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TSE in Sheep Contingency Planning

Assessment of Risk due to BSE Infectivity from Disposal of Sheep

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TSE in Sheep Contingency Planning: Assessment of Risk due to BSE Infectivity from Disposal of Sheep

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Management Summary

It has been recognised for a considerable time that sheep in the United Kingdom may have been infected with BSE. To date no evidence has been found to demonstrate that the national flock is actually infected with the disease. DEFRA have prepared a draft contingency plan in the event that BSE were to be identified in UK sheep. The worst case scenario under this plan is the disposal of the entire UK flock, some 40 million sheep and lambs. This study has estimated the potential exposure of the UK population to BSE infectivity present in sheep in the event that this plan had to be put into effect.

The preferred means of disposal of carcasses would be by incineration and/or rendering. However, there would not be sufficient capacity from incineration and rendering for any large scale disposal programme, and it takes time to install additional capacity. Alternative disposal routes would therefore need to be considered. These would include burial, landfill and open air burning. The potential exposure to BSE infectivity has been estimated for each of these disposal routes. The estimates presented assume a medium level of BSE prevalence in sheep (0.1% of scrapie cases are BSE) but it is not intended to imply that this is considered more likely. If the prevalence of BSE in sheep was higher (or lower) the risk estimates would vary in proportion.

Based upon the available information the level of risk associated with burial of all sheep and lamb carcases is estimated to be 5.7×10^{-2} human oral ID_{50} units. Of this, 4.6×10^{-2} human oral ID_{50} units would be attributable to sheep > 1 year, with the remaining 1.1×10^{-2} associated with lambs. If the burial were to take place in properly designed lined landfill sites with leachate management and treatment facilities, much less infectivity would be released into the groundwater. This would be expected to reduce the exposure by at least 1 and probably 2 orders of magnitude.

The risk of exposure associated with open air burning of all sheep and lambs is estimated to be 8.4×10^{-3} human oral ID_{50} units; 6.8×10^{-3} human oral ID_{50} units from sheep > 1 year, and 1.6×10^{-3} from lambs. If infectivity was reduced by 99% rather than 90% in open air fires the infectivity ingested would be reduced by one log unit.

All these values represent the total infectivity ingested by all people exposed from the disposal of all animals. In the event of such a large disposal programme the disposal would be spread over many sites. For each site the resulting infectivity would be spread over a wide area and a wide population, so the dose received by any one person would be extremely small.

If BSE infectivity was present in the animals culled during the foot and mouth outbreak the potential exposure to infectivity is estimated to be 6×10^{-3} human oral ID_{50} units, based upon the scenario where 3.5 million of the total 4.5 million animals were buried and the remaining 1.0 million burned. . Again this infectivity would be spread over a large number of people and the maximum exposure to any one person is likely to be very small. Any attempt to exhume the carcases to recover infected material is likely to prove very difficult as much of the material would have decomposed and liquefied significantly, and such an operation would require a substantial number of contractors operating heavy machinery and working over an extended period. The risks of industrial accidents from such an operation are likely to be far greater than the hypothetical risk of exposure to BSE infectivity.

This is a high-level generic risk assessment and is heavily dependent on the assumptions made. These relate to not only the environmental pathways, but also the potential levels of infectivity associated with sheep of different ages and the likely prevalence of BSE in sheep.

Contents

1. INTRODUCTION

It has been recognised for a considerable time that sheep in the United Kingdom may have been infected with BSE. To date no evidence has been found to demonstrate that the national flock is actually infected with the disease. DEFRA have issued a draft Contingency Plan (28 September 2001) for consultation to seek views on the actions to be taken should BSE be found to be present in the UK sheep flock. The worst case scenario envisaged in this Contingency Plan is the disposal of the entire UK sheep flock, which would mean some 40 million animals. This worst case scenario is, however, just one of several scenarios that might apply in practice if BSE were to be found in the sheep population.

The preferred means of disposal of carcasses would be by incineration and/or rendering. However, there would not be sufficient capacity from incineration and rendering for any large scale disposal programme, and it takes time to install additional capacity. As in the recent foot and mouth emergency, alternative disposal routes would therefore need to be considered. These would include burial, landfill and open air burning. However, these methods also raise concerns over the potential exposure to humans from the release of the BSE agent through environmental pathways related to the disposal.

DEFRA have therefore requested that DNV carry out a risk analysis to assess the public health risks due to the BSE agent from disposal of sheep by burial, landfill and open air burning as a contribution to the development of the contingency plan. DNV were also asked to consider the risks associated with sheep culled as a consequence of the recent foot and mouth outbreak.

Earlier this year DNV carried out a study for MAFF on the risks of exposure to the BSE agent from the disposal of cattle due to the foot and mouth epidemic (DNV, 2001 a). That study was reviewed by SEAC and many of the issues covered will be the same as for the disposal of sheep. This present assessment builds on that work, utilising the same approach and assumptions, and combines it with data collected for a study for the Food Standards Agency ‘Risk of Exposure to BSE Infectivity in UK Sheep’ (DNV 2001 b, currently in draft form).

It is emphasised that this report must not be viewed in isolation, as preceding reports describe at some length the methodology applied and significant assumptions made in arriving at the figures presented.

2. INFECTIVE LOAD

The first stage in the assessment is to assess the total amount of BSE infectivity that may be present in sheep to be disposed of. This then provides the input to the event tree model that considers the effect of the disposal route on the infectivity and the pathways by which people could be exposed.

The amount of infectivity present will depend on the numbers of animals being destroyed, the ages of those animals and the prevalence of BSE in the national flock. These is no evidence to confirm that BSE is present in sheep in the UK and this assessment is therefore based on an assumed prevalence of BSE in sheep.

The following section describes how the initial input values to the disposal model have been derived. Figures used in this section are taken from the DNV report 'Risk of Exposure to BSE Infectivity in UK Sheep' (DNV, 2001 b), and the chapter references given below apply to that study.

2.1 Number of Animals for Disposal

In 2000 the June farm census carried out by DEFRA showed a total of 20,447,000 breeding ewes in the United Kingdom plus 20,855,000 lambs under 1 year old and 959,000 other sheep. The latter will include rams and hoggets. The lamb total represents the numbers on the farm in June; a number of lambs will have been slaughtered before June (about 4 million in February to May 2000) and will not be included in any farm survey.

For the purpose of this assessment it has been assumed that the total number of sheep to be disposed of in the event that BSE was found in sheep, and if the worst case scenario applied, would be the number recorded in the June 2000 farm census. The actual numbers on farm at the present time will have been affected by the FMD cull programme, and the number of lambs will depend on the time of year. With the lack of data on numbers of sheep at different ages, only two groups of sheep have been considered; sheep over 1 year old, combining breeding ewes and others (21,406,000), and lambs less than 1 year old (20,855,000).

2.2 Numbers of Sheep Infected with BSE

It is not known whether or not BSE infectivity is currently present in the UK sheep flock and if it were what the incidence might be. A programme to look for evidence of BSE in sheep diagnosed with scrapie has so far found no cases. However, the experiment is still ongoing, relatively few brains have been tested (about 180) and even these tests are incomplete. This result does not exclude the possibility of a low level of BSE in sheep.

In 'Risk of Exposure to BSE Infectivity in UK Sheep' the assessment was based on four infectivity scenarios, defined in terms of the percentage of scrapie cases that are BSE; Low (0.01%), Medium (0.1%), High (1%) and Maximum (10%). The prevalence of scrapie in the UK breeding flock was assumed to be about 0.1%.

For this study the assessment is based on the premise that BSE is present in the UK flock at the Medium scenario, i.e. 0.1% of scrapie cases are BSE. Thus it is assumed that 0.0001% of the breeding flock are infected with BSE. The prevalence in lambs is assumed to be the same.

This implies about 20 breeding ewes and 20 lambs infected with BSE in the whole UK flock. Results for the other scenarios will be a factor of 10 up or down as appropriate.

2.3 Infectivity of Sheep with BSE

There is little information about the potential infectivity of infected tissues in a sheep with BSE. In order to make some assessment it is necessary to draw parallels with both scrapie and BSE in cattle. Two main assumptions will be made:

1. The infectivity of CNS tissue in a sheep with BSE as an oral dose to humans will be assumed to be the same as the infectivity of the CNS tissue of a cow with BSE.
2. The relative infectivities of different tissues in a sheep with BSE will be similar to those for scrapie as reported by Hadlow (1982) and presented in the SEAC (1994) report.

The infectivity of the BSE agent has been considered in detail by the Scientific Steering Committee (SSC) of the European Commission and their assessment presented in their opinion adopted at their meeting on the 13-14 April 2000 “Oral Exposure of Humans to the BSE Agent: Infective Dose and Species Barrier”. This opinion is used as the basis for this risk assessment.

The infectivity (i.e. the potential to cause infection) of tissue from an animal with BSE is expressed in terms of its Infectious Dose 50 (ID_{50}) value. This is the dose (i.e. the quantity which each person would need to consume) to cause infection of 50% of the exposed population. This term acknowledges that some people may become infected from much smaller doses, while others may be uninfected after consuming much larger doses.

2.3.1 Infectivity of CNS Tissue in Cattle with BSE

Infectious Dose

The SSC concluded that the various approaches to assessing the infectivity from a clinically infected brain yielded a range of values from 10^1 to 10^3 cattle oral ID_{50}/g. They noted that the higher value may represent a worst case scenario if the oral route is more efficient than data suggests and a particularly high titre of infected brain is sampled. They conclude that such a high dose cannot be ruled out. The lower value is based in part on the results of the attack rate experiment carried out by the UK MAFF. It is noted that this experiment is incomplete and that it is not possible to obtain a final value for the infectious dose. The SSC gives some weight to the calculations of Diringer (1999) using the results of published and peer reviewed experiments. This results in an estimated infectious dose of 50 cattle oral ID_{50}/g.

From this data it is proposed to adopt a distribution of values ranging from 10 to 10^3 cattle oral ID_{50}/g with a best estimate value of 50 cattle oral ID_{50}/g.

Species barrier

The infectivity of BSE for humans is believed to be lower than in cattle due to the species barrier. The species barrier in this context is defined as the factor by which the effective infectivity in one species is reduced when given to a second species. Thus, if the cattle–human species barrier was 100, it would mean that 100 times more infective material would be required to infect a man than a bovine.

In their opinion, the SSC concluded that the size of the species barrier between BSE in ruminants and BSE in humans (vCJD) is not known. They considered that a worst case scenario considering no (=1) species barrier should be included, although available evidence indicates that values greater than one are likely to be more realistic. They recommended that, until more scientific data are available, for risk assessments of human exposure to potentially BSE infected products, a species barrier of about 1 should be considered as a worst case scenario and that the range from 10^4 to 10^1 be considered. This supports the assumptions made by DNV in previous risk assessments in which the species barrier was represented as a distribution using values of 10, 100, 1000 and 10,000 with equal probabilities, and a 1% probability of it being 1 (DNV, 1997 a & b). It is proposed to use the same distribution in this assessment.

Assumed Infectivity of BSE Infectivity in Sheep

The infectivity density of CNS tissue from an infected bovine to humans is obtained from the product of the infectious dose for cattle and the cattle human species barrier. Combining the distributions given above in a probabilistic assessment, results in an estimate of the median value of the infectivity density for humans of 0.25 human oral ID_{50} per gram, with a 95 percentile range of 0.002 to 50. This is assumed to apply to the CNS tissue of a sheep with clinical BSE. Relative infectivities of other tissues are based on the work of Hadlow and summarised in Table 2.1. The infectivity of each tissue to humans is then obtained from the calculated value of the infectivity for CNS tissue multiplied by the relative infectivity for the relevant tissue category.

Table 2.1: Relative Infectivity of different tissues for BSE Infectivity in Sheep

Tissue	Titre Mouse i/c	Relative Infectivity
Category I Brain Spinal Cord	5.5.	1
Category II Lymph nodes Spleen Tonsil	4.5	0.1
Category III Stomach Liver Thymus	2	3.2×10^{-4}
Category IV Heart Kidney	1	3.2×10^{-5}

Development of infectivity with age

In ‘Risk of Exposure to BSE Infectivity in UK Sheep’ the development of infectivity with age was modelled for four age classes. For this assessment only two age groups are considered; 1) lambs less than 1 year old, and 2) sheep older than 1 year. Sheep > 1 year with BSE infectivity will be assumed to have the same level of infectivity as at the end of the incubation period, i.e., a clinical case. For lambs, the infectivity in an infected lamb is assumed to be that for the 6 months to 1 year age group from DNV 2001 b, and the factors applied to each tissue are given in Table 2.2. Both these assumptions will tend to overestimate the infectivity.

2.3.2 Total Infectivity in an infected animal

The infectivity in each tissue is then estimated from the typical weight in a carcase, the infectivity per gram of CNS tissue (section 2.3.1 above), the relative infectivity for that tissue (Table 2.1), and for lambs the age factor. These are all summarised in Table 2.2. The total infectivity in an animal for disposal is taken to be the sum of the infectivities for the selected tissues.

Table 2.2: Total Infectivity in an Infected Animal

Infectivity in CNS Tissue (as for cattle)				
Infectious dose for cattle	50	Cattle oral ID50/g		Range: 10 - 1000
Cattle human species barrier	1 (1%), 10, 100, 1000, 10000			
Infectivity to humans	Median =	0.25	Human oral ID50/g	
	95 % range	0.002 - 50		

Infectivity in one infected animal						
	Tissue	Relative Infectivity	Weight kg	Age factor for lambs	Total Infectivity median value Lambs	Total Infectivity median value Sheep
Category 1						
	Brain	1	0.10	0.001	0.03	25
	Spinal Cord	1	0.04	0.001	0.01	10
Category 2						
	Lymph node:	0.1	0.04	0.1	0.10	1
	Spleen	0.1	0.10	0.1	0.25	3
	Tonsil	0.1	0.01	0.1	0.03	0
	Intestine	0.1	1.20	0.5	15.00	30
Category 3						
	Stomach	3.0E-04	1.00	0.1	0.01	0
	Liver	3.0E-04	0.61	0.1	0.00	0
	Thymus	3.0E-04	0.30	0.1	0.00	0
Category 4						
	Heart	3.0E-05	0.20	0.1	0.00	0
	Kidney	3.0E-05	0.10	0.1	0.00	0
Total	(Human oral ID50 units per infected animal)				15	69

3. RISK ASSESSMENT

3.1 Approach

Earlier this year DNV carried out a study for MAFF on the risks of exposure to the BSE agent from the disposal of cattle due to the foot and mouth epidemic (DNV, 2001 a). That study covered disposal both by open air burning and burial. The issues affecting exposure to BSE infectivity from disposal of sheep in the event of BSE being found in the UK flock are the same, and the same approach has been adopted in this assessment. That study was based on an earlier DNV study; 'Overview of Risks from BSE via Environmental Pathways" (DNV, 1997). All assumptions beyond input data used in this study are as per the previous studies and are described in detail in those reports.

The approach involves the building of an event tree that shows the pathways by which people could be exposed to any infectivity present in the animals being buried or burned. The branches of the event tree can then be quantified and the overall risk of exposure estimated. Where possible the main input parameters for the tree and the branch probabilities have been represented as ranges of values or distributions rather than single values and the tree quantified using a probabilistic risk assessment tool.

3.2 Event Tree for Disposal of Sheep by Open Air Burning

An event tree showing the pathways by which people could be exposed to any infectivity present in the animals being burned is shown in Figure 3.1. There are four main routes by which people could be exposed:

- Direct inhalation of smoke particles.
- Consumption of unprocessed crops
- Consumption of water supply from ground water
- Consumption of water supply from surface water

3.2.1 Source Term

The total infectivity entering the disposal process is obtained by combining the total number of animals for disposal, the assumed prevalence of BSE in the sheep, and the estimated infectivity per infected animal. The value shown on the event tree in figure 3.1 is the median value for sheep over 1 year old assuming that the entire breeding flock is destroyed.

3.2.2 Infectivity Destroyed in Fire

The main cause of infectivity remaining in the products of combustion will be incomplete combustion. This is a particular danger when a complete carcase is burned, since the infected material may be protected to some extent inside the skull. Incomplete combustion has been found to be a problem in small SRM incinerators.

It is expected that the effect of open air burning on infectivity would be much less than that estimated for incineration (estimated to be a million fold reduction). If conducted carefully, the effect would probably be similar to that of rendering, i.e. a 50-fold reduction. However, since there is a possibility of incomplete combustion, a cautious assumption would be a 10-

fold reduction. (DNV, 1997 b). This value was discussed at the SEAC meeting on the 30th March, and it was agreed that it represented a cautious estimate.

Since the "Assessment of risk due to BSE infectivity from disposal of cattle due to FMD" was carried out, the Environment Agency have analysed ash samples from different types of open air pyres to determine the degree of destruction of protein. This has shown that in most cases the destruction was greater than the 90% assumed, and in several cases up to 2 orders of magnitude greater. In the light of this the 90% reduction in infectivity will be kept as a base case, but the effect of 99% reduction in infectivity will also be considered.

3.2.3 Burial of Ash

The ash remaining following completion of a burn would normally be buried on site in pits, located with advice from the Environment Agency so as not to directly affect water resources. A small proportion of the ash (assumed to be 1%) may be spilled in the process of burial and infiltrate directly into the ground water. The bulk of the ash will remain in the pit, but rainwater falling on the site will flow through the soil cover and could pick up some infectivity. An important attribute of the prion agent is that it is hydrophobic, and will tend to be attached to solids (Gale, 1998). Thus any infectivity remaining in the ash is unlikely to be dissolved in water or transported away from the ash pit. Any infectivity that does get carried from the ash pit is likely to be filtered out or adsorbed by the ground.

As for the FMD study the proportion of infectivity in leachate is assumed to be 5% based on advice from the Environment Agency. This is significantly greater than the estimate used in the Overview Study (0.07%) and is likely to be an overestimate of the infectivity in the leachate.

3.2.4 Distribution of Infectivity in the Smoke

With an open fire, it is likely that a significant proportion of the ash produced will be drawn up into the plume of combustion products and dispersed over the surrounding area. Pyres would be designed to burn at a significant temperature to destroy the infectivity and to reduce the material to ash. The hot gases will rise in the atmosphere and draw in air at the base of the fire. This action can tend to entrain light ash particles. There is however no data available on the proportion of ash expected to be entrained in the plume rather than remaining on the ground. As for the FMD study, it has been assumed that 10% of the infectivity produced would be entrained as particles in the smoke plume from the fire. For the probabilistic assessment, this was assumed to have a normal distribution with a mean value of 10%, a 95 percentile of 20% and a minimum value of 1%.

3.2.5 Infiltration into Ground water

Infectivity flowing into ground water would be reduced firstly by filtration and adsorption in the soil, and secondly by the proportion of groundwater abstracted and then the proportion of abstracted water consumed by people. The reduction due to soil will depend on whether the infectivity passes through the soil layer, and on the local geology. Material buried in pits (whether ash or carcases) would be below the soil, and so would not have the benefit of passing through an organic layer which would be likely to retain any prion protein present.

The values in Table 3.1 were proposed by the Environment Agency for the FMD study to represent a range of different geological formations and are used again here.

Table 3.1: Infectivity Transmitted to Ground Water

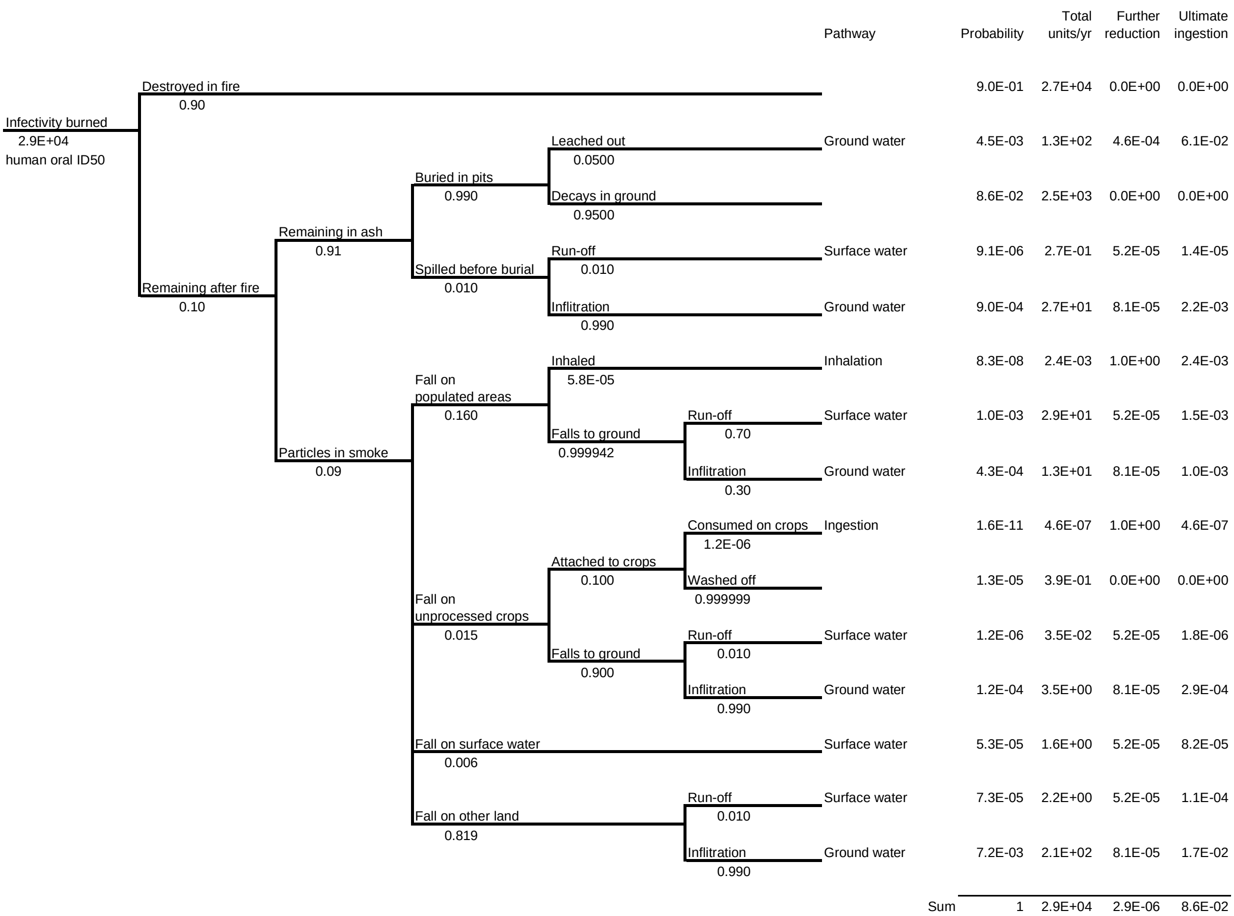
	Minimum	Maximum
Infectivity deposited below soil	0.0225	1
Infectivity deposited above soil	0.00225	0.25

These were modelled as normal distributions, taking the minimum and maximum values as the 5 percentile and 95 percentile values respectively.

3.3 Event Tree for Disposal of Sheep by Burial

The event tree for disposal by burial is a subset of the tree for burning. The same event tree has been used, with 100% of the infectivity in the animals slaughtered buried. The same fraction of infectivity transmitted to ground water from the burial pit has been used as that for ash given in Section 3.2.3 (0.05), and the same values for infiltration into the ground water.

Figure 3.1: Event Tree for Burning Sheep in the Event of BSE



4. RESULTS

The Event Tree model has been evaluated using a probabilistic risk assessment approach. To do this a range and distribution is defined for each of the input factors, and a Monte Carlo simulation tool is used to predict the range of possible values for the result. A software tool called ‘Crystal Ball’, which works with Excel spreadsheets has been used to carry out the simulation. The detailed assumptions used for the simulation are summarised in Appendix I.

Monte Carlo simulation is a well-established technique that enables the modeller to take account of the chance variation that is inherent in most real life situations. The simulation is based on the use of random number generators to select a value from each of the input parameters for which a distribution has been defined. Over a number of iterations the simulation enables the full range of possible values for each variable to be tested, but weights each scenario by its probability of occurrence. In each iteration a new value is selected for each variable and an output value (or values) calculated. This is repeated a large number of times so that a distribution of the output value is built up.

4.1 Summary Results for Sheep and Lamb

The simulation for the Event Tree model has been carried out for three cases; the burning of carcasses assuming 90 and 99% inactivation rates, and for burial of carcasses. The model has been run using input data for sheep and lambs separately. The Medium scenario for prevalence of BSE in sheep has been used (0.1 % of scrapie cases are BSE). Median values of the total infectivity potentially ingested, together with the 2.5 and 97.5 percentile ranges are shown in Tables 4.1 and 4.2 respectively.

Table 4.1: Summary of Results for Sheep (> 1 year old)

Case	**Total Human Oral ID_{50} units ingested from disposal of sheep > 1 year old**		
	Median Value	**95 percentile Range**	
		2.5 percentile	97.5 percentile
Burning – 90% inactivation	6.8×10^{-3}	3.9×10^{-5}	1.4
Burning – 99% inactivation	7.1×10^{-4}	4.0×10^{-6}	1.3×10^{-1}
Burial	4.6×10^{-2}	2.4×10^{-4}	10.0

Using the model, it has been estimated that the median value of the total infective units potentially ingested by those exposed from burning sheep over 1 year would be 6.8×10^{-3} human oral ID_{50} units assuming 90% inactivation. If the efficiency of burning is increased to 99% the amount of infectivity is reduced to 7.1×10^{-4} human oral ID_{50} units. In the scenario where the animals are buried, the estimated infectivity consumed is 4.6×10^{-2} human oral ID_{50} units. These values represent the total infectivity ingested by all people exposed from the disposal of all sheep greater than 1 year old in the UK. The range of uncertainty associated with this estimate is high, with the 95 percentile range estimated to be 5 log orders. This wide range is primarily due to the uncertainty in the value for the cattle human species barrier.

The risk of exposure associated with disposal of lamb are shown in Table 4.2. The estimated infectivity consumed from disposal of lamb under the three scenarios are lower than for older sheep by a factor of approximately four. This reflects the lower infectivity values associated with the younger animals.

Table 4.2: Summary of Results for Lamb (< 1 year old)

Case	**Total Human Oral ID_{50} units ingested from disposal of lamb < 1 year old**		
	Median Value	**95 percentile Range**	
		2.5 percentile	97.5 percentile
Burning – 90% inactivation	1.6×10^{-3}	8.5×10^{-6}	3.2×10^{-1}
Burning – 99% inactivation	1.5×10^{-4}	8.1×10^{-7}	3.2×10^{-2}
Burial	1.1×10^{-2}	4.7×10^{-5}	2.5

If the entire UK flock (all sheep and lambs) were subject to disposal the estimated total infectivity ingested based upon the median values for burning at 90% and 99% efficiency would be 8.4×10^{-3} and 8.6×10^{-4} human oral ID_{50} units respectively. In case of burial, the combined median figure for sheep and lambs would be 5.7×10^{-2} human oral ID_{50} units.

As already noted, these values represent the total infectivity ingested by all people exposed. In the event of such a large disposal programme the disposal would be spread over many sites. For each site the resulting infectivity would be spread over a wide area and a wide population, so the dose received by any one person would be extremely small.

The exposure from burial alone is clearly greater than for open air burning. If the burial were to take place in properly designed lined landfill sites with leachate management and treatment facilities, much less infectivity would be released into the groundwater. This would be expected to reduce the exposure by at least 1 and probably 2 orders of magnitude. Thus burial in landfill sites would result in a similar risk of exposure as open air burning.

4.2 Infectivity Associated with Disposal of Animals with Foot and Mouth

Precise figures for animals disposed of under foot and mouth regulations are not yet available, however estimates of the likely numbers and age distributions have been provided by DEFRA (Mike Tas, personal communication). The total number of sheep killed under FMD controls and the Livestock Welfare Disposal Scheme was approximately 4.5 million, but there is some uncertainty associated with both the ages of these animals and their means of disposal.

It has been estimated that between 60 and 75% of the animals killed were sheep > 1 year old and the remainder lambs (i.e. < 1year). It has also been estimated that approximately 3.5 million of the sheep were disposed of either by landfill, in mass burial sites or on farms. In order to present a worst case scenario, the assessment will assume that of the 4.5 million animals killed 75% were ewes. A range of three scenarios will be presented relating to disposal of 2.5, 3.0 and 3.5 million animals being buried with the remainder burned. It will also be assumed that the level of inactivation by burning is 90%, even though there are indications that the level of inactivation may be closer to 99%.

Table 4.3 shows the median values for infectivity ingested per 1000 animals for each of the disposal scenarios, derived from total infectivity values for sheep and lambs presented in tables 4.1 and 4.2 respectively.

Table 4.3: Total Human Oral ID_{50} Units Ingested per 1,000 Animals

Case	Total Human Oral ID_{50} units ingested per 1,000 animals	
	Sheep	Lamb
Burning – 90% inactivation	3.2×10^{-7}	7.7×10^{-8}
Burning – 99% inactivation	3.3×10^{-8}	7.2×10^{-9}
Burial	2.2×10^{-6}	5.3×10^{-7}

The potential exposure to infectivity if BSE had been present in the sheep disposed of (assuming the medium scenario for prevalence of BSE in sheep) can now be estimated by combining these values with the numbers on sheep buried or burnt. The results of these analyses are shown below (Table 4.4). This assumes that all animals buried were in unlined pits and not landfill sites.

Table 4.4: Estimated Levels of Infectivity Associated with The Burial and Burning of 4.5 Million Sheep (75%) and Lambs (25%) Associated with the Foot and Mouth Outbreak

Scenario	Number of Animals (M)		Infectivity Ingested*		Total Infectivity*
	Burial	Burning	Burial	Burning	
Scenario 1	2.5	2.0	4.4×10^{-3}	5.2×10^{-4}	4.9×10^{-3}
Scenario 2	3.0	1.5	5.2×10^{-3}	3.9×10^{-4}	5.6×10^{-3}
Scenario 3	3.5	1.0	6.1×10^{-3}	2.6×10^{-4}	6.4×10^{-3}

*Human oral ID_{50} units

Based upon the available information relating to potential infectivity, together with numbers and age distribution of animals culled during the foot and mouth outbreak, the total infectivity ingested would range from approximately 5×10^{-3} to 6×10^{-3} human oral ID_{50}

units. Again this infectivity would be spread over a large number of people and the maximum exposure to any one person is likely to be very small.

The potential risks of exposure to BSE infectivity from sheep disposed of during the foot and mouth outbreak are therefore likely to be small. Most of the tissues that may contain infectivity would have decomposed and liquefied significantly so that any attempt to exhume the carcases to recover infected material would be very difficult. Any such operation would also require a substantial number of contractors operating heavy machinery and working over an extended period. The risks of industrial accidents from such an operation are likely to be far greater than the hypothetical risk of exposure to BSE infectivity.

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APPENDIX I

MODEL INPUT DATA

RISKS FROM BSE INFECTIVITY IN DISPOSAL OF ANIMAL CARCASES

a) Input Data for Probabilistic Variables

The variables shown below have been assigned distributions as input to the Monte Carlo simulation for the 90% burning scenario. Other variables have fixed values and are given in Section b) below.

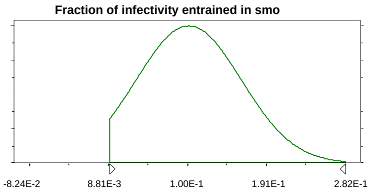
Assumptions

Assumption: Fraction of infectivity entrained in smo

Normal distribution with parameters:

Mean	1.00E-01
95% -tile	2.00E-01

Selected range is from 1.00E-2 to +Infinity

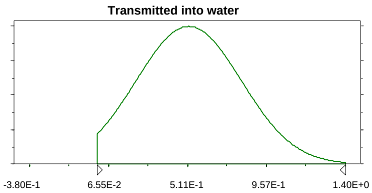


Assumption: Transmitted into water

Normal distribution with parameters:

5% -tile	2.25E-02
95% -tile	1.00E+00

Selected range is from 0.00E+0 to +Infinity

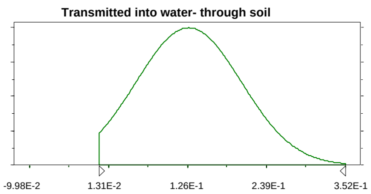


Assumption: Transmitted into water- through soil

Normal distribution with parameters:

5% -tile	2.25E-03
95% -tile	2.50E-01

Selected range is from 0.00E+0 to +Infinity

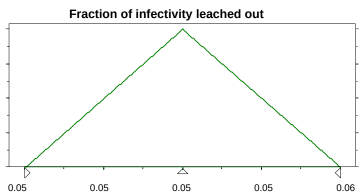


Assumption: Fraction of infectivity leached out

Triangular distribution with parameters:

Minimum	0.05
Likeliest	0.05
Maximum	0.06

Selected range is from 0.05 to 0.06



B) DATA INPUT

Fraction of infectivity not destroyed in fire	0.1	Overview App III.8.3
Fraction of infectivity entrained in smoke	8.90E-02	Guess
Fraction of ash spilled before burial	0.01	Guess
Fraction of infectivity leached out	0.05	Environment Agency
Fraction of particulates falling on populated area	0.16	Incinerator 5.2.1
Fraction of particulates falling on unprocessed crops	0.015	Incinerator 5.2.1
Fraction of particulates falling on inland water	0.006	Incinerator 5.2.1
Fraction of particulates inhaled in populated area	5.80E-05	Incinerator 5.2.2
Fraction of particulates attaching to crops	0.1	Incinerator 5.2.3
Fraction of particulates not washed off crops	1.18E-06	Incinerator Table 6.1
Fraction of particulates running off in populated areas	0.7	Incinerator 5.2.5
Fraction of particulates running off unpopulated land	0.01	Incinerator 5.2.5
Fraction of surface water ingested	5.20E-05	Overview Fig IV.19
Fraction of ground water ingested-burial	4.60E-04	
Fraction of ground water ingested-through soil	8.12E-05	
Transmitted into water- Burial	3.76E-01	
Transmitted into water- through soil	6.65E-02	
Abstracted	0.26	
Ingested	0.0047	