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Costs analysis of carcass burial site construction: Focused on the foot and mouth disease 2011, South Korea

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ABSTRACT
Many burial sites were constructed in a short time to prevent the rapid spread of foot and mouth disease in infected livestock carcasses in Korea. More than 4,700 carcass burial sites were constructed in 2011. Approximately seven million poultry and 3.5 million livestock, including cattle and swine, were buried on farmland. Some burial sites were suspected of leachate leakage and were excavated and carcasses redisposed in a bioaugmentation process. This study performed interviews in order to understand the economic issues related to carcass burial and redisposal. The internal data from local government and the assumption data from online sites were analyzed to evaluate the costs; the focus was on burial site construction. The results showed that the local government paid $4.7 and $10.9 per carcass for traditional burial and redisposal. The comparable costs shown online were $4.5. This study found that the standard operating procedures should be carried out to reduce environmental impact and avoid additional costs. We estimated that the cost could be reduced by the advance preparations of materials against the emergency situations such as catastrophe of epidemics. In addition, the innovative technology for the stabilization of carcasses should be established through a future study.

Keywords: Aerobic thermophilic, Costs analysis, Economic impact, Foot and mouth disease, On-farm burial

1. Introduction

Livestock mortality must be managed to avoid hygiene problems and to ensure environmental protection and aesthetics [1]. Various methods including burial, burning, composting, incineration, rendering, sanitary landfills, anaerobic digestion, and alkaline hydrolysis are currently used throughout the world to dispose of carcasses [2]. In practice, the burial method is still widely utilized outside the EU [3]. Catastrophic mortality can occur when an epidemic infects and destroys a herd or flock in a short time, or when a natural disaster, such as a flood, strikes. There may also be incidences when an entire herd of flock must be destroyed to protect human health [1]. The burial method was utilized when avian influenza (AI) and foot and mouth disease (FMD) broke out in Korea. It was estimated that many burial sites were constructed without systematic management; therefore, secondary environmental pollution was a cause for concern. Some burial sites, which were determined or suspected of leaking of leachate, were excavated and redisposed by using bioaugmentation.

The economic loss from the FMD breakout had a material and social impact on dairy farming and related industries; therefore, the ripple effect through industrial society should be measured to determine the total economic effect. The economic loss was calculated in direct and indirect costs reported by Korea Rural Economic Institute. The direct costs were government expenditure and compensation payments for farmers, a secure stability fund (i.e. expenses for medical care, congratulations and condolences, education, and housing rental), disinfectants, vaccines, and burial cost payments. It compensated farmers for fluctuations in supply and demand and decreased exports. The indirect costs resulted from market contractions in related industries and damage from environmental pollution [4].

The outbreaks of livestock disease have increased all around the world, and burdened with the consequential increase of expense [5]. Ko and Seol reported that Taiwan spent approximately $6.9 billion for five years since FMD broke out in 1997. About 4.2 million head of livestock were culled from FMD in UK, 2001, and £8.0 billion and £2.0 billion were spent for direct costs and indirect costs respectively [6]. The Ministry of Agriculture, Food, and Rural Affairs reported that approximately 3.48 million livestock were buried from May 18, 2011 to November 29, 2011. The government spent

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approximately $2.76 billion [4]. The detailed cost subsection was estimated as approximately $1.58 billion for compensation paid to farmers for livestock slaughtered, $104.18 million for disinfectants and vaccines, $20.14 million to the secure stability fund, $327.48 million to purchase livestock, $27.35 million to the management stability fund (i.e. expenses for small company management for recovery financial problems), $364.91 million for water supply facilities, and $22.83 million for the management of burials.

The Ministry of Environment reported that approximately $30.50 million for the maintenance, $418.63 million for water supply, and $15.21 million for groundwater quality management were spent for environmental costs [7]. Ko and Seol evaluated the total economic loss of livestock carcass disposal [6]. Kim and Seol estimated the expenses for restoration of burial sites at the post-management stage [8]. However, the detailed subsection for burial site construction costs and post-management costs were not officially established by government or private institutes. Local governments should have an emergency plan for FMD; therefore, data on costs for burial site construction should be established to support optimized standard operating procedures (SOPs) and to better prepare in the face of future disease outbreaks and the need for mass burial.

This study was performed to analyze the cost of constructing an on-farm burial site and a redisposal. Direct costs determined by interviews with government officers and directors when FMD occurred were evaluated. The goal of this study was to provide basic data for engineers, farmers, and decision makers.

2. Materials and Methods

2.1. Current Status

In Korea, there were 216 burial sites for AI and 4,583 burial sites for FMD as of April, 2011. The burials are in Kyeongi (47.4%), Gyeonbuk (24.8%), Gangwon (10.3%), and Chungnam (8.9%) provinces [8]. A considerable number of burials were constructed in vulnerable sites; therefore, secondary pollution was a cause for concern. In the case of several vulnerable burials suspected of leachate leaking, the burial sites were excavated, and the carcasses were reburied or redisposed by using bioaugmentation method.

2.2. Methodology

The selected sites, A and B, were located in E city in Kyeonggi province where most burial sites were constructed. The traditional burial site A located at Seolsongmyun in E city was normally constructed on farms following the guidelines issued by the Ministry of Environment [9] in January, 2011, during the FMD break out. The burial site was consistent with on-farm burial sites: 5 m wide (5.5 m of upper section and 5 m of lower section), 12 m long, and 5 m deep which was representative size in Korea. The species of the buried animal was swine; approximately 2,000 heads of swine were buried at the site. The redisposal site, B located at Mogamyun in E city was constructed to retreat of excavated carcasses, since leachate leaking was suspected from the traditional burial site. The original burial site was constructed on a similar scale with the site A in January, 2011, during the FMD break out. Approximately 2,100 heads of swine of mortality carcasses were redisposed at nearest of the same farm in May, 2012. The reconstruction was processed by a company J, made a contract with E city.

We investigated the construction costs in face-to-face interviews with officers the E city in local government because the detailed subsection of the costs for burial site construction was not exist in the official documents. In addition, by using an online database containing market costs, the online cost data were analyzed and established.

2.3. Processes of Burial and Redisposal Constructions

2.3.1. Burial (site A Seolsongmyun)

According to the guidelines for environmental management of carcass burial by the Ministry of Environment, the burial site should take into account the water table, well water, and the local population. The burial site should be located approximately 1 m from the water table and approximately 30 m from any rivers, water sources, or residential areas. The bottom width of the site should be 4 m to 5 m, the upper width should be 5 m to 6 m, and the depth should be 5 m (Fig.1).

The guideline for burial site construction by the Ministry of Environment suggests the following construction method and materials:

- Liner and cover materials: Environmentally friendly double layered vinyl (more than 0.1 mm thick) or high-strength waterproof fabrics.
- Gas discharge pipe: Polyvinyl chloride (PVC) (greater than 100 mm diameter, 5 m in length) pipe set at 1–2 m from the ground, the shape at the end of the pipe as like "↶"; approximately five pipes are needed in a burial area of 90 m^2, and more pipes may be needed to cope with gas production.
- Leachate discharge pipe, water tank: PVC (greater than 100 mm diameter, 5 m of length) pipe set at 2–3 m in the ground with caps installed on the upper side of the pipe.
- Lime (for sanitation), sawdust (for absorbent), and gravel (for preventing clogging of the discharge pipes) were used.
- Monitoring well: durable and waterproof materials, such as stainless steel, 75 mm in diameter and 10 m in length, and cap installation on the upper side of the well.

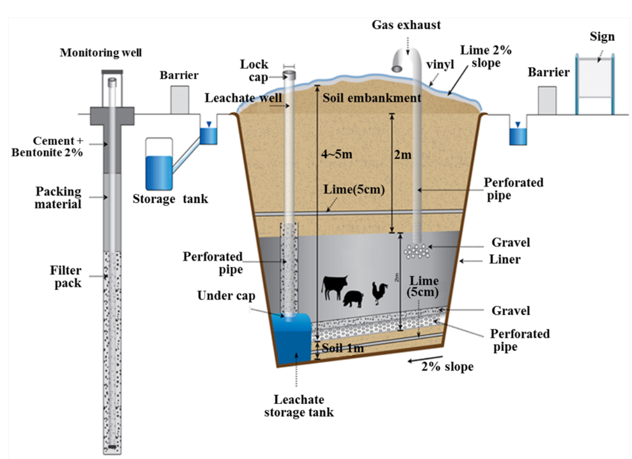

Fig. 1. Schematic description of carcass burial [9].

2.3.2. Redisposal using aerobic thermophilic microbes (site B Mogamyun)

In the redisposal method of decomposition, the carcass was buried with rice bran or husks mixed with the culture soil and culture fluid of aerobic thermophilic microbes. Most water content was vaporized by the heat produced during the decomposition process. The construction process investigated in the current study was that suggested by the Ministry of Agriculture, Food, and Rural Affairs. The disposal of carcasses by aerobic thermophilic microbe activity was as follows:

- Sites were prepared for redisposal(excavating the soil).
- The culture soil and microbial culture fluid were sprayed (20 kg) on the ground for leachate decomposition by destroying vinyl during the construction.
- A double layer of vinyl was laid on the ground.
- Air blowers were set up (The plastic pipes were connected at both ends of the air blower tube, which was made of vinyl. Air pressure was produced in the middle of the pipe by air bowers installed in a ⊂-shaped design on the vinyl liner. Air entered the system at an inflow rate 80 L per minute through the end of the pipe).
- The culture soil and culture fluid were sprayed on the vinyl liner.
- Around 10 m^3 of rice husks were mixed with 3 t of rice bran, 2 t of culture fluid, and 50 kg of culture soil. The rice bran was used for initializing microbial activity. The culture fluid was used to control the water content, which was one of the most important factors for microbial growth, of the rice husks.
- The rice husks mixed with the rice bran, culture soil, and culture fluid were spread on the vinyl liner to a depth of 30 cm.
- The carcasses were laid on the rice husks layer.
- Secondary rice husks were put on the carcasses.
- Secondary carcasses were laid on the rice husks layer.
- The rice husks were piled over the carcasses in a pyramid shape. (The culture soil and culture fluid were sprayed on the husks as the carcass and rice husks were put in. The pyramid shape preserved heat and increased the surface area for microbial growth).
- A well and a thermometer were installed to monitor the decomposition of the carcasses.
- A plastic covering was placed on the surface of the disposal site to keep the site warm.

We found the records for monitoring temperature of the site B. The monitoring data were measured for 130 days from May 8 to Sep. 20, 2012. The initial temperature of 42˚C was sharply decreased to 33℃ for 7 days, then continued from 32℃ to 35℃ for 50 days. On the 90th day of redisposal, the temperature was increased to 42℃ and then, sharply decreased to 34℃. After that, it was steadily decreased and kept at 32 ℃ (Fig. 2). We estimated that the temperature trends were one of the critical factors for the cost prediction at the management stage of the burial site for a future study.

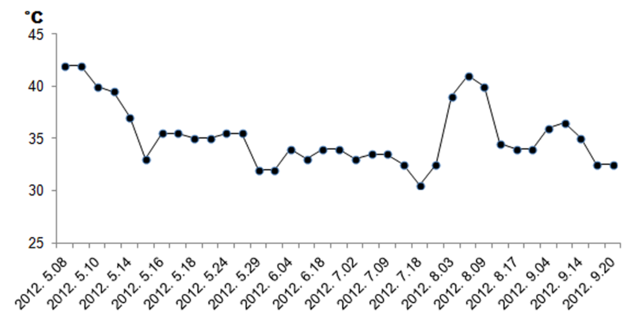

Fig. 2. Temperature trends of reburial site.

3. Results and Discussion

3.1. Costs for Burial Process

In internal E city documents, we found direct costs included preventive epidemic costs, such as vaccines, materials, and labor. The internal documents showed that the selected burial sites A were constructed according to the guidelines developed by the Ministry of Environment. We estimated that approximately 63% of the total costs were spent on material purchase, 34% for food expenses of labors and disinfectants, 2% for labor costs, and 1% for diesel and electricity.

- Material costs: For the construction process, three sheets of vinyl (12 m 10 m), a sheet of high-density polyethylene (HDPE), a water tank (5 t), five PVC pipes, a perforated pipe, cable, and ancillary materials were used.
- Energy consumption costs: The energy cost was separately paid to two companies in a lump sum of $881.2 each. One was for the electric installation of lighting and equipment during night work, and another was for diesel for operating excavators and boilers for heating a watch house.
- Equipment costs: Two excavators (0.6 m^3, 0.8 m^3) were used continuously for about 25 hours each. Equipment costs were paid to a company in a lump sum, including rental for two excavators, labor, and fuel. The rental fee per hour was $55.1 for 0.6 m^3 and $71.6 for 0.8 m^3 of operation. The cost for night work was 1.5 times higher than day work.
- Labor costs: Labor costs were reduced since government employees and the military were provided for burial site construction when FMD broke out in 2010. Labor costs incurred by a service company were paid to the company in a lump sum. Detailed labor costs do not exist.

According to the internal government data and the results of interviews, the total construction cost of a burial site was $9,493. The detailed costs of each subsection are shown in Table 1.

It was estimated that the total cost of a burial site was $9,493, including $2,890 for materials, $70 for transportation, $1,762 for energy use, $3,800 for equipment rental, and $969 for labor. It was recalculated that the cost of burial per swine was $4.7. According to the interviews, we estimated that the distribution ratio of buried swine was 60% ofweaned swine and 40% of piglets. Under the assumption that the average weight of a weaned swine and piglet was 200 kg (160 kg–240 kg) and 105 kg (80 kg–130

Table 1. Costs for the FMD Burial Process in 2010 [7]

	Subsection	Cost (USD)	Quantity	Note
Material	Vinyl	881.2	3 piece	-
	HDPE	819.5	1 piece	-
	Gas pipe, drain pipe, socket, cable, ancillary materials	308.4	5 pipes	-
	Water tank	881.2	1 piece (5 t)	-
	Transportation	70.5	-	Transportation of raw materials
Energy	Electricity	881.2	-	Subcontractor company, a lump-sum payment (including installation)
	Diesel	881.2	-	Subcontractor company, a lump-sum payment
Equipment	Excavators rental	3,800.2	-	-
Labor costs	-	969.3	-	Subcontract company, a lump-sum payment
Sum		9,492.9		

kg) per head, respectively, the total disposal weight was 324 tonnes. The disposal cost per tonne was $29.1. $4.7 was required for burying each head of swine.

3.2. Burial Costs Based on Web

The costs for burial site construction based on online data were investigated (see Table 2).

- Material costs: The inventory of the required materials for burial site construction was prepared based on the guidelines established by the Ministry of Environment. The cost of each material was investigated through web searches of internet markets.
- Transportation costs: The selected material costs of PVC pipes (3–5 kg each, average weight 20 kg for five pipes) obtained through websites did not include transportation costs. The costs of materials (approximately 5 kg), including socket, cable, ancillary materials, water tank (100 kg), and lime (5 t), we obtained did not include the delivery fee. The transportation costs for delivery of these materials were estimated and included variable costs (fuel cost), semi-fixed costs (depreciation, tax, insurance), and fixed costs (labor costs, repairing costs).
  - Fuel costs: Distance × oil unit cost/km ($/liter/fuel efficiency by truck type)
  - Repairing costs: Average consumption per km (tire, oil)
  - Tax and insurance: Annual cost/(number of days for operating × daily average distance)
  - Depreciation: Vehicle price/[(endurance period/year) × (number of days for operating/year) × (average driving distance/day)]
  - Labor costs: Daily unit price of the driver cost/daily work hours

We estimated $5.4 for truck utilization, $10.5 for eight liters of oil consumption, and $4.0 for operating costs by using estimating standards used by the Korean Construction Management Corp [11]. The driver's cost was $17.3 per hour by using wages and the unit cost of mechanical parts from the Construction Association of Korean; the oil cost was calculated using 2011 price information from the Korea Price Information Corp. The total cost for transportation per hour was $37.2 by assuming a 6 t dump truck for delivery.

The distance was limited to 8 km based on a study that a distance over 10 km was not cost effective [12]. An average speed 10 km/h for a vacant vehicle driving in double lane on a mountain road without intersections was used in the calculation according to standard estimates for road transportation and average speed. We estimated that 1.5 hours were required for material transportation; therefore, the total material cost was $55.7.

- Equipment utilization: It was assumed that two excavators (0.6 m^3, 0.8 m^3) were utilized. The unit labor cost for heavy equipment utilization was $19.1 per hour based on 2011 standard estimates. The energy consumption for the equipment operation was calculated based on the standard estimates of fuel consumption rates in construction machinery. The utilization costs of a 0.6 m^3 excavator was $51.3 factoring depreciation. The costs included $15.9 for equipment use, $13.4 for 10.2 liters of diesel consumption, $2.9 for materials, and $19.1 for the driver. The utilization cost of a 0.8 m^3 excavator was $60.8 factoring depreciation. The costs included $17.3 for equipment use, $20.0 for 15.3 liter of diesel consumption, $4.4 for material costs, and $19.1 for the driver of the construction machinery. The excavators were utilized for 24 hours continuously, and the night work wages were 1.5 times higher than day work.
- Labor costs: According to the 2011 labor costs of the Construction Association of Korea, daily labor costs of $85.1 for a skilled worker and $66.2 for a field worker were applied to the calculations in the study. We estimated that approximately 20 laborers worked to drive carcasses to the burial sites during the process of burial site construction, and four laborers were required for fieldwork. This is based on interviews with officers working in the local government and directors participating in the burial site construction.

The cost for one burial site construction, in which approximately 2,000 swine were buried, totaled $9,067.6 including $1,618.3 for materials, $55.7 for transportation, $700.5 for energy use, $3,363.3

for equipment utilization, and $3,329.8 for labor. These costs were recalculated so that $4.5 was spent for a swine burial and $27.9 for 1 t of carcasses.

3.3. Cost of the Redisposal Process

Some of the burial sites that were suspected of leaking leachate from the sites were excavated, and the carcasses were redisposed using a bioaugmentation method. The costs for a redisposal construction of B site were collected in interviews with officers and directors who participated directly in the construction work in E city. Funds were paid in a lump sum to companies.

- Material costs: Two sheet of vinyl and a sheet of HDPE were used for redisposal site construction. The unit cost of vinyl and HDPE was $2.10 and $3.36 per m^3, respectively. The costs of a ring blower for supporting air as well as five PVC pipes for gas and leachate discharge were $709.2 and $87.6, respectively. The costs of sawdust, effective microorganisms, and disinfectant included transportation. Total material costs

Table 2. Market Prices for the Construction of the Carcass Burial Pit Based on a Web Search [10]

Input	Price ($)	Quantity & Size	Note	Source
Vinyl	204.9	3 piece vinyl (7 m ×7 m/ea) including 3 piece tape (14(W) cm/ea)	Free delivery (> $87.6)	KPIC*
HDPE	606.4	1 piece	Delivery & installation fee included	KPIC*
PVC pipe	103.2	5 pipe s(4 gas, 1 leachate) Socket, cable, bond including ancillary materials	Area (> 60 m^2) delivery not included VAT included	KPIC*
Perforated pipe	38.4	5 pipes	Delivery not included VAT included	KPIC*
Quicklime	394.0	5 t	Delivery not included	KPIC*
Water tank	192.6	1 piece (volume 2 t) round shaped PE tank	Delivery not included labor cost (20%) included	KPIC*
Warning sign	78.8	1 piece	Delivery fee included	Experts survey
Transportation	55.7	Material transportation	-	KPIC*
Energy	700.5	-	Cost including installation and diesel usage	Experts survey
Excavators rental	3,363.3	Two excavators 0.6 m^3: $51.3/h 0.8 m^3: $60.8/h	Cost including diesel usage	Standard estimate
Labor costs	3,329.8	$85.2/person (skilled work) $66.2/person (normal field work)	24 laborers (4 skilled workers, 20 field workers) for 2 days	Standard estimate
Total costs		9,067.6		

*Source: Korea Price Information Corp.(KPIC), http://www.kpi.or.kr

Table 3. Costs for the FMD Redisposal Process using Bioaugmentation

Items	Material costs	Labor costs	Expenditure	Total costs (USD)	Quantity	Note
Vinyl	673.8	1,213.7	-	1,887.5	900 m^2	Subcontract company (a lump-sum payment)
HDPE	683.0	1,333.5	-	2,016.5	600 m^2	
Ring blower	709.2	-	656.7	1,366.0	1 set (2HP)	
XL pipe	67.8	47.3	-	115.1	180 m	
Water tank	900.0	63.2	-	963.2	-	
PVC pipe	87.6	43.8		131.4	1 set	
Sawdust	7,355.6	-	-	7,355.6	30 t	
EM (Effective microorganisms)	2,626.9	-	-	2,626.9	2,000 liter	
Disinfectant	-	-	1,120.8	1,120.8	-	
Waste disposal	-	-	998.3	998.3	20 m^3 wastes	
Excavators use	435.7	1,653.3	311.2	2,400.2	2 excavators (0.7 m^3, 0.8 m^3)	
Dump truck use	108.6	354.9	328.4	791.8	313 m^3 of carcasses	
Sum	13,648.2	4,683.2	3,411.9	21,773.3	-	

were $13,648.2.

- Energy consumption costs: The energy cost was paid to purchase diesel to operate two excavators for digging and back filling and a dump truck for delivery of the excavated carcasses. The oil cost included $435.7 for excavators and $108.6 for delivery to the redisposal site.
- Equipment costs: Equipment costs included rental of two excavators and a dump truck. Two excavators (0.7 m^3, 0.8 m^3) were used continuously for about 25 hours each. The equipment costs of $311.2 for excavators and $328.4 for a truck included depreciation and a vehicle utilization rental fee.
- Labor costs: Wages were paid to workers for overall construction work, excluding drivers for excavators and the delivery truck. The wages of excavators and truck drivers was $1,653.3 and $354.9, respectively. Total labor cost excluding drivers was $4,017.1.

We found that the total cost of one redisposal construction was $21,773.3. The detailed cost of each item is shown in Table 3. We estimated that the burial cost for one tonne of swine disposal was $67.2 which were 2.3 times more than burial construction.

4. Conclusions

The result of survey showed that the local government paid $2,890.4 in material costs. In contrast, we found that the material costs for the same construction process were $1,618.3 based on Korea Price Information Corp statistics online. Therefore, we estimated that a cost effective burial could be constructed and material costs might be reduced through advanced preparation. The online cost inventory was established based on the guidelines developed by the Ministry of Environment. The analysis of data from local governments showed that local expenditures on labor were lower, since public servants and military people worked provided the labor when FMD occurred. According to the survey results, approximately 24 laborers were required for the burial site construction. We estimated that the labor costs would otherwise be about 3.5 times more than the original burial site cost report. Internal data showed that the energy costs and equipment utilization costs were paid as a lump sum to a contractor company. We calculated the subsection of equipment costs using standard estimation and interviews. The results showed that equipment costs could be decreased by than 10%.

We estimated that the local government covered the additional costs for the burial site construction, since there were economic constraints due to the urgency to prevent FMD from spreading. In comparison with the online cost inventory, we established that the burial site construction costs could be reduced by advanced planning of an effective construction design. The cost for a traditional burial was $29.1 per tonne. The costs were recalculated to $27.9 per tonne by using online data.

The redisposal site was constructed for redisposal of carcasses from a traditional burial site, which had been constructed when FMD broke out. Local governments paid a lump sum for disinfectant, delivery of the excavated carcasses, waste disposal, and excavator rentals from contractor companies. The costs for redisposal processes were the highest at $67.2 per tonne of carcasses disposed.

In fact, it is hard to predict about the time, region, and scale of occurrence of livestock diseases. Alternatively, the innovative technology for burial construction should be established for a future study.

This study established the cost inventory for burial site construction and analyzed the economic impact of the process.

However, there are some limitations to this study.

1) Data from government paid expenses and the online cost inventory were not comparable; therefore, successive work is required to increase reliability.

2) Costs inventory was established without accounting for the inflation rate.

3) This study was focused on the construction cost; therefore, the maintenance and post-management costs should be analyzed through a future study.

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