus has infected or might have infected. The second preventive measure is to dispose of all contaminated goods, such as poultry carcasses, eggs, feed, poultry faeces and compost. The third preventive measure is to disinfect. The killing of HPAI-infected birds cannot be executed as long as disposal measures have not been decided. Among the methods of disposing of carcasses, farmers can choose between burial, fermentation disinfection (composting) and incineration in Japan. The HPAI H5N1-infected birds in Oita Prefecture (Oita) were pets, the carcasses of which were disposed in the incinerator of the Oita Livestock Hygiene Service Center (LHSC) after inspection. However, the HPAI H5N1-infected birds in Yamaguchi Prefecture (Yamaguchi) and Kyoto Prefecture (Kyoto) were layers, and the carcasses were disposed of by burying near the farms. In Kyoto, residents around the farms did not agree to the burying easily because the outbreak was the first case in an extra-large-scale layer farm with 225,000 birds in Japan and the residents were anxious about the pollution of soil and underground water and a decrease of the land utility. All the carcasses were finally disposed of 22 days after diagnosis under the condition that they had to be dug up after 3 years and redisposed of by burning. Moreover, in Kyoto, 5 days later (13 days after deaths increased at the layer farm), HPAI H5N1 broke out at a meat-broiler farm with 15,000 birds near the layer farm. Infection from the layer farm by crows or human beings was suspected epidemiologically [1].

In this way, the delay of killing and disposing of the HPAI-infected birds caused another infection. Moreover, the HPAI H5N1 virus was detected at a slaughterhouse in Hyogo Prefecture (Hyogo). Some HPAI-infected birds in Kyoto had been transported to the slaughterhouse in Hyogo. Although almost all the birds had been processed already, 16 birds survived and spread the HPAI H5N1 virus to 6,800 used layer birds that were scheduled to be processed the next day. Therefore, we had to kill and dispose of them all. Moreover, agreement to bury them around the slaughterhouse was not obtained because the HPAI-infected birds had been brought in from another prefecture, Kyoto. There was no space to compost them in the slaughterhouse. Therefore, we had no choice but to pack the carcasses into flex container bags, disinfect them, transport them to an incineration facility 40 km away and dispose of them by burning. We had experienced the difficulty of deciding a disposal method.

In an outbreak of HPAI, farmers are required to carry out speedy killing and disposal. Disposing of contaminated goods, especially carcasses, becomes an important factor in the measures to prevent epidemics. Additionally, a basic
policy of the government for disposing of HPAI-infected birds is necessary because many farmers and residents have various wishes with regard to disposal.

Therefore, we investigated all the farms for their feeding situations and their available disposal methods farm by farm in order to determine an appropriate disposal policy in Hyogo, Japan, as we thought that it is very important to prepare in advance for the prevention of epidemics.

MATERIALS AND METHODS

Preparation to establish disposal plans: Before starting this investigation, we produced “Guidelines to make available disposal plans for all poultry carcasses infected with highly pathogenic avian influenza (HPAI) virus in Hyogo Prefecture” in April 2005 and gathered all the farmers feeding over 1,000 birds in Hyogo and explained the guidelines to them. In the guidelines, we first explained the whole procedure of preventive measures required in an HPAI outbreak, then, the necessity of killing birds to prevent the spread of the HPAI virus and finally, the possible methods of disposing of carcasses and their features (merits and problems).

Investigation of factors and procedures

Basic farm information: We recorded the following factors: each farmer’s name, address, phone and fax numbers; manager’s name; feeding bird species (layer, broiler or parent stock) and the number of birds; farm facilities; the poultry house number and structure (open-type, windowless-type, cage, cage-free) as well as the size (length and width) and arrangement; the compost house number and size (length and width); the location (latitude and longitude) of the farm; the presence of a water supply, river, pond and irrigation channels; the underground water uses of residents; land space (area) that the farmer owns; the conditions of the land such as slopes, plains, hollows and low or high altitudes; and the nature of the land surface of the farm, such as soil, clay or sand.

Prefecture Veterinary Inspectors (PVIs: veterinarians of the LHSC) in Hyogo organized guidance teams with the officers of cities or towns and country officers of the prefecture in charge of agriculture and forestry (fishery) promotion in September 2005. Guidance teams went around to all the farms and led the farmers through the process of making plans. First, they recorded the above-mentioned factors and measured the geographic positions of the farms (latitude and longitude) in detail with a Global Positioning System [GPS, Pokenavi mini (FG-530); Empexc Instruments, Inc., Tokyo, Japan].

Methods of disposing of carcasses available at farms: With this information, we judged whether a farmer had a private land area sufficiently large to bury all the carcasses in or near the farm and whether a farmer had sufficient space to compost all the carcasses.

First, we accumulated data on the amount of contaminated goods related to the species and number of birds, the quantities of stocked feed, the eggs being stocked before shipping and poultry feces and compost usually stocked in cooperation with the farmers. Next, we converted the number of carcasses into the number of flex container bags in which they would be put and calculated the land area necessary for burial. The number of carcasses that could be put into one flex container bag (1.1 m^3; φ 1.1 m × H 1.2 m) was reduced to below 60% capacity (0.66 m^3) in the calculation because the hooks of the flex container bag could cut the bag at the time of hanging if put into a full bag. For layers (1.5 kg/bird), 300 birds could be contained in one bag; for broilers (3.0 kg/bird), 150 birds could generally be contained in one bag. In addition, the length of a ditch with a ditch surface width of 11.0–12.0 m, ditch bottom width of 4.0 m, and depth of 4.5 m was decided under the condition that 15 bags were to be put in a 1.0-m length of the ditch. This accumulation of necessary land area for burying is based on the burying method of Yamaguchi, the “Standard burial method of flex container bags into which contaminated goods (poultry carcasses) were put” [14]. Third, we judged whether the farmer owned sufficient land for burial in or near the farm.

Fourth, we also calculated the necessary area for composting based on “The method of composting poultry carcasses (the cross section of hay method)” [7–12]. The area required for composting 1,000 layers or 500 broilers is basically 3.6 m^2.

Fifth, we also judged whether the farmer had space for composting. We identified space among compost houses, under the floors of poultry houses in the case of high floors, feeding floors in the case of cage-free feeding and any other flat spaces under a roof in the farm.

In this way, we first calculated the necessary private land area and space to dispose of all the carcasses and then calculated the necessary land area and space to dispose of other contaminated goods.

The investigation was executed in the Himeji LHSC jurisdictions (Himeji), the Kobe branch LHSC jurisdiction (Kobe branch), the Wadayama LHSC jurisdiction (Wadayama) and the Sumoto LHSC jurisdiction (Sumoto). The number and proportion of farmers at the Kobe branch were added to those in the Himeji for total values. Finally, we classified all the farms into three groups, A (farms with sufficient private land to bury all the carcasses around the farm), B (farms with sufficient space to compost all the carcasses in the farm) or C (farms that had no disposal methods except burning at incineration facilities), using the obtained results. Some farms could be classified into both A and B. We added up the proportions of farmers classified as A, B and C for the units of LHSC and the entire prefecture.

The available disposal plans that were established in this investigation are owned jointly by the farmer, city or town office and the LHSC.

Questionnaire on environmental problems: Moreover, not only the farm situation (the farm space for composting and the farm land area for burying) but also the farm location (locations of residents and the placement of the farm) are important for whether the farmer can execute the disposal methods of burying and composting.
We created a questionnaire concerning the environmental problems of ground water pollution caused by burying and the unpleasant odors caused by composting.

To determine the availability of the disposal methods for carcasses, we investigated the farm circumstances and judged the availability of disposal methods following a flow chart, “The decision flows of disposal methods for contaminated goods such as poultry carcasses” in the guidelines.

The order of priority of the disposal methods was as follows: burying had the highest priority, composting was next and burning was last. Concerning the choice of burying, we judged this under the conditions that digging up and redispersing of carcasses were unnecessary and selection of an ideal site within the land that the farmer owns was necessary. Moreover, concerning the risk of underground water pollution, we judged this using information of the city or town office engineering works. In the case that this information was not available, we judged this using information about underground water use, the presence of people living around the farm and the distance (500 m or more) from rivers. We judged problems such as whether the agreement of local residents was needed in accordance with the judgment of the farmer. However, in this investigation, we ignored whether agreement was obtained or not. Moreover, concerning the problem of generation of unpleasant odors, we judged it to be an issue in cases where houses of local residents (within a radius of 500 m) were present near the farm and the space for composting was out in the open. However, we judged it to be no problem in cases where the poultry houses could be covered with a vinyl sheet or curtain.

This questionnaire on environmental problems was undertaken for only 134 farms in Himeji (including Kobe).

Farmers’ wishes for disposal methods of each contaminated goods: We investigated all the farmers’ wishes for the methods of disposal of the contaminated carcasses, contaminated eggs, contaminated poultry feces and compost and contaminated feed at each farm. The farmers chose from among the available disposal methods. We also added up the farmers’ wishes in each LHSC jurisdiction and totalled the results for the prefecture.

Investigation of available incineration facilities: We investigated the locations and processing performances of the incineration facilities that municipalities (cities or towns), broader-based local government unions or private industrial waste disposal traders owned with the help of the Environment Directorate Management Section of the Healthy Life Division in Hyogo. Additionally, we judged from their structure whether the facilities would be available for disposal of carcasses.

Mapping of the investigated results: We produced a digital map of the farms (for prevention of epidemics) with the latitudes and longitudes acquired in this investigation and expressed the poultry species and feeding numbers on a white map of Hyogo by plotting markers of various shapes and sizes to indicate the poultry feeding distribution. The core locations in which more than one million birds were kept within a 30-km radius were calculated with the computer map software ProAtlas [for Windows, Creo Co., Ltd., Tokyo, Japan] and expressed on a white map.

Statistical analysis: The ratios of the three disposal methods were compared by Tukey’s test. Differences were considered significant at p<0.01.

RESULTS

Poultry feeding in Hyogo: Hyogo is in the mid-west of Japan (Fig. 1). It is one of the leading areas in the Japanese poultry industry. In 2005, 5.5 million layers (130 farms) and 2.7 million broilers (161 farms) were kept in Hyogo. The annual number of layers was ranked 10th in Japan, and the annual number of broilers was ranked 7th. The numbers of farms and birds in Himeji (containing birds from the Kobe branch), Wadayama and Sumoto and the poultry feeding farm distribution are shown in Fig. 2. There were three core poultry feeding areas in the prefecture. One of the cores was a broiler feeding area (Area 1, the east district of North Tajima and the west district of South Tajima: 2.34 million birds in 110 farms) in Wadayama. Another was a layer feeding area (Area 2, East Harima and Central Harima district: 3.53 million birds in 109 farms) in Himeji. The third was a layer feeding area (Area 3, West Harima district: 2.04 million birds in 46 farms) in Himeji. An outbreak of HPAI in the three cores was simulated as an extra-large outbreak.

Available disposal methods for carcasses that farmers could execute

Burial: The proportions of farms (A) that could bury carcasses were 61.2% in Himeji, 24.8% in Wadayama, 54.0% in Sumoto and 44.0% in the entire prefecture (Fig. 3 and Table 1).

Fermentation disinfection (composting): The proportions of farms (B) that could compost were 89.6% in Himeji, 42.9% in Wadayama, 58.3% in Sumoto and 65.6% in the entire prefecture (Fig. 4 and Table 1).

Incineration: The proportions of farms (C) that could only incinerate were 14.2% in Himeji, 34.6% in Wadayama, 12.5% in Sumoto and 23.4% in the entire prefecture (Fig. 5 and Table 1).

Questionnaire on environmental problems: Eighty farms (61.2%) among the 134 farms had land for disposing of all the carcasses by burial. However, there were risks of groundwater pollution at 44 farms (32.8%), and these risks were unknown at 12 farms (8.9%). Burying all the carcasses could be executed at 24 farms (17.9%) without environmental problems if the residents’ agreement was obtained.

One hundred and twenty farms (89.6%) among the 134 farms had space to dispose of all the carcasses by composting. However, there were risks of generation of unpleasant odors at 75 farms (56.0%), and the risks were unknown at 33 farms (24.6%). Composting all the carcasses could be executed at 68 farms (50.7%) if the 56 farms (41.8%) that could seal off the unpleasant odors by covering the poultry houses were added. However, the number of farms where the disposal method of composting was judged to be possible with-
out covering was only 12 (9.6%).

Farmers’ wishes for disposal methods of each contaminated good: The farmers’ wishes are shown in Table 2. For the methods of disposal of carcasses, 65.9% of the farmers desired burning, 48.7% desired burying and 33.6% desired composting. On the other hand, for the method of disposal
Fig. 3. Poultry farms (A) that have sufficient private land to bury all their poultry carcasses.

Fig. 4. Poultry farms (B) that have sufficient space to compost all their poultry carcasses.
of feed, poultry feces and compost, about 70% of the farmers desired composting because they frequently converted poultry feces into compost. The difference was significant for poultry feces and compost \( (p<0.05) \). For the method of disposal of contaminated eggs, each method was equally desired in about 40% of the farmers.

**Available incineration facilities:** The locations of the incineration facilities in Hyogo are shown in Fig. 6 along with their processing performance. There were 54 general garbage processing facilities in Hyogo in total. However, two of them processed garbage with refuse-derived fuel (RDF; solid fuel made of garbage) and could not dispose of carcasses, and five of them were incineration facilities with fluid sand floors, some of which were inappropriate for burning contaminated goods because they employed the process of ripping garbage into minute pieces between the throwing entrance and the furnace. However, 47 of them were incineration facilities with a smelting furnace or stoker furnace (furnace with a grate), in which packed carcasses could be disposed of without ripping. In addition, there were six (owned by 5 companies) incineration facilities owned by private industrial waste disposal traders, but 3 of them could not dispose of carcasses. In terms of the distribution of incineration facilities, Area 2 had many incineration facilities, but Areas 1 and 3 had few.

**DISCUSSION**

In Japan, it is assumed by every farmer in Japan that “The owner of the infected birds has to incinerate or bury the carcasses according to the direction of PVIs” in accordance with Article 21 of the “Act on Domestic Animal Infectious Diseases Control (ADAIDC)”\(^{14}\). In addition, according to Article 22 of the ADAIDC, the farmer can dispose of carcasses by burial at locations far from private houses, public roads and rivers and where underground water does not

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**Table 1.** Available disposal methods for poultry carcasses that all poultry farms in each jurisdiction can choose (%)

<table>
<thead>
<tr>
<th>LHSC (jurisdiction)</th>
<th>Himeji</th>
<th>Wadayama</th>
<th>Sumoto</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposal</td>
<td>Burying</td>
<td>61.2</td>
<td>24.8</td>
<td>54.0</td>
</tr>
<tr>
<td></td>
<td>Composting</td>
<td>89.6</td>
<td>42.9</td>
<td>58.3</td>
</tr>
<tr>
<td></td>
<td>Burning</td>
<td>14.2</td>
<td>34.6</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Figures in parentheses are the mean values of 3 LHSC jurisdictions. No significant difference by Tukey’s test.
The farmer can also dispose of carcasses by burning at locations defined in the standards of the enforcement rules of the ADAIDC. However, it has become difficult to burn carcasses in the open air because this generates air pollution. However, farmers can dispose of carcasses by burning at incineration facilities under the condition that the prescribed written report is submitted. Moreover, farmers can dispose of carcasses by disinfecting only in the case of poultry. Disinfection includes fermentation disinfection (composting). Carcasses can be disposed of by composting, like that for poultry feces, litter and compost.

On the basis of the rule stated above, the farmer can choose one method among burial, fermentation disinfection and incineration to dispose of carcasses when HPAI breaks.
out.

Concerning the effect of disinfection by composting, 2 avian influenza (AI) virus and 3 Newcastle disease (ND) virus, which infect egg products, were inactivated by treating with the industry standard pasteurization protocols (at 55–63°C) [8]. Moreover, typical temperatures generated in composts were generally expected to peak at 55°C to 65°C by day 2 or 3 [4]. Additionally, at the end of the first ten days of composting, virus-isolation efforts showed that the HPAI virus had been inactivated [7]. In this way, composting carcasses is highly rated as an economic and reasonable method of carcass disposal because it can be used to process a large number of carcasses at once and can produce fertilizer.

Nevertheless, the disposal method of composting is not so acceptable in Japan. In the breakout of low attenuated HPAI (H5N2) in Ibaraki Prefecture (Ibaraki; and partly in Saitama Prefecture) in 2005, the carcasses at 4 farms were disposed of by composting, but the carcasses in 36 other farms were disposed of by burning because problems due to generation of unpleasant odors developed and much effort and time for fertilizing were needed while processing [6]. Moreover, the final disposal of composted carcasses was left unfinished. Compost that was generated by disposal of the HPAI-infected carcasses was not acceptable for Japanese farmers as fertilizer and was disposed of by burying or burning.

Concerning the disposal method of burying, the carcasses of HPAI-infected birds in Yamaguchi were disposed of by burying. Poultry farmers should consider carcass disposal techniques that do not require off-farm movement, such as burial, composting and incineration, because of the highly infectious nature of AI virus and the devastating economic impact of outbreaks [3]. In an outbreak of HPAI, in-farm or near-farm disposal is basically required. If the farmer owns sufficient land for burying and is able to acquire agreement of local residents, disposal by burying is one of the available methods. However, Kyoto experienced the worst case in 2002. The disposal method of burying is becoming unacceptable in Japan.

Concerning the disposal method of burning at an incineration facility, 6,600 birds in Hyogo were disposed of by burning without spreading the HPAI H5N1 virus. In Ibaraki, 5.58 million carcasses at 36 farms were also disposed of by burning [6]. Additionally, in the outbreaks of HPAI H5N1 in Miyazaki and Okayama Prefectures in 2007, all the HPAI-infected carcasses were disposed of by burning [2].

Although disposing of carcasses by burning requires much attention with regard to the risk of spreading the virus and causing an epidemic and is expensive compared with disposing of carcasses by composting or burying, it is rated highly and becoming one of the standard disposal methods in Japan.

Hyogo set a clear policy for the method of disposal of carcasses that farmers should choose the method of burning as the first choice when HPAI breaks out. The reasons for this were as follows.

**Reason 1**: In this investigation, 44.0% of farms in the entire prefecture (61.2% in Himeji) had sufficient land to bury all the carcasses around their farms. However, in the questionnaire on environmental problems in Himeji, only 17.9% of farms were shown to be able to bury without fear of groundwater pollution.

**Reason 2**: In the entire prefecture, 65.6% (89.6% in Himeji) of the farms had sufficient space to compost all the carcasses within their farms. However, in the questionnaire on environmental problems in Himeji, only 8.9% of farmers were shown to be able to compost without generating unpleasant odors.

**Reason 3**: In the entire prefecture, 23.4% of farmers (14.2% in Himeji) could not dispose of all the carcasses except by burning at incineration facilities. Additionally, 65.9% of farmers desired burning as the method of disposal of carcasses.

In this investigation, many farmers had various wishes for disposal. However, residents around farms would have more requirements. Farmers also have rights to choose the disposal methods. Therefore, we thought that a basic policy for disposing of HPAI-contaminated goods, especially carcasses, was necessary at the level of the local government to direct farmers to kill, dispose and disinfect.

We have decided to choose the method of disposing of HPAI-infected carcasses by burning at incineration facilities as the first choice in Hyogo.

However, there are some problems with disposing of carcasses by burning. In the outbreak of HPAI in Hyogo in 2004, agreement of the residents living near the incineration facilities was not obtained beforehand. Therefore, the burning was implemented without their agreement. Explanation of the disposal policy and obtaining resident approval should be undertaken beforehand.

Moreover, concerning the incineration facilities, there are 5 facilities with fluid sand floors in Hyogo. In such facilities, contaminated goods such as carcasses cannot be processed because the pathogen of HPAI would be scattered before being disinfected. Of course, the facilities that utilize RDF could not dispose of them.

There are a lot of farms in rural areas and a lot of incineration facilities in urban areas. Additionally, large-scale farms are likely to be in areas where large-scale incineration facilities are not located, which is the case in Hyogo (Figs. 4 and 5). It is necessary to dispose of all HPAI-infected carcasses, which requires cooperation with the cities that have large incineration facilities. It is also necessary to establish biosecurity and biosafety procedures for work related to packing and transporting carcasses to incineration facilities to prevent spread of the HPAI virus, such as requiring the use of medical waste disposal packing and container trucks, as was done in Miyazaki in 2007.

Fortunately, HPAI H5N1 in Japan is not infectious or fatal to humans. However, HPAI H5N1 in Southeast Asia, including Indonesia and Vietnam, was confirmed to be fatal to humans, and there was concern of it mutating to a new influenza (pandemic type) [13]. In the case that a pandemic-
type HPAI breaks out on a farm, it would be necessary to dispose of all the carcasses in a short period with the minimum amount of work so as not to infect laborers and residents around the farm, while keeping humans away from contaminated goods such as carcasses. In such a case, it might be necessary to dispose of the carcasses by burying or composting.

In this investigation, the farm facility size, such as the compost house size and the privately owned land area, for the birds was important to judge whether the farmer would be able to dispose of all the carcasses by composting or burying.

In this way, investigation of all the available disposal methods in every farm in advance might be one of the measures of preventing epidemics.

So long as the HPAI virus is not a pandemic type, we would choose to dispose of carcasses at incineration facilities as the first choice in Hyogo.

We believe that logistical disposal plans for contaminated goods in each prefecture and country have rarely been established, but that they are important in preparation for countering epidemic diseases.

REFERENCES


