Department of Health

A Rapid Qualitative Assessment of possible risks to Public Health from current Foot & Mouth Disposal Options

Main Report

June 2001

SUMMARY

The study

At the beginning of April, the Chief Medical Officer called for a qualitative risk assessment to examine the current methods of disposing of animals slaughtered in response to the foot and mouth outbreak from a public health perspective. The findings of the risk assessment have been used to determine policy on disposal of slaughtered animals. The purpose of this report is to bring together and document the risk assessment information for reference. It should also act as a useful starting point for assessing the public health implications of any future outbreak of farm animal disease requiring large-scale slaughter and disposal. The report pulls together a wide range of contributions concerning possible biological and chemical hazards. Starting with a selected list of approximately 100 hazards potentially arising from carcass disposal, options have been primarily assessed with regard to risks from the following chemical and biological sources:

- Combustion gases (most importantly, SO_2)
- Air-borne particulates (PM_{10})
- Bacteria (such as Verotoxin-producing E. coli (VTEC), *Campylobacter, Salmonella* and *Leptospira*) potentially spread by water
- Water-borne protozoa (including *Cryptosporidium* and *Giardia*)
- BSE from cattle (specifically, older cattle).

In the time available, other novel methods of disposal were not considered nor, given the scientific uncertainties, was a full quantitative analysis of all potential hazards undertaken. Instead, a framework was developed for identifying the key hazards and assessing how effective the different disposal methods are in minimising them. Within this framework, we have made use of results of quantitative modelling where available, but it should be stressed that the more easily-quantifiable risks are not necessarily the most important ones.

Findings

While the risk of humans acquiring FMD itself is extremely small, disposal of carcasses on the scale now being undertaken cannot be carried out without some risks to human health. Prior to this analysis, the preferred options at a national level for dealing with animal carcasses were, in descending order:

- rendering
- incineration
- landfill, using a licensed site (excluding older cattle)

- pyre burning
- on-farm burial (excluding older cattle).

Although there are many uncertainties, this analysis shows that this ranking is consistent with minimising the overall risks to public health. In the main, this reflects the point that while the overall impact of burning carcasses (if properly controlled) should add relatively little to other sources of air-borne pollution, it is more difficult to rule out potential risks from pathogens carried by groundwater, especially to users of private water supplies.

In practice, both air and waterborne risks will have been mitigated by the Environment Agency's further, site-specific risk assessment and risk management processes. The importance of carrying out disposal according to specified guidelines is also stressed here. In particular, where pyre burning has taken place and a risk assessment indicates that in-situ burial of ash is not an acceptable option, it should be recovered for high temperature incineration.

The report also stresses the potential risks to human health of delays in disposing of slaughtered animals. It is suggested that on a per-carcass basis the risks of prolonged delay might exceed the risks of any disposal method.

The focus of this study has been on public rather than occupational health risks. However those conducting the disposal are inevitably subject to some exposure to occupational hazards. These can be reduced, but not entirely eliminated, by proper use of protective measures, though these have to be tempered by considerations of practicality. The potential risks of front-line workers passing on infection must also be borne in mind.

As the analysis has progressed, provisional findings have been used to aid policy formulation. Examples include preparation of further guidance from the Department on minimising risks to public health from slaughter and disposal used in draft form from 13th April onward and published on 24th April (available at www.doh.gsi.gov.uk/fmdguidance), and ongoing development of immediate and longer term environmental and public health surveillance.

Related Documents

This report forms part of a stream of documents related to Foot and Mouth Disease. Other Department of Health reports can be found in pdf format on the Department's web site and include the following documents:

- Foot and Mouth Disease – disposal of carcasses. Program of monitoring for the protection of public health.
  http://www.doh.gov.uk/fmdguidance/
- Measures to Reduce Risk to Public Health From Slaughter and Disposal of Animals – Further Guidance.
  http://www.doh.gov.uk/fmdguidance/
- Foot and Mouth – Effects on Health of Emissions from Pyres Used for Disposal of Animals.
  http:///www/doh.gov.uk/fmguidance/
- Public health guidance (in English and Welsh)
  http://www/doh.gov.uk/fmguidance/

Other Department and Agency web sites that also contain useful foot and mouth information include:

- SEAC (Spongiform Encephalopathy Advisory Committee)
  http://www.maff.gov.uk/animalh/bse/bse-science/level-4-seac.html

- MAFF (Disease surveillance and control web page including information on Zoonoses)
  http://www.maff.gov.uk/animalh/diseases/default.htm

- MAFF (Foot and Mouth Disease web page)
  http://www.maff.gov.uk/animalh/diseases/fmd/default.htm

- PHLS (Public Health Laboratory, advice web page)
  http://www.phls.co.uk/advice/index.htm

- The Environment Agency (for example information on care with disinfectants)
  http://www.environment-agency.gov.uk/

- The Food Standards Agency (information on dioxins)
  http://www.foodstandards.gov.uk/

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1. Introduction

Origins of this study

1.1 At the time of writing, the current outbreak of Foot and Mouth Disease (FMD) has yet to run its course. However it is clear that an unprecedented number of animals – over 4 million, including associated Animal Welfare culls – will need to be disposed of. This report considers the potential risks to public health that might arise from disposal on this large scale.

1.2 The work reported here had its origins in a special meeting on the outbreak on 1st April, at which the Chief Medical Officer committed the Economics and Operational Research (EOR) Division of the Department of Health to providing a fast public health risk assessment. Specifically, it was agreed that:

"The Department of Health, working with other government departments and relevant agencies will carry out a rapid, comprehensive, qualitative assessment of the potential risks to public health of the disposal policy to help inform decisions as the numbers of animals to be disposed of increases."

As the work progressed, its findings fed into policy formulation, including guidance issued by DH and others.

1.3 The approach adopted is outlined below. A key role for EOR has been to collate, summarise and use more detailed investigations carried out by others, notably:

- modelling of air-borne pollutants carried out in parallel with this study by the Public Health Division (PH5) of the Department of Health (DH), the Department of the Environment Transport and the Regions (DETR), the Food Standards Agency (FSA), the Environment Agency (EA) and AEA Technology, and available on the DH website.

- detailed identification of potential hazard pathways from carcass disposal to humans carried out by the Environment Agency (EA), and generic analysis provided by DNV Ltd.

- existing analysis of potential Bovine Spongiform Encephalopathy (BSE) / variant Creutzfeldt-Jakob Disease (vCJD) risks already endorsed by the Spongiform Encephalopathy Advisory Committee (SEAC)

- commentary on potential radiological risks provided by the National Radiological Protection Board (NRPB), and

- information on water-borne pathogens from the Public Health Laboratory Service (PHLS)

- input on potential food-borne risks from the Food Standards Agency, and

- information from the Institute for Animal Health, Compton (IAH – Compton) on potential human health hazards present in farm animals.

A list of specific contacts is provided at Annex A.

Scope of Study: questions addressed

1.4 To investigate the current preference ranking of disposal methods from a Public Health point of view, a key initial task was to clarify the potential risks associated with each one if carried out as specified. So as to keep a broad view of the issues, this was not taken to be the sole task: the study also considered:

- potential risks associated with the processes leading up to disposal, in particular those arising from large piles of carcasses left on open sites awaiting transport
- the extent to which risks from each disposal method could be increased by imperfect implementation (e.g. incomplete compliance with guidelines or intended specifications), bearing in mind the extreme pressures of time and numbers early in the outbreak
- other factors that might compromise the safety of each method. Examples included vulnerabilities in the normal systems protecting public health – e.g. treatment of public water supplies, and adverse weather – e.g. the flooding and wet conditions hampering disposal in some areas
- the implications of any residual / contingent risks to public health, whether in terms of additional precautionary measures, monitoring and support, or contingency planning.

1.5 The study concentrated on potential risks to public health, whether of populations living nearby or more generally. The present report does not systematically consider specific risks to those involved in handling and disposal of carcasses. However some points on occupational exposures are noted, and the study served to emphasise the importance of adequate protection.

1.6 Given the tight timescale involved, much of the work was necessarily desk-based. Nevertheless this was supplemented by first-hand observation and reportage of the situation on the ground in one part of the country (the South-West). While observations must to some extent reflect local conditions that may differ elsewhere, they allowed us to gain more information about how disposal – especially by pyre burning – was being carried out, and about the processes leading up to disposal. As well as direct observation, the site visits (reported in Annex B) drew on information provided in local interviews with staff of the Environment Agency, MAFF and disposal contractors, and members of the armed forces and Police Force. Cooperation was provided generously under difficult conditions and is gratefully acknowledged.

1.7 Although this study is confined to potential impacts on human health, other risks also warrant consideration. The EA's ongoing study also encompasses potential environmental risks – e.g. pollution of groundwater and rivers. A separate study being carried out by MAFF is considering the potential feedback of disease into animal populations. Any implications for public health from either study will need to be kept under review.

Numbers of animals involved

1.8 As a working assumption, analysis was based on an initial MAFF estimate of the numbers of animals that might have to be slaughtered, i.e. approximately

- 2.6m sheep
- 0.2m cattle born before 1st August 1996

- 0.6m cattle born on or after 1st August 1996
- 0.6m pigs.

This gives a total of about 4m animals: other animals such as goats have also been involved, though in much smaller numbers.

1.9 As of Monday 28th May, the MAFF website reported that approximately 3.2m animals in total had been identified for slaughter in the FMD cull. About 3.13m of these had actually been slaughtered, of which about 26,000 (down from a recorded earlier peak of over 400,000) were awaiting disposal. In addition, over 1m animals had been slaughtered under the Livestock Welfare (Disposal) Scheme introduced to cope with restrictions on animal movements.

Disposal options

1.10 The principal disposal methods prior to the FMD outbreak and the use of mass burial were:

- **Rendering**
- **Incineration**, i.e. "industrial", high-temperature burning, at a permanent site or using mobile equipment
- **Landfill**, i.e. disposal in a lined pit within a licensed engineered landfill site
- **Pyre burning**, i.e. burning on an open site, either at or away from the site of slaughter
- **Burial** in unlined pits, either on farms or at other small-scale sites.

1.11 The risk assessment concentrated on the potential hazards associated with each of these options – especially those toward the bottom of the list – rather than explicitly considering alternative or novel methods. Though constraints on capacity mean that all have been used, the options are listed in their order of preference as at the start of the outbreak for animals *other than* older cattle.

1.12 For disposal of cattle born before August 1996 or over 30 months of age, specific restrictions have applied. Where possible, carcasses have been rendered and the products then incinerated. Most importantly, burial of older cattle in any site (including landfill) has been prohibited in order to minimise any potential risk from BSE.

1.13 For "on-farm" burial, the *Code of Good Agricultural Practice* and *the Animal By-Products Guidance* that supports the Environment Agency Groundwater Regulations normally limit burial to 8 tons (roughly 100 sheep, 40 pigs or 16 adult cattle), though in present circumstances larger quantities may be buried and sites are considered on a case-by-case basis. Small-scale burial of farm animals was already commonplace prior to the FMD outbreak, as farmers must otherwise pay for removal of carcasses. However the large number of animals requiring disposal in some areas created a novel situation in terms of the scale of burial.

1.14 A further option considered was that of **mass burial**, potentially involving tens of thousands of animals at a single site. As compared with on-farm burial, this concentrates the location of hazards, and therefore requires more stringent site selection, monitoring and aftercare. All such sites have been subject to approval by the Environment Agency and require authorisation under the Groundwater Regulations 1998. To provide significant overall risk reductions over 'on farm' burial, mass burial sites need to make use of particularly favourable natural features (e.g. of geology) and be designed, engineered and constructed to high quality standards. Even in engineered sites, however, the amount of leachate produced by decomposing carcasses will be higher than for household waste and, in general, there will be less absorptive capacity available for leachate within the site.

International Examples of Carcass Disposal

1.15 A brief international literature review was undertaken of FMD outbreaks between 1999 and 2001 (see Annex K). In all there were 14,898 cases of FMD in 16 countries: 41,989 animals were culled and disposed of. Eight countries used vaccination to control the disease (154,750 animal being vaccinated) with quarantine and branding of vaccinated animals also used as control measures. Disposal of animals culled was mainly by rendering and/or burial, with burning seldom the preferred option. There was no evidence of disposal having had any effects on human health. As can be seen though, the numbers of animals culled were much lower than in the current UK outbreak.

1.16 The scale of the FMD cull in the UK arguably gives it more similarities to animal disposal after a major natural disaster such as a flood or drought than to FMD outbreaks controlled predominantly by vaccination. A brief literature review was undertaken, involving about 50 articles, many relating to the disposal of large quantities of animal material. Examples include events in North Carolina in 1999 after Hurricane Floyd, the disposal of drought-affected sheep in Victoria, Australia in 1982, trials of composting sheep carcasses in Canada, and the disposal of beached Sperm Whales in the Netherlands.

1.17 Hurricane Floyd put much of North Carolina under water, leading to pig waste lagoons bursting their banks and large numbers of animals drowning (including 2,860,827 poultry and 28,000 swine, though only 619 cattle). Proper burial and disposal was seen as crucial to prevent public health problems resulting from decaying animals, including the spread of harmful pathogens, ground and surface water contamination, and pests. Though dilution of hazards in the floodwaters lessened the potential health impacts, wells were contaminated e.g. with animal wastes. Such waste products can cause nitrate solution within drinking water and has been linked to harmful effects in humans and particularly newly born babies. It is therefore important to test domestic wells for raised levels of nitrates. North Carolina has drawn together the main lessons learnt. These focus on the fast disposal of carcasses and burial, where necessary, at sites posing no risk to groundwater. In addition, health advice was issued to local residents asking them to boil and treat their water, and groundwater wells were tested after the waters subsided. Potential risks to public health were thus mitigated by the initial dilution of contamination, fast disposal of carcasses, clear health advice to residents and effective monitoring (Personal correspondence, S. Cline, North Carolina State Department; Stringham and Watson, 1999; Carver and Morrow,1999).

1.18 In the 1982 drought in Victoria, 250,000 sheep were culled. Due to shortages of solid fuel for burning, animals were disposed of at mass burial sites, in clay soil where possible. Health risks were minimized by the animals being slaughtered beside the pits and buried immediately. Although the abdomen of sheep did rupture and viscera and body fluids contaminated excavation equipment, the risk of pits being blown open by putrefying carcasses was avoided. It has been suggested that such a disposal method could be used to good effect elsewhere (Atkins and Brightling, 1985). As an alternative to burial, trials of composting sheep carcasses have been conducted in Canada (Stanford *et al*, 2000)

1.19 In the Netherlands in 1994, beaching of sperm whales on the Flemish coast posed a serious disposal problem (Tassyns, 1997). Being classified as hazardous, the material could not be rendered: large scale incineration was not possible locally. Burial in a Grade 2 landfill was seen as posing the least risk to human and animal health, as the site could be monitored and containment was already effective for domestic waste. Nevertheless difficulties arose, as these sites were not licensed for such disposals.

1.20 As these examples illustrate, general experience is that carcasses should be disposed of promptly to mitigate human health risks. The case of North Carolina in particular also highlights the need for timely health guidance, monitoring and coordination. Containment is never perfect: even engineered facilities with double and triple liners leak. The difference is in the extent of leakage and the attenuation of pollutants within and outwith the site. Even the best containment engineering does not remove the need for vigilant monitoring.

Carcass removal and transport

1.21 As noted, the study aimed to take account of potential risks arising prior to actual disposal of carcasses. It is therefore worth noting some key points about the pre-disposal process, as far as we have been able to determine it (see Annex B). In general:

- After confirmation of FMD at a farm, the first priority has been that animals should be slaughtered to prevent the spread of the disease, if possible within 24 hours of initial notification. Animals on other farms classified as "dangerous contacts" and those on contiguous premises have been culled within 48 hours where possible.

- Slaughter has often proceeded before identification of a disposal option. Animals were then removed as soon as possible, but disposal had been taking up to 3 weeks early in the outbreak.

- Animals' coats and fleeces have then been disinfected with 0.2% citric acid or other approved FMD disinfectant. Carcasses have been left as they fell or piled up, some covered with PVC sheeting. Animals clinically affected with FMD have had their heads and feet covered to prevent the spread of disease. Proximity to watercourses or habitation has not been the prime factor at this point, ease of road access and animal welfare being the key considerations.

- It should be noted that sheep start to liquefy more quickly after slaughter and should be moved and disposed of within a few hours of death. In practice however, this has not always been possible. Animals have been known to lie in the fields or close to homes for several days, though this situation has eased as increasing resources have become available for the disposal operation.

- A vermin control agent has attended the sites where possible and laid rat poison, but birds such as carrion crows have typically settled and fed on carcasses not covered with PVC sheeting. If possible, electric fences have been used to exclude foxes.

- Transport from the farm to disposal sites has been in covered vehicles designed to be leakproof. For farms without good road access, alternatives – e.g. trailers – have been needed: these should also have been enclosed.

2. The Risk Assessment

Principles

2.1 Given the urgency of this work, EOR did not, in the main, attempt to build new quantitative models. Rather, we sought to make best use of results from existing models and other ongoing analysis, and to integrate knowledge of various potential hazards. As far as practicable, the approach itself was shared with other Departments and Agencies, at the same time as seeking inputs and information.

2.2 The aim of the study was to provide an overall framework in the form of a (largely) qualitative model which could be used to weigh up the potential risks from different disposal methods, prioritise attention to the most significant, and note how these can be avoided or mitigated.

Overall Approach

2.3 The approach used followed standard Risk Assessment methodologies (see bibliography), with some modifications to take account of timescales etc. The five main elements were as follows:

Identification of Potential Hazards

The study began with a basic listing of potential hazards, roughly categorised by type. The intention at this stage was to be as wide-ranging as possible. While as yet going into little detail, information was gathered on the key characteristics of each hazard.

Identification of Exposure Pathways

The pathways by which hazards from animal disposal could reach humans were categorised. This work adapted existing generic models of environmental pathways – e.g. leaching from burial sites or ash pits, or for wind-borne pollutants being inhaled or entering the food chain – to obtain a picture of those most relevant to each disposal method.

Preliminary shortlisting of hazards

Drawing on the first two stages, a provisional shortlisting of the hazards that warranted further analysis was established. Reasons for *not* including potential hazards in the shortlist were made explicit and have been kept under review.

Further examination of shortlisted hazards

For the shortlisted hazards, a more detailed assessment has been undertaken. While not fully quantitative, this makes use of any quantitative information or estimates available.

Comparison of disposal methods

This analysis sought to establish a simple rank ordering amongst the disposal methods listed, based on their (lack of) contribution to the shortlisted public health risks.

2.4 These steps are discussed in turn in the following five sections (3 – 7), though in practice there has been some iteration between them. Section 8 then offers some brief overall conclusions.

3. Identification of Potential Hazards

Introduction

3.1 To produce a broad characterisation of potential hazards to human health from animal slaughter and disposal, we collated data and judgement from a wide range of sources (listed in Annex A). This was cross-checked with a detailed assessment of pathways produced independently by the Environment Agency (extracts from which are at Annex H). The intention was to be as comprehensive as possible, without pre-judging which hazards might pose the most serious risks.

3.2 As it became available, information was progressively summarised in a format based on the *Qualitative Source-Pathway-Receptor Analysis*. This is a standard method used by the National Centre for Risk Analysis and Options Appraisal based on DETR and Environment Agency guidance, and adapted here to focus on Public Health issues. The result has been assembled within a spreadsheet and the result circulated periodically for comment, so providing a single point of reference.

3.3 Key points addressed include:

- *type of hazard* (e.g. chemical, biological or other) and agent involved
- *potential for release:* i.e. where the agent would come from, the potential mechanism for release (e.g. burning, burial or surface decay) and over what timescale
- *pathways to human exposure:* i.e. the likely location of the hazard and the possible paths to the human population. Also noted were existing preventive measures that should reduce the risk of human exposure, or its extent
- potential *health consequences* of exposure. For example, what population could or would be exposed? What is known about *potential* effects on human health of the agent (e.g. dose-response, symptoms, populations particularly at-risk)? What would be the "leading indicators" (if any) of significant exposure and/or adverse health effects?

Summary of Information

3.4 The current contents of the spreadsheet are displayed in full at Annex C, "Data Grid of Potential Hazards". Each row in the grid characterises a potential hazard, the table being divided into "biological", "chemical" and "other".

Biological hazards

3.5 Most numerous in this list are microbial agents potentially released by burial of carcasses. We have drawn on an extensive listing of bacterial and other pathogens that might appear in private water supplies, provided by PHLS and reproduced at Annex D. Organisms are categorised as follows:

- Zoonoses prevalent in the UK herd, transmissible to humans through drinking water and considered likely to represent a risk to human health if they gain entry to private water supplies;
- Zoonoses or environmental organisms assessed for the nature of any risk but considered unlikely to cause human infection if they gain entry to private water supplies;
- Other organisms that have the potential to cause waterborne disease but are considered highly unlikely to present a risk to private water supplies as a result of animal burials. This may be because they are not zoonoses transmitted through consumption of contaminated water (and/or are not found in cattle, sheep or pigs), and/or because they are not indigenous infections.

All organisms in the first two categories were considered as potential hazards: Annex D provides alphabetical listings and a brief description of each. Further information was provided by the Institute for Animal Health on pathogens liable to be present in carcasses, divided into short and longer-term risks.

3.6 For all these hazards, the main potential route to the human population is through water supplies, plus in some cases contact via crops, fish or direct contact with animal material. The populations at most risk appear to be users of private water supplies, and in some cases recreational water users. Due to the unusual winter weather conditions, flood water and waterlogged soil may heighten concerns.

3.7 It should be noted that a substantial number of consumers are served by "private" water supplies. Direct domestic use of private supplies is common in some areas affected by the outbreak. Large commercial food, drink and dairy establishments can also use supplies from their own boreholes, though such water will be subject to treatment. Not all household supplies in rural areas may be recorded, though shared and commercial supplies should be known to local Environmental Health Departments.

3.8 The most significant of the bacteriological hazards to human health are the Verotoxin-producing O157 strain of *E. coli* (VTEC) and *Campylobacter*. Public water supplies are believed to be at low risk of bacterial infection because of standard water treatment, provided there is no inadequacy in this. In contrast private supplies are vulnerable because of lack of (or less elaborate) treatment and/or from risk of contaminated run-off reaching holding supplies after treatment. The microbiological quality of these supplies is particularly vulnerable to heavy rainfall. The importance of site-specific risk assessment for burial should again be stressed: indeed a number of sites have been abandoned as "too risky" during the course of the outbreak.

3.9 Some biological agents are less reliably eliminated by public water treatment, though the greatest risks will still be to users of private water supplies. This applies particularly to *Cryptosporidium* and *Giardia*. As discussed in more detail below, both agents are protozoa (rather than bacteria) and are resistant to chlorination, though exposure risk is reduced by physical/chemical water treatment processes.

3.10 Other agents that might be present include prions associated with BSE, as discussed further below. Possible hazards from Hepatitis E., Polio viruses and human Enteroviruses were also considered, but none is thought to be prevalent in pigs, sheep or cattle in the UK.

3.11 It is important to note that some biological hazards are liable to be short-lived: for example many bacteria will be killed during decomposition of the carcass. Other hazards may survive in the environment for much longer periods: protozoa are longer-lived and form cysts, while VTEC can also persist in soil and water for many weeks. The first, and highest, risk period (potentially involving the full spectrum of bio-hazards included in the grid at Annex C) is thus while carcasses are awaiting disposal. After disposal, biological hazards become less numerous over time, dependent on conditions during carcass decomposition.

Chemical agents

3.12 Most numerous hazards here are products of combustion, either of animal carcasses or of material used in pyres. Examples include sulphur and nitrogen dioxide and particulates. Other chemicals may be released by burning of specific fuels, or by preservatives that might be present in wood used (principally railway sleepers). Direct inhalation is the most obvious pathway, and exposure would generally be temporary rather than long-term and cumulative. However with some releases the situation is more complex, and ingestion could occur through deposition and incorporation into food. In particular, dioxins are known to be highly persistent in the environment.

3.13 Other chemicals, such as methane, ammonia and nitrates, are produced during decomposition – i.e. after burial or during decay of carcasses awaiting disposal. Under anaerobic conditions, the nitrogen cycle is likely to proceed first to ammonia, which could be then converted to nitrate or nitrite. This would be a lengthy, continuous process, which could lead to a slow long-term transfer to groundwater. Nitrate contamination of drinking water would be detected by regular statutory monitoring of public water supplies. For any potential siting of a large burial pit close to aquifers serving public or private sources, the site-specific risk assessment should identify the need for suitable frequency of monitoring for contaminants – not just nitrates – at nearby abstraction points.

3.14 Airborne pollutants have been the subject of a detailed modelling exercise produced in parallel by Public Health Division (PH5) of DH, DETR and the Environment Agency, with inputs from AEA Technology. Subject to inevitable uncertainties, for example on local weather conditions, this allows some quantification of exposure to each pollutant caused by pyre burning, and also for this to be placed in the context of emissions from other sources. Results of this study are discussed in Section 6 below.

Risks from delays in disposal and from other sources

3.15 Though there is limited information available on which to judge their seriousness, hazards can come from decomposing carcasses awaiting disposal, and fluids released from them. Delays in disposal thus carry risks of their own. Physical hazards and pathways are likely to be qualitatively similar to those arising from burial, as in both cases carcasses are decomposing into products that may then enter local water. In addition, the effects of delay seem likely to exacerbate health problems due to stress and anxiety, though again this is difficult to quantify.

3.16 In addition to the hazards associated with burial, further factors may come into play when carcasses decay on the surface:

- Scavenging animals – notably rats, gulls and crows – could act as additional vectors for some of the hazards already listed, and may also spread other biological hazards. For example rodents may spread *Streptobacillus moniliformis* and *Leptospira*, contaminating untreated water supplies. The latter, in particular, can have very serious health consequences.

- Carcasses of pregnant or lambing sheep can introduce further hazards via dried-out solids or putrefied fluids left in topsoil. Some agents may be released in wind blown dust, soil or animal particles: for example *Coxiella burnetii* could potentially infect humans with Q-fever.

- In normal circumstances, human infection of botulism is rare, and usually food-borne and there have been no reports of human botulism associated with consumption of drinking water. This probably reflects the stable and low occurrence of *Clostridium botulinum* spores in soils and water. The risk of contaminating ground and surface water may increase if carcasses are left to decompose.

3.17 Finally, radiation (from burning or burial of Chernobyl-affected sheep) was also considered as a potential hazard. However in this case advice available from the National Radiological Protection Board showed clearly that the possible levels of exposure involved would have negligible effects on health.

Occupational Exposures

3.18 Those actively engaged in slaughter and disposal of the carcasses will inevitably be placed at some risk of exposure to occupational hazards. Leaving aside physical risks from the process of disposal (e.g. accidental wounding with firearms), the hazards are likely to be substantially as identified in Annex C and D, though with potentially very different exposures.

3.19 An example is provided by the use of disinfectants. Large volumes have been used and large numbers of staff and contractors working with carcasses could potentially be exposed to them. While the citric acid used to disinfect carcasses should present no risk to health, other disinfectants recommended for use against FMD (as listed on the MAFF website) may be used to disinfect vehicles, buildings and people and are potentially hazardous. In concentrated form they can be corrosive and/or irritant and need to be handled with care. In previous FMD outbreaks overseas, small children were injured by ingesting disinfectant (Deutsch *et al,* 1974). There is also some (probably small) risk of ingestion by staff on site if disinfectants are sprayed or applied through pressure hoses. However in the diluted form in which the they are used, they are generally of low toxicity and unlikely to present a substantial risk to health. The general public should have very little exposure to them.

3.20 Occupational risks can be reduced by proper use of protective measures, albeit tempered by practicality (fitness for use) considerations. For biological hazards, pathogens of particular relevance to occupational risks are indicated in Annex D. In some cases, occupational exposure could have wider implications for public health, for example if front-line workers were to acquire diseases with propensity for human-to-human transmission, or if pathogens were to be spread on clothing, in vehicles etc.

3.21 It should be stressed that these concerns do not primarily relate to the risk of humans acquiring FMD itself. This is very rare, with only a handful of cases in the scientific literature. (A PHLS review can be accessed in the British Medical Journal of March 11th 2001, at www.bmj.com/cgi/content/full/322/7286/565.) The 1967 UK outbreak saw only one reported human case, and there have been no known instances of human-to-human transmission. Nevertheless, doctors have been asked to report all suspected cases to the Public Health Laboratory Service (PHLS) as a precautionary measure. In the present outbreak, no suspected human infection has so far been confirmed.

4. Relating Pathways to Disposal Methods

4.1 In parallel with the initial listing of hazards, we adapted existing models of environmental pathways relevant to each disposal method, drawing on models used by EA and risk consultancies. These have been produced with assistance from DNV Ltd., who have provided an overview of the main pathways to humans from each disposal option in diagrammatic form (see Annex E).

4.2 The findings of this stage of analysis are summarised in Table 1 overleaf. This considers potential pathways to humans for each hazard in the full Data Grid (Annex C) for each method of carcass disposal. For simplicity, some hazards are grouped together. The disposal option for each group of hazards for which the exposure to humans would be greatest is shown in dark grey: others that would imply some exposure are shown in light grey.

4.3 It should be noted that the absence of hazard pathways for rendering is strongly dependent on this process being carried out to high standards. As the generic diagrams in Annex E show, there are in fact many potential hazard pathways associated with this process, including the disposal of its by-products. For rendering to warrant its place at the top of the preference list, control measures must ensure that only very small probabilities are associated with these pathways. In particular, current guidance is that MBM and tallow produced by rendering cattle must be incinerated to reduce the potential risk from BSE (rather than going to landfill, as had historically been the case).

Table 1: Summary of Potential Health Risks, Disposal Methods and Pathways

Potential Public Health Hazard	DISPOSAL OPTION					Pathwaysof agents to humans
	Rendering	Incineration	Landfill	Pyre	Burial	
Campylobacter, E.coli (VTEC), Listeria, Salmonella, Bacillus anthracis, C. botulinum, Leptospira, Mycobacterium tuberculosis var bovis, Yersinia						Private water supplies Direct contact Recreational water use (Possibly also shellfish)
Cryptosporidium, Giardia						Water supplies (mains and private) Crops, shellfish Direct contact Recreational water use
Clostridium tetani						Contact with contaminated soil
Prions for BSE, Scrapie						Water supplies via leachate, runoff, ash burial
Methane, CO_2						Leakage into housing
Fuel-specific chemicals. Metal salts						Inhalation Deposition into food chain
Particulates, SO_2 , NO_2, nitrous particles						Inhalation
PAHs, dioxins						Inhalation Deposition into food chain
Disinfectants, detergents						Water supply Inhalation of products?
Hydrogen Sulphide						Inhalation
Radiation						Distribution of burnt sheep products

Key: within each row disposal option with greatest exposure of humans to hazards shaded in dark green; other options entailing some exposure in light green

5. Provisional Prioritisation of Hazards

Methodology

5.1 To ascertain which of the "long list" of hazards should be prioritised for further attention, we used modelling studies and expert judgement to consider three simple questions relating to each:

(a) whether the agent/substance involved can have severe health effects on humans in quantities associated with the disposal operation

(if so)

(b) whether, if released, the hazard would be likely to evade being destroyed or negated prior to human exposure (i.e. a preliminary judgement about potential pathways)

(if so)

(c) whether the quantity to which humans would be exposed could be sufficient to cause significant health effects, bearing in mind the type and timescale of exposure (e.g. transient versus persistent).

5.2 Following this logic (summarised in Figure 1 below), hazards meeting each of these criteria were prioritised for more detailed analysis. The characteristics of the others also remain on record for further review.

Results of Hazard "sift"

5.3 The result of each stage of the "sifting" process is represented in Figure 2 below. The initial list of hazards is taken directly from the grid in Annex C: brief notes as to why each has been sifted out or taken forward have been added throughout.

Figure 1: Flow chart for identifying principal public health hazards from disposal of carcasses of cloven-hoofed animals

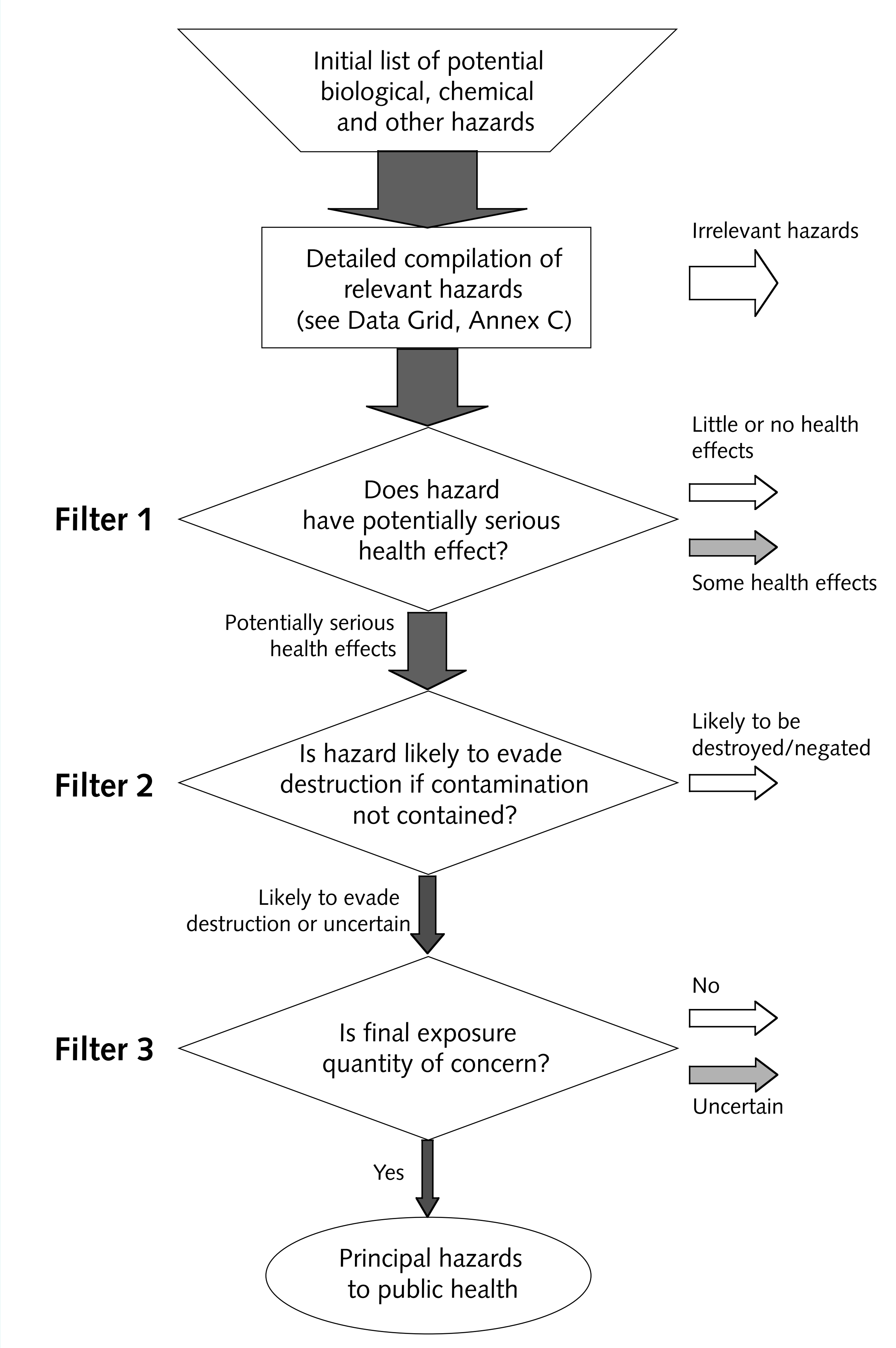

Figure 2: Sift for principal public health hazards associated with disposal of cloven-hoofed animals

Pool of hazards (as in Annex C)

Pool of hazards (as in Annex C)

Biological	Chemical	Other
Bacillus anthracis (anthrax)	Ammonia and nitrates	Radiation
BSE	Benzene etc.	
Campylobacter spp	Carbon dioxide	
Clostridium botulinum (botulism)	Carbon Monoxide	
Clostridium perfringens	Chemicals in wood preservatives	
Clostridium tetani (tetanus)	Chloride	
Coxiella burnetii (Q-fever)	Detergents	
Cryptosporidium spp.	Dioxins	
Erysipelothrix rhusiopathiae	Disinfectant	
Escherichia coli	Feedol	
Foot-and-Mouth Disease	Hydrogen Chloride (HCl)	
Giardia spp.	Hydrogen Sulphide/ Mercaptans	
Leptospira spp.	Metal Salts	
Listeria	Methane	
Mycobacterium avium paratuberculosis (Crohn's disease)	Nitrogenous products	
Mycobacterium tuberculosis var bovis	NO 2	
Salmonella spp.	Particulates	
Scrapie	Polycyclic Hydrocarbons (PAHs)	
Streptobacillus moniliformis	SO 2	
Streptococcus suis		
Toxoplasma gondii		
Yersinia (Y. enterocolitica, Y. fredriksenii, Y. pseudotuberculosis and Y. kristensenii)		

Filter 1: Does hazard have potentially serious health effect?

Potential serious health effects (including moderate or serious illness, death)	**Some health effects** (potential to cause mild to moderate illness)	**Little or no effects** (little or no chance of becoming ill)
Bacillus anthracis (anthrax)	Foot-and-Mouth disease (flu-like symptoms)	Clostridium *perfringens* (unlikely to cause infection)
BSE	Detergents (potentially when concentrated)	Scrapie (thought to affect only animals)
Campylobacter spp.	Car & boot disinfectant	Ammonia and nitrates (harmful only in industrial rather than agricultural quantities)
Clostridium botulinum (botulism)		Chloride (ditto)
Clostridium tetani (tetanus)		Feedol (not seen as dangerous to health)
Coxiella burnetii (Q-fever)		Citric acid disinfectant (food industry product)
Cryptosporidium spp.		Nitrogenous products (bad odour)
Erysipelothrix rhusiopathiae		
Escherichia coli		
Giardia spp.		
Leptospira spp.		
Listeria		
Mycobacterium avium paratuberculosis (Crohn's disease)		
Mycobacterium tuberculosis var bovis		
Salmonella spp.		
Streptobacillus moniliformis		
Streptococcus suis		
Toxoplasma gondii		
Yersinia (Y. enterocolitica, Y. fredriksenii, Y. pseudotuberculosis and Y. kristensenii)		
Benzene etc. (possible cancer risk)		
Carbon Dioxide (asphyxiation)		
Carbon Monoxide (anoxia)		
Chemicals in Wood preservatives (range of effects)		
Dioxins (ditto)		
Hydrogen Chloride (HCl) (irritant)		
Hydrogen Sulphide/ Mercaptans (toxic effects)		
Metal Salts (range of effects)		
Methane (localised explosion risk)		
NO2 (breathing difficulties)		
Particulates (worsen heart & lung disease)		
Polycyclic Hydrocarbons (PAHs) (cancer)		
SO2 (breathing difficulties)		
Radiation (cancer)		

Filter 2: Potentially serious health effect AND is hazard likely to evade destruction if contamination not contained?

Uncertain (human disease resulting from pathway/agent not fully understood)	**Likely to evade destruction** (normal public health measure or nature will not destroy or negate agents)	**Likely to be destroyed/ negated** (normal public health measures or nature should destroy or negate agents)
Clostridium botulinum *Clostridium botulinum* Botulism (Likelihood of toxicosis resulting from **drinking water** is unclear)	*Bacillus anthracis* (can remain in soil for many years)	*Clostridium tetani* (can survive in the **soil** for long periods but **population should be inoculated** against Tetanus. No reports of infection due to contamination of **water supplies**)
Mycobacterium avium paratuberculosis (Crohn's disease). Association with human disease not fully established.	BSE (Very difficult to destroy: remains in **all environment** for undetermined time)	*Coxiella burnetii* (not likely to be **waterborne**)
Mycobacterium tuberculosis var *bovis* (Likelihood of TB resulting from carcase burials is unclear).	*Campylobacter* spp. (**private and recreational water supplies**)	*Erysipelothrix rhusiopathiae* (not likely to be transmitted via **water** and most farm animals are vaccinated)
	Clostridium botulinum (If present in **private, recreational and surface water** could wash into open wounds be ingested etc.)	*Escherichia coli* (destroyed by water treatment of **public water supplies**)
	Coxiella burnetii (can remain in **soil and dust** for many months)	*Leptospira* spp. (very sensitive to chlorine and is therefore not a risk to **public water supplies**)
	Cryptosporidium spp.(can **evade destruction in both private and public water supplies** and remains in environment for many months).	*Listeria* (Does not appear to be a problem in **water** distribution main transmission is by food)[3]
	Escherichia coli (experience in developing world suggests risk to UK **private/ recreational water supplies** and food watered with it)	*Streptocobacillus moniliformis* (as with *Leptospira*)
	Giardia spp. (resistant to chlorine causing **public water** contamination and has caused outbreaks through private and **recreational water** contamination)	*Streptococcus suis* (not likely to be transmitted via **water**)
	Leptospira spp (known to infect **recreational and private untreated Water** supplies)	*Toxoplasma gondii* (possibly not transmitted by **water, oocysts only excreted by cats**)
	Salmonella spp. (recreational, **private and sometimes public water supplies** have been affected)	*Yersinia* (*Y. enterocolitica,Y. fredriksenii, Y. pseudotuberculosis and Y. kristensenii*) (sensitive to chlorinating therefore does not contaminate public water supplies)
	Streptobacillus moniliformis (as with *Leptospira* spp.)	Benzene etc. (likely to be burnt off in the fire)
	Streptococcus suis (**soil**)	Carbon Dioxide (mass burial sites will be vented and monitored)
	Yersinia (*Y. enterocolitica, Y. fredriksenii, Y. pseudotuberculosis and Y. kristensenii*) (Infections through private water supplies and recreational use)	Methane (ditto)
	Carbon Monoxide (definitely released into the **air** from pyre)	
	Chemicals in wood preservatives (ditto)	
	Dioxins (remain in environment e.g. **soil** for long periods)	
	Hydrogen Chloride (HCl) definitely released into the **air** from pyre	
	Hydrogen Sulphide/ Mercaptans (ditto, from burial)	
	Metal Salts (combustion products remain in **soil** for long periods)	
	NO 2 (definitely released into **air** from pyres)	
	Particulates (ditto)	
	Polycyclic Hydrocarbons (PAHs) (ditto)	
	SO 2 (ditto)	
	Radiation (radioactivity remains in environment e.g. **soil** for long periods)	

Filter 3: As above AND is final exposure quantity of concern?

Uncertain (human disease resulting from this pathway/agent is not fully understood)	**Yes** (amount and/or timing of exposure to agent could potentially cause a problem)	**No** (amount and/or timing of exposure to agent is unlikely to cause a problem)
Clostridium botulinum (Botulism: likelihood of toxicosis resulting from **drinking water** unclear but there could be a risk from **private water supplies**) [1]	BSE (very difficult to destroy: remains in **all environments**)	*Bacillus anthracis*: can remain in soil for many years but **unlikely to be present** in carcase. Last UK outbreak of anthrax was in 1997 (1-2 positive carcase due to a incident many years before on same site). 7,000 carcase were checked for the disease after sudden death but none was positive. [3]
Mycobacterium avium paratuberculosis (Association with Crohn's disease not fully established) [1].	*Campylobacter* spp. (**private and recreational water supplies** The most commonly isolated bacterial gastrointestinal pathogen in the UK (870/100,000). Often attributed to raw chicken but this only explains a proportion of the cases. The role of water and non food borne exposure is still under investigation) [3]	*Clostridium botulinum* (Can be present in **recreational and surface water** which could wash into open wounds be ingested etc. **Risk relates to the amount of toxin present**) [1]
Mycobacterium tuberculosis var *bovis* (Likelihood of TB resulting from carcase burials is unclear. No known cases of transmission to humans through drinking water.)	*Coxiella burnetii* (can remain in **soil and dust** for many months)	Carbon Monoxide (only a risk **very close to the pyre** which would be too hot) [2]
Chemicals in wood preservatives (if **ash** remains in situ after burns)	*Cryptosporidium* spp. (known to **remain viable in recreational, private and public water supplies** and remains in environment for many months. 3745 cases in 1998 in England and Wales) [1, 3]	Dioxins (exposure in diet **minor compared** with background exposure via rest of diet) [2]
Metal Salts (ditto & railways sleepers are used)	*E. coli* (especially VTEC : experience in developing world suggests risk from **private and recreational water supplies and food** watered with it. Considered a serious risk by PHLS, but not as robust as protozoa) [1,3]	Hydrogen Chloride (HCl) (modelled effects shown to be **very close to the pyre**, which would be too hot and therefore not pose a health risk) [2]
	Giardia spp. (resistant to chlorine causing **public water** contamination and has caused outbreaks through **private and recreational water** contamination)[1]	Hydrogen Sulphide/ Mercaptans (not present in concentrations needed to cause a problem)
	Leptospira spp. (known to infect **recreational and private untreated water** supplies [1] 29 indigenously acquired cases in 1983	NO_2 (**air quality standard not exceeded at 2 km**) [2]
	Salmonella spp. (Recreational, **Private and sometimes public water supplies** have been affected [1]. Present in UK pigs, cattle and sheep. Prevalence falling in recent years but still seen as an important pathogen [3].	Polycyclic Hydrocarbons (PAHs) **exposure has to be for decades** [2]
	Streptobacillus moniliformis (as with *Leptospira* spp.) [1]	Radiation (Extremely small: radioactivity **below EA exemption levels**)
	Streptococcus suis (**soil**) IAL - Compton suggest a possible risk if pigs are buried in large quantities or people come into contact with the carcase.	
	Yersinia enterocolitica (108 cases in 1998) [3]: *Y. fredriksenii, Y. pseudotuberculosis and Y. kristensenii* (Infections through private and recreational water supplies possible) [1]	
	Particulates (modelling suggests these will exceed air quality standard locally)	
	SO_2 (modelling suggests this will exceed air quality standard locally) [2]	

Sources:

[1]. PHLS (2001): Pathogens that may present theoretical threats to private water supplies as a result of disposal of animal carcases (Annex D)

[2]. Department of Health (2001): Foot and Mouth: effects on Health of emissions from pyres used for disposal of animals, www.doh.gsi.gov.uk

[3]. MAFF et al (1998) Zoonoses Report UK 1998

6. Further Examination of Selected Hazards

Inputs to Specific Risk Assessments

6.1 The information collected on each hazard allowed a provisional characterisation of:

- Exposure pathways of most relevance to each disposal method
- The likely effectiveness of barriers to exposure already routinely in place (e.g. normal water treatments)
- Predicted human exposure in "normal" circumstances – how many people might be exposed, at what levels and for how long.

These factors helped provide an indication of possible consequences for human health.

6.2 Rather than attempting a comprehensive evaluation for all the hazards identified, a sub-set was considered at this stage, comprising:

- sulphur dioxide (SO_2)
- air-borne particulates
- bacterial agents (especially VTEC and *Campylobacter*)
- protozoa such as *Cryptosporidium*
- BSE prions from older cattle.

6.3 In addition to choosing from amongst hazards that pass the "sifting" criteria, the aim was to use a set that could be considered as "representative". In the first four cases, the chosen hazards represent the most serious of a family of items to which similar comments apply.

Airborne pollutants: Sulphur Dioxide and particulate emissions

6.4 As already noted, these were the subject of a quantitative modelling exercise led by DH, DETR and EA, assisted by AEA Technology . The initial study concentrated on pyres of 250 cattle (or equivalents) and was then extended to consider larger pyres burning 1,000 cattle per day for 20 days, with preliminary analysis also of burning 1,000 cattle in total over 3 days. Summaries of these studies are reproduced in Annexes F, G respectively and the full report is available on the DH website.

6.5 Sulphur dioxide (SO_2) is potentially the most harmful of the various gases released by burning, which also include NO_X, Hydrogen Chloride, Carbon Monoxide, and Polycyclic Aromatic Hydrocarbons (PAHs). SO_2 has been associated with bringing forward the deaths of those already seriously ill with heart or lung disease. Emissions of particulates would also pose a hazard. However the quantitative models suggest that pyre-burning about half the estimated number of animals destined for disposal would add only small percentages to normal UK emissions. For example, burning 700,000 cattle, 100,000 pigs and 2,000,000 sheep would add just under 0.3% to annual UK emissions of SO_2 and about 0.35% to those of particulates.

6.6 Assuming that the pollutants emitted from a pyre are roughly proportional to the number of animals burnt on it, the overall emissions from burning a given number of animals in total should be independent of the size of pyres used. However the distribution of pollutants would obviously affected by the size of pyres (and by whether plumes from adjacent pyres overlap). The potential local effects of large pyres could be substantial. For example in the scenarios modelled, recommended air quality standards would be regained at a maximum of 3.5km downwind of a pyre burning 250 cattle, but would be substantially exceeded at 4km from a pyre burning 1000 cattle per day. This finding had clear implications for the siting of large pyres relative to human habitation, even though the effects on air quality would be temporary.

6.7 The same studies also modelled the emissions of dioxins, which would be deposited on grass and crops downwind of pyres. Though the proportional impact on total UK airborne emissions would be much greater than for SO_2 or particulates, the potential effects on health appear to be substantially less. For food intakes of dioxins, the Food Standards Agency has estimated that the deposits from the pyres will not make a significant increase to the overall exposure to dioxins from the diet. The Agency advised that some monitoring of dioxin concentration in soil, plants or food, particularly from sites within 2km of larger on continuous pyres, would be necessary to confirm the original estimates. (Initial air monitoring results have indicated that dioxin concentrations were below levels typically present in urban areas.) The Agency is currently sampling around selected pyres to assess the levels of dioxins in locally produced food, soil and grass, to ensure that there are no long-term effects on food safety.

6.8 As already noted, industrial incineration would contribute to many of the same air pollutants, but at a much lower level per animal due to this being a higher-temperature and more tightly-controlled process.

Bacterial pathogens: VTEC, *Campylobacter* and others

6.9 These are two of many bacterial pathogens of which carcasses are a potential source.

- The Verotoxin-producing strain of *E. coli* (VTEC) is of particular concern, for several reasons. Firstly, its health effects can be severe: up to 10% of those affected develop acute renal failure, of whom around 5% die. It is carried by up to 2% of sheep and 5-8% of cattle in the UK, and can survive for many weeks, or longer, in soil and water.

- *Campylobacter* is also of concern on the basis of the probability both of its presence in carcasses and of human exposure. It is the commonest cause of outbreaks of infection associated with private water supplies.

- Both require only a very small dose to cause infection in humans. For example in Walkerton, Canada last year, contamination of an unchlorinated public water supply with *Campylobacter* and VTEC from cattle led to over 1,000 cases.

6.10 Other significant pathogens include *Listeria, Salmonella, Streptobacillus,* and *Yersinia.* Additional risks might in theory be posed by other agents, including those causing anthrax and botulism and also *Mycobacterium tuberculosis* var *bovis* (bovine tuberculosis). Prevalence of TB in cattle varies greatly by region: for example there is high prevalence in Devon (where on-farm burial is in any case rare) but not in Cumbria. To date, however, there have been no recorded instances world-wide of bovine TB spreading to humans via water supplies.

6.11 For all the above, water supplies represent the major potential pathway of human exposure. Bacterial agents should however be killed off by normal water treatment (chlorination). Provided that these treatments are operating correctly, risks to consumers should therefore be confined to those using private water supplies. However recreational water users would also be at risk. Some risk might also attach to exposure to *Streptococcus suis* if pigs are buried in large quantities and people were to come into contact with contaminated soil.

Cryptosporidium

6.12 Together with *Giardia*, this is distinctive in that the agent is a protozoon rather than bacterium. Both, particularly cryptosporidium, are resistant to chlorine treatment. Although the risk of exposure will be reduced by treatments such as coagulation, sedimentation, dissolved air flotation and filtration, these have not always proven to be effective. There are recent and well-documented instances of cryptosporidiosis being spread by the public water supply (DETR, 1998), some in areas now heavily affected by FMD. Following these however (and prior to the FMD outbreak), additional measures have been put in place. These involve a risk assessment for each water treatment site and monitoring of the supply for *Cryptosporidium* if the assessment suggests that this is needed. The FMD cull makes it particularly important that these measures are robust in protecting public water supplies, and that private supplies are thoroughly monitored.

BSE/vCJD

6.13 Potential risks from BSE have been subject to extensive modelling. Large scientific uncertainties remain, not least about potential pathways of transmission. For example, there is no evidence that transmission by air or water has ever taken place, though a precautionary approach must allow for the possibility. A helpful overview is provided by the public summary of the SEAC meeting held on 30th March (http://www.maff.gov.uk/animalh/bse/bse-science/seac/seac0301.html).

6.14 Low prevalence of BSE in younger cattle (i.e. those born on or after 1st August 1996) has been reasonably well established, and suggests a differential factor of at least 400 as compared with older animals. No BSE has been detected in sheep, though the possibility has been raised and a research programme initiated. This makes this hazard qualitatively different from the others, in the sense of any risk being highly-dependent on the animals disposed of.

6.15 A risk assessment endorsed by SEAC (SEAC, 2001) tracks the infective dose that might reach the human population at large from each disposal method via all environmental routes. This implies that for a mix of dairy and beef cattle (58% and 42% respectively) as in the national herd:

- If 100 older cattle were to be burnt on a pyre, this could be expected to cause of the order of 0.00003 vCJD infections in the whole population (or odds of about 33,000 to 1 against a single human infection). This is a median estimate, with a confidence interval ranging from essentially zero to about 0.007 infections.
- Estimates for infections caused by on-farm burial of the same number of cattle are greater by a factor of just over 6.

6.16 In view of this differential, burial of older cattle in any site (even landfill) had already been prohibited in late March, prior to this study. Pyre burning of older cattle is also restricted by Environment Agency guidance requiring site-specific risk assessments. Nevertheless implementation of these procedures may not have been complete, particularly given the extreme pressures of time and numbers earlier in the outbreak. It is projected that about 200,000 older cattle will have been disposed of by the end of the outbreak. While the great majority will have been rendered or incinerated, some have been burnt on pyres. A smaller proportion will have been buried in the early stages of the outbreak.

6.17 Investigations are under way as to the numbers of animals potentiall involved. Pending these, some illustrative calculations may be illuminating. These are based on the SEAC-endorsed assessment and Ignore any risk reductions due to site-specific assessments:

- If 25% of these older cattle (i.e. 50,000) were to be *pyre-burnt*, this would imply a median expected number of human infections of 0.015, with a 95% confidence range of essentially 0 to 5 infections

- If 5% (i.e.10,000) of the older cattle were to be *buried*, the median expected number of human infections would be 0.002, with a 95% confidence range of 0 to 3.5 infections.

6.18 In such a scenario, the chance of vCJD infection would remain small. The median estimates suggest that it would be very unlikely that anyone would be infected. However the large range of uncertainty is important too, as is the particular nature of the disease – incurable and invariably fatal. Overall then, these figures serve to illustrate the importance of following the disposal guidelines as closely as possible. Work is currently under way to check sites at which older cattle may have been buried. Site-specific risk assessments will then be carried out to determine how any residual risks could be minimised.

6.19 The risks from disposal have also to be weighed against the risks of delay, allowing carcasses to decompose on the surface. Preliminary calculations set out at Annex J indicate that the relative risk of vCJD from leaving older cattle to rot on the ground could be higher than on-farm burial – significantly so if carcasses were to decompose entirely – and much higher than for pyre burning.

Quantification of Risks

6.20 Though providing limited quantification of the risks attaching to BSE/vCJD, we have stressed the uncertainties involved. Quantification of risks to human health from the water-borne biohazards is also extremely problematic. Some sense of their relative importance can be gained from the number of infections normally occurring within the population, of which some details appear in Annex I. We have carried out some further investigation of how estimates of the likely load per carcass might be combined with analysis of potential pathways to humans. However any such analysis would be subject to great uncertainty. Scientific data for different pathogens is of variable quality, and the survival of pathogens in farm soil is not fully understood. We do not therefore feel that further quantification of these risks can be credibly carried out.

6.21 A confounding factor is the need to take into account the hazard that would have been posed by the same animals if left alive, i.e. agents passed by normal excretion, or by burial of fallen stock had no FMD outbreak occurred. For some pathogens, mass slaughter of livestock may well have decreased the overall load going into the environment (though it should be stressed that only a small proportion of national herds are being slaughtered). However, there are likely to be significant local variations, arising both from slaughter and from prevention of normal livestock movements. This interplay of national and local effects is particularly hard to model. However a rough calculation for the effect of decreasing national herd size is provided in Annex I. Taking figures from the 1998 Zoonosis Report, this considers the percentage of the (non food-borne) infections that might be avoided by a reduction in the number of animals through culling.

Summary Risk Characterisations

6.22 Summary "risk characterisation sheets" for each of the chosen hazards follow on the next few pages.

SUMMARY RISK CHARACTERISATION

Agent: SO_2

Description: Sulphur dioxide (SO_2) is gas formed during combustion, which oxidises in water droplets to form sulphuric acid (H_2SO_4). It causes acidification of soil and surface water. If inhaled, SO_2 is a potent bronchoconstrictor. Sulphur in coal is the main source.

Prevalence in FMD disposal: There is minimal sulphur in carcasses. SO_2 will mainly be formed during combustion of the fuel. There is more sulphur in low-grade fuel oil than kerosene or natural gas.

Main potential pathway from FMD disposal:
- Inhalation of gas emitted from incinerator/pyre.

Persistence in the environment:
- Precipitated from the atmosphere usually within several days.
- Inactivation timescale in the ground – unknown, assumed several months (precipitation as solid salt).
- Inactivation timescale in water – unknown, assumed as for ground.

Desirable disposal options: Methods involving no combustion or low-sulphur fuel. Order of preference for this hazard:

1= Landfill (no combustion)
1= Burial on farm (no combustion)
3 Rendering (no combustion but SO_2 generation from fuel needed for high temperature process)
4 Incineration (combustion, but with effective controls on releases)
5 Pyre Burning (less controlled combustion, not necessarily with low-sulphur fuel)

Population exposed: Workers near to pyres, residents within area affected by smoke/stack emissions.

Health effects: Atmospheric exposure to SO_2 is considered to be linked to respiratory symptoms, reduced lung function. Bronchoconstriction is most pronounced in people with asthma. May bring forward deaths due to heart and lung disease.

Risk perception: High public concern regarding asthma in children, even given difficulty of demonstrating cause and effect.

Safeguards:
- Fuels for combustion should be low-sulphur as far as possible (e.g. use of kerosene instead of fuel oil for pyres).
- Pyres should be located in areas of low population.
- Workers and nearby residents should be advised to avoid exposure to smoke.

Risk evaluation: Exposure appears small relative to other sources of SO_2, provided pyres are well-sited and use low sulphur fuels. Acceptability can be improved by further use the safeguards.

SUMMARY RISK CHARACTERISATION

Agent: Particulates

Description: Particulates (airborne fine particles) are produced in combustion of fuels. If inhaled, particulates affect lung function.

Prevalence in FMD disposal: Particulates in burning and incineration consist of ash particles entrained in the smoke or stack emissions. Particles of cooled ash may also be entrained in the wind. There are also particulates emitted from rendering due to fuel combustion for the heating process.

Main potential pathway in FMD disposal: (Based on judgement)

- Inhalation of particulate emissions from incinerator/pyre/rendering plant.

Persistence in the environment:

- Precipitated from the atmosphere, often within several days but can last longer and travel many kilometres.

Desirable disposal options: Methods involving no combustion or production of fine residue. Order of preference for this hazard:

1= Landfill (no combustion)

1= Burial on farm (no combustion)

3 Incineration (efficient combustion with flue gas scrubbing)

4 Rendering (no combustion but fuel generation for high temperature process)

5 Pyre Burning (inefficient combustion and no emission control)

Population exposed: Workers near to pyres, residents within area affected by smoke/stack emissions.

Health effects: Inhalation of particulates is linked to increases in respiratory and cardiovascular disease. May bring forward deaths amongst those already ill.

Risk perception: Difficulty of linking cause and effect may reduce concern.

Safeguards:

- Measures to control air pollution by minimising particulate emissions from incinerators/rendering plants.
- Pyres should be located in areas of low population.
- Workers and nearby residents should be advised to avoid exposure to smoke.

Risk evaluation: Statistical effects of particulates are well-established, though rarely linked to specific deaths. Exposure appears slight compared to other pollution sources. Reductions possible by further use of safeguards (May also imply evacuation from areas of major plumes).

SUMMARY RISK CHARACTERISATION

Agent: Verotoxin *E. coli* (VTEC)

Description: *Escherichia coli (E. coli)* is a type of faecal coliform bacteria commonly found in the intestines of animals and humans. Infection occurs through ingestion of bacteria. Most strains are harmless, and the few toxic ones are designated as Verotoxin-producing *E. coli* (VTEC). The most common VTEC strain responsible for human disease is *E. coli* O157-H7. The infective dose is low, possibly only 10 cells. Human infections have occurred through water supplies

Prevalence in FMD animals: VTEC strains occur mainly in cattle, but also in pigs and sheep.

Main potential pathways in FMD disposal: (Based on judgement)
- Direct ingestion of faeces of contaminated animals.
- Contamination of water supplies by leachate/effluent containing faeces or intestine contents: hazard can survive for many weeks in soil and water.

Persistence in the environment:
- Can persist in soil or water for many weeks.
- Should be removed by water treatment used for public supplies.
- Destroyed by cooking.

Desirable disposal options: Methods minimising handling of carcasses; methods involving combustion or high temperatures; methods minimising risks of water supply contamination. Order of preference for this hazard:

1. Incineration (most complete combustion)
2. Pyre burning (combustion and minimum handling)
3. Rendering (high temperature)
4. Landfill (minimum handling)
5. Burial on farm (possible direct contact if exhumed; more likely contamination of water supplies)

Population exposed: Workers handling carcasses; consumers of untreated private water supplies.

Health effects: Symptoms of VTEC infection are mainly diarrhoea, which may range from mild to severe (haemorrhagic colitis). People normally recover within 2 weeks. About 5% of cases develop haemolytic uraemic syndrome, which can include kidney failure and have a fatality rate of about 10%. This is most likely in children.

Risk perception: The effects on children may increase concern.

Existing safeguards:
- Measures protecting hygiene of workers handling carcasses.
- Water supply treatment.

Additional safeguards:
- People handling FMD carcasses to be monitored for infection.
- Water extraction points potentially contaminated to be monitored for *E. coli.*

Risk evaluation: Risk appears moderate, due to combination of low infective dose and potentially severe effects. Could be reduced with additional safeguards.

SUMMARY RISK CHARACTERISATION

Agent: *Campylobacter*

Description: Ingestion of *Campylobacter* is the most common cause of diarrhoea in Britain.

Prevalence in FMD animals: Occurs mainly in poultry, but also in sheep and cattle.

Main potential pathways in FMD disposal:
- Direct ingestion of offal or faeces of contaminated animals.
- Contamination of private water supplies.

Persistence in the environment:
- Readily removed by drying, heating or exposure to oxygen.
- Transmission to chickens is believed to have occurred through groundwater.
- Commonest cause of outbreaks associated with private supplies.

Desirable disposal options: Methods minimising handling of carcasses; methods involving combustion or high temperatures; minimisation of water supply contamination. Order of preference for this hazard:

1. Incineration (most complete combustion)
2. Pyre burning (combustion and minimum handling)
3. Rendering (high temperature)
4. Landfill (minimum handling, contained burial)
5. Burial on farm (possible direct contact if exhumed, more likely contamination of ground and surface water)

Population exposed: Workers handling carcasses, consumers of private water supplies

Health effects: Symptoms usually include diarrhoea and stomach cramps. People normally recover within a week. In rare cases, infection may trigger more serious disease such as Guillain-Barré syndrome (a severe, paralysing neurological condition).

Risk perception: The common nature of the infection may moderate concern.

Existing safeguards:
- Measures protecting hygiene of workers handling carcasses.
- Water supply treatment.

Additional safeguards:
- People handling FMD carcasses to be monitored for infection.

Risk evaluation: Risk appears low, even for workers, due to combination of ready disinfection and minor health risks. Acceptability could be improved with additional safeguards.

SUMMARY RISK CHARACTERISATION

Agent: *Cryptosporidium*

Description: *Cryptosporidium* is a parasite that causes diarrhoea (Cryptosporidiosis). Infection occurs when a person ingests oocysts (eggs) from contaminated faeces of infected animals or humans.

Prevalence in FMD animals: Unknown at present, so should assume all infected.

Main potential pathways in FMD disposal: (Based on judgement)

- Direct ingestion of faeces while handling carcasses.
- Contamination of water supplies by leachate/effluent containing faeces.
- Ingestion of contaminated soil.

Persistence in the environment:

- Resistant to disinfection by chlorine, and hence may pass through water treatment plants.
- Removal by sedimentation and biological sewage treatment is not assured.
- Destroyed by boiling, and hence by incineration, burning or rendering.
- Removal by filtration.
- Can contaminate groundwater.
- Inactivation timescale – unknown, but may be weeks (assumed viable life of oocysts).

Desirable disposal options: Methods minimising handling of carcasses; methods involving combustion or high temperatures. Order of preference for this hazard:

1. Incineration (most complete combustion)
2. Pyre burning (combustion and minimum handling)
3. Rendering (high temperature but disinfection not certain)
4. Landfill (leachate treatment may be ineffective)
5. Burial on farm (possible contamination of water supplies)

Population exposed: Workers handling carcasses, water consumers within affected area

Health effects: Symptoms usually include diarrhoea, stomach cramps, fever and nausea, normally with recovery within a few weeks. People with impaired immune systems, such as cancer patients, organ transplant recipients and people with HIV/AIDS, may suffer prolonged diarrhoea and weight loss, which may be life-threatening. There is no cure at present.

Risk perception: The effects on already vulnerable groups may arouse particular concern.

Existing safeguards:

- People with immune impairment are advised to avoid drinking unboiled water.
- Water utilities are expected to use risk assessment to minimise potential contamination.

Additional safeguards:

- People handling FMD carcasses to be screened for immuno-suppression, reminded to avoid faecal contamination, and provided with adequate washing facilities.
- Water extraction points potentially affected by burial/landfill/rendering to be monitored.

Risk evaluation: Risk appears significant, both for workers in all disposal options, and for private water consumers in landfill/burial areas. Might be made acceptable with additional safeguards.

SUMMARY RISK CHARACTERISATION

Agent: Prions (BSE)

Description: a fatal neurological disease of cattle, in which a distorted form of protein (prion) slowly propagates through nervous and lymphoid tissue. The human form is variant Creutzfeldt-Jakob disease (vCJD). Variant CJD infection is believed to occur via ingestion of BSE-contaminated tissue.

Prevalence in FMD animals: Approximately 0.4% of older cattle tested positive on slaughter during 2000. Prevalence in younger cattle is substantially less, by an estimated factor of at least 400.

Main potential pathways from FMD disposal:

- Contamination of water supplies by leachate/residual ash/effluent containing particles of nervous tissue.
- Inhalation of particles emitted from incinerator/pyre.
- Ingestion of contaminated surface water.

Persistence in the environment:

- Resistant to disinfection by chlorine: may pass through water treatment plants.
- Removal by sedimentation and biological sewage treatment is not assured.
- Destroyed by prolonged heating (effective incineration); substantially reduced by burning or rendering.
- Removal by filtration is uncertain, and hence may remain in groundwater.
- Inactivation timescale in the ground – several years (biodegradation of proteins).
- Inactivation timescale in water – unknown.

Desirable disposal options: Methods involving combustion or high temperatures; methods minimising spills of uncombusted material. Order of preference for this hazard:

1= Rendering (high temperature and contained products)
1= Incineration (most complete combustion)
3= Pyre Burning (combustion, but possibly combustion)
3= Landfill (contained, but some risk from leaching: *currently prohibited for older cattle*)
5 Burial on farm (possible contamination of water: *currently prohibited for older cattle*)

Population exposed: Water consumers within area potentially contaminated, workers near to pyres, residents within area affected by smoke/stack emissions

Health effects: Following an asymptomatic period of around 10 years or more, vCJD symptoms involve a deteriorating mental condition usually leading to death within months of clinical onset. There is no cure at present.

Risk perception: The rapid mental deterioration in young victims and the uncertainty over the population infected have aroused particular concern.

Existing safeguards:

- Measures aimed at preventing animal waste/effluent contaminating water supplies.
- Older cattle not to be buried on any site and given priority for rendering/incineration.
- Site-specific risk assessment of pyre burning (should make this preferable to landfill).

Risk evaluation: Any significant risk of vCJD infection would be considered unacceptable. Risk will be minimised if existing safeguards are followed.

7. Comparison of Disposal Methods

7.1 One aim of this study was to compare the relative merits of different disposal options from a public health point of view, taking account of the range of different hazards. In particular, it was important to assess whether the preference order for methods established at the start of the outbreak appeared justifiable and robust. Scientific uncertainties precluded the use of a fully-quantitative analysis (even leaving aside the challenge of comparing different individual health outcomes), while time did not permit the alternative of a full weighting-and-scoring system based on expert judgement.

7.2 Some reasonably robust conclusions could however be suggested. Unsurprisingly, (engineered, licensed) landfill is always preferable to unlined burial, and incineration to pyre burning. In both cases, the more preferred option was subject to existing controls, which would reduce potentially-harmful emissions. (Dependent on the procedures put in place, the same may apply to mass burial in lined pits.) One way of arriving at an overall ordering is through a comparison matrix, for example as in Table 2 below. This considers how each disposal option performs against the "shortlisted" hazards discussed in the last section. As in the Table 1, shading in each cell represents one of three risk ratings, **dark grey** (for the option creating greatest human exposure to the given hazard), **blank** (where the risk is non-existent or negligible), and **light grey** (for all intermediate cases).

Table 2: Rough scoring of disposal options against hazards

Potential Public Health Hazard	DISPOSAL OPTION				
	Rendering	Incineration	Landfill	Pyre	Burial
Cryptosporidium					
BSE*					
Sulphur Dioxide					
Particulates					
E. coli, Campylobacter					
RANK	1	2	3	4	5

*older cattle only: note that the "blank" cell for rendering is dependent on solid products then going for incineration

7.3 While obviously a very rough approach, the result is informative. If “dark grey” cells are always counted as worse than “light grey” and these are always worse than “blank”, this largely qualitative assessment actually suffices to establish the ranking in the bottom row.

7.4 This approach does however treat the hazards in each row as being of equal weight, which is at best arbitrary. Although this is open to debate, there are some reasons (e.g. reflected in the “summary characterisation” sheets given in the previous section) to regard the hazards in each row as of roughly decreasing order of importance from provided the appropriate control measures are in place. Thus, for example, the risk from *Cryptosporidium* is less easily managed and more persistent than that from *E coli* or *Campylobacter*. Modelling of the air-borne hazards suggests that these pose relatively little general risk, given attention to issues around the siting of large pyres: the exposure is also temporary in nature.

7.5 It can be shown that linear weighting of the hazards, from top to bottom, will usually preserve the ordering of the overall scores for the disposal options. Both the weighted and unweighted models thus supported the existing preference ordering. The entry for BSE is, as already noted, a special case in applying only to older cattle. However its removal leaves the preference order unchanged if the disposal of other animals is evaluated against the remaining hazards to public health.

7.6 Though insufficient time was available in this case, available, this crude approach to ranking can be extended in a number of ways. For example a “Delphi” approach of repeated consultation can facilitate consensus expert judgements. Alternatively, an index can be built up for each disposal option by scoring different components of each risk. If used in future, either approach could be complemented with sensitivity analysis of the overall ordering of options.

8. Conclusions

Overview

8.1 In order to inform policy, this necessarily rapid and mainly qualitative risk assessment considered a wide range of biological, chemical and other hazards. The expertise of many contributors was used to draw up a comprehensive listing of hazards generated by the five carcass disposal methods in use, and their potential pathways to human exposure. The risk assessment methodology identified and focussed on the most significant of these, as follows:

Biological hazards

- bacteria such as VTEC, *Campylobacter*, *Salmonella* and *Leptospira* potentially spread by water
- Water-borne protozoa (including *Cryptosporidium* and *Giardia*)
- BSE/vCJD from older cattle

Chemical hazards

- airborne particulates (PM_{10})
- combustion gases (primarily SO_2)

8.2 To consider the potential risks to public health, and how they would be avoided, contained, spread or mitigated by the various disposal methods, the principal hazards were characterised using the data grid and exposure pathways detailed in the annexes. The absence of data on the scale of individual biological hazards for cattle, sheep and pig carcasses has only allowed the overall analysis to be qualitative. However it has drawn on quantitative models where possible, notably on BSE/vCJD and on the effects of chemical air pollution.

8.3 Comparing the residual hazard from each disposal option from a public health point of view suggested a preference ranking matching that adopted by MAFF and the Environment Agency, i.e.:

Sheep, pigs and younger cattle

- rendering
- incineration
- landfill
- pyre burning
- burial

Older cattle

- rendering (with MBM/tallow incinerated)
- incineration
- pyre burning

Quality Assurance

8.4 Exposure to hazards will obviously be minimised if selected disposal options are applied speedily and properly. Some effects of poor disposal practice would be immediately apparent (e.g. smoke plumes from inappropriately-sited pyres). Others, such as seepage from burial pits, could take longer to be noticed. Residual risks have been minimised by local risk assessment of the sites and the monitoring of the disposal process to ensure that MAFF and EA guidelines are met.

8.5 This report has also stressed the potential risks of delay in disposal of carcasses, for example through local contamination of water supplies if animals are left to decompose on the surface. Potential concerns here relate to many of those identified for burial, albeit with carcasses decaying on open ground on sites not chosen for their hydro-geological characteristics. The additional hazards posed by scavengers and by dried-out animal remains have also been noted, as has the relative risk posed by BSE in older cattle if these are left to decay. In general, the risks of surface decay are liable to exceed those of any current disposal method. Should delays occur in future, the process of decay will be speeded up by the onset of warmer weather.

Health guidelines

8.6 Guidelines to reduce potential public health risks from slaughter and disposal of animals are shown in Annex L. Consolidating earlier advice and site-specific guidelines, these:

- emphasise the need for early disposal of carcasses, with identification and segregation of older cattle
- recommend the preference order of disposal methods cited above
- provide specific guidance on burial and pyre-burning, including the disposal of ash
- set out monitoring measures to ensure the safety of the human food chain and the integrity of water supplies
- set out the organisational arrangements for public health input locally and regionally.

8.7 Systematic longer term monitoring of the disposal sites and their immediate proximity will be required. This may involve monitoring the environment, personnel involved in the disposal process and the public. Such monitoring is now in train, and should be of help for contingency planning and in providing information in the event of local environmental problems – e.g. flooding – later on.

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