Risk Assessment of Landfill Sites for SRM Disposal:

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MANAGING RISK DNV

Risk Assessment of Landfill Sites for SRM Disposal

for

The Investment Agriculture Foundation of British Columbia

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Summary: A quantitative risk assessment of the disposal of bovine slaughter waste in naturally controlled landfills in British Columbia has been carried out. Three hypothetical landfill configurations were defined as the basis for the study. Various exposure pathways were assessed and it was decided that the only credible exposure pathway was through infectivity moving from the landfill site with leachate and contaminating the groundwater. The risk estimates show that the possible exposure to BSE infectivity for either cattle or people in the vicinity of a landfill taking SRM is very low. It is therefore concluded that the disposal of bovine slaughter waste in naturally contained landfills would not pose any significant risk to either cattle or people provided that the risk management factors assumed in this risk assessment are valid.

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Executive Summary

The Investment Agriculture Foundation of British Columbia have commissioned Det Norske Veritas (DNV) to carry out a study to assess the risk of exposure of domestic ruminants and humans to the BSE infective agent resulting from the disposal of slaughter waste including Specified Risk Material (SRM) in naturally contained landfills in British Columbia. The study has adopted a quantitative risk assessment approach based on a series of similar studies carried out previously by DNV for various agencies.

There are a number of natural control landfill sites in BC that could take slaughter waste, so rather than base the study on individual sites, the study has been based on two hypothetical natural control landfills, one taking 80,000 tonnes/year of municipal solid waste (MSW) and the other taking 4000 tonnes/year of MSW. In each case these have been evaluated for two levels of slaughter waste, 2% of MSW and 5% of MSW, and for high (1000 mm/year), medium (600 mm/year) and low (300 mm/year) rainfall. In addition, a third option has been considered to reflect the position at one landfill where the slaughter waste is placed in a separate cell. Site characteristics and operating procedures have been assumed to conform to the technical requirements for sites taking slaughter waste as proposed in the recent report from Sperling Hansen Associates (SHA, 2006).

A number of possible exposure pathways were assessed qualitatively, and it was concluded that the only credible exposure pathway was through infectivity moving from the landfill site with leachate and contaminating the groundwater. Water, for both bovine and human consumption, is assumed to be extracted from a well adjacent to the landfill. This would not happen in practice and represents a worst case assumption.

The potential exposure for this pathway has been assessed in terms of the ingestion of BSE infectivity in terms of bovine oral ID_{50} units for both people and cattle. This is the dose that would, on average, infect with BSE 50% of the cattle population exposed to it. When interpreting the exposure to people it is necessary to take account of the species barrier that will reduce the potential for infection. The size of the cattle to human species barrier is not known with any certainty, but comparison of the numbers of potential vCJD cases in the UK with the potential exposure shows that this must be a factor of 1000 or more.

The median values of the total exposure for the various scenarios assessed are shown in Figure i) for people and Figure ii) for cattle. These both show the exposure per day assuming that all the water consumed is from the well adjacent to a landfill that is taking bovine slaughter waste. For people the results vary from 2×10^{-6} bovine oral ID_{50} units per day for the landfill taking 80,000 tonnes of MSW per year with 5% slaughter waste and 300 mm/yr rainfall to 1×10^{-7} bovine oral ID_{50} units per day for the landfill taking 4,000 tonnes of MSW per year with 2% slaughter waste and 1000 mm/yr rainfall. For cattle, the equivalent values are 1×10^{-4} and 7×10^{-6} bovine oral ID_{50} units per day.

These are all very low exposures and the most likely outcome would be that they would not result in any additional cases of BSE in exposed cattle or cases of vCJD in exposed people. This is reinforced by the range of conservative assumptions included in the assessment that will mean that the exposures will tend to be overestimated. It is therefore concluded that the disposal of bovine slaughter waste in naturally contained landfills would not pose any significant risk to either cattle or people provided that the risk management factors assumed in this risk assessment are valid.

Figure i): Human Exposure from Groundwater
Median Value – Bovine oral ID_{50} per day

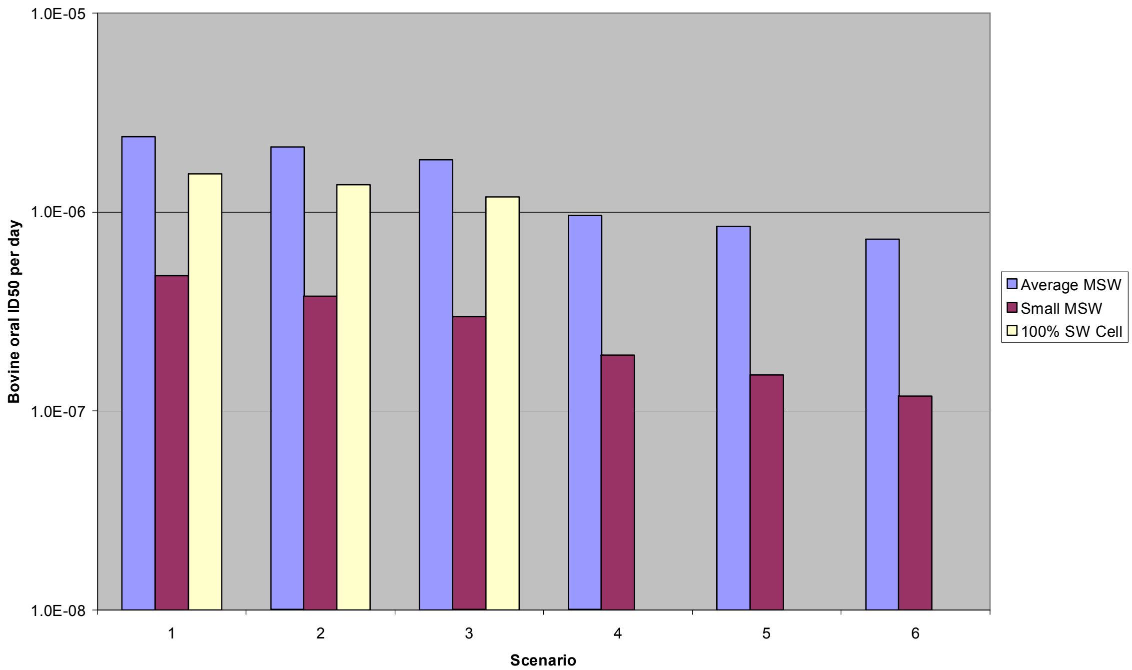
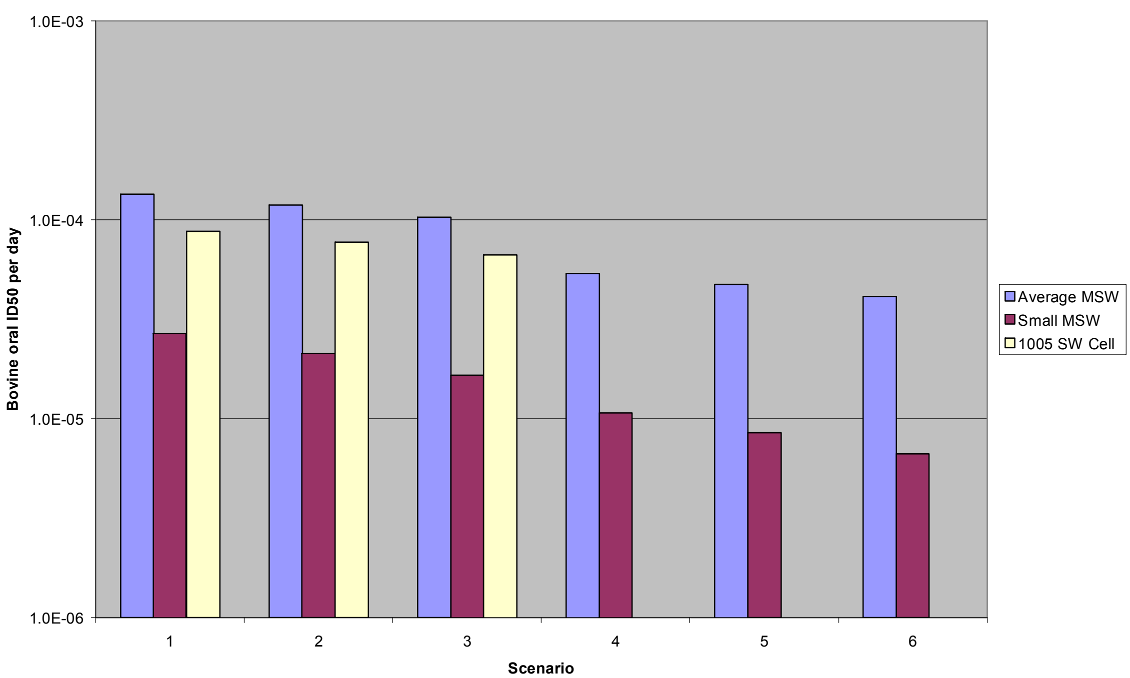


Figure ii): Cattle Exposure from Groundwater
Median Value – Bovine oral ID_{50} per year



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1.0 Introduction and Objectives

1.1 Introduction

Landfill sites are being considered for the disposal of specified risk material (SRM) from the slaughter of cattle in British Columbia (BC). All landfills receiving SRM in Canada will need a CFIA permit by July 12, 2007. The CFIA has carried out risk assessments for "engineered" landfills, but in British Columbia these are located remotely from the slaughter plant. Landfills which do not meet the operating parameters defined for the current CFIA risk assessment will require a risk assessment.

The Investment Agriculture Foundation of British Columbia have contracted DNV to carry out a risk assessment of the disposal of slaughter waste in naturally controlled landfill sites in British Columbia to satisfy the requirements of CFIA.

1.2 Objective

The objective of this study is to assess the risk of exposure of domestic ruminants and humans to the BSE infective agent resulting from the disposal of SRM in naturally contained landfills in BC.

DNV have carried out a large number of TSE risk assessment studies for a variety of government agencies and commercial organisations. These have included studies on the disposal on BSE infected material and MBM in landfill sites and the spreading of materials on land. Our approach to this study builds on that adopted in these earlier studies, using the latest information available about BSE. Data and assumptions as used by the CFIA have been used where possible.

1.3 Det Norske Veritas (DNV)

DNV is an independent foundation, established in 1864, with the objective of safeguarding life, property and the environment. DNV is among the world's leading companies in managing risks in areas of safety and the environment for today's industrial and societal settings. Throughout its history DNV has had a rule-setting function and/or determined conformance and compliance to Rules, Standards and Regulations. Being an independent, autonomous and self-owned foundation, DNV undertakes third party services requiring high technical expertise and the utmost integrity in all respects.

This study has been undertaken by DNV Consulting, the risk management consulting business of DNV.

2.0 Scenario Definition

2.1 Specified Risk Material

Specified Risk Material (SRM) are defined as those parts of a bovine carcase that are most likely to contain the BSE infective agent if the animal were infected with BSE. Definitions of SRM vary from country to country, and in Canada SRM are defined as:

- The skull, brain, trigeminal ganglia (nerves attached to the brain), eyes, tonsils, spinal cord and dorsal root ganglia (nerves attached to the spinal cord) of cattle aged 30 months or older; and
- The distal ileum (portion of the small intestine) of cattle of all ages.

SRM must be removed from all cattle slaughtered for human consumption, and are banned from all animal feeds, pet foods and fertilizers.

Because the definition of SRM depends on the age at slaughter, the amount of SRM produced will depend on the proportion of animals older than 30 months at slaughter (OTM) or under thirty months (UTM). The approximate amounts of SRM and slaughter waste produced for average cattle in BC are summarised in Table 1.

Table 1: Quantities of SRM and Slaughter Waste from Cattle slaughter

	Live weight	Slaughter Waste (kg)			% SRM
		SRM	Non-SRM	Total	
UTM Cattle	630	13	211	224	5.80%
OTM Cattle	604	40	236	276	14.49%
Average for 32% percent OTM		21.6		240.6	8.99%

Data on the numbers of under and over 30 month old cattle slaughtered in BC have been provided for selected landfill sites. These data are given in Table 2, and show that the proportion of OTM animals varies from 10% up to almost 50%, with an average for these sites of 32%. The model will reflect this variation in proportion of OTM animals using a discrete distribution based on the data in Table 2.

Table 2: **Numbers of Cattle Slaughtered by Landfill site**

Landfill	UTM	OTM	Total	% OTM
Clearview	400	100	500	20.0%
Foothills	2500	700	3200	21.9%
Big Lake	750	650	1400	46.4%
Heffley Creek / Lower Nicola	2840	2252	5092	44.2%
Bessborough	2000	500	2500	20.0%
Creston	700	80	780	10.3%
Total	9190	4282	13472	31.8%

2.2 BSE in Canada

There have been a total of ten cases of BSE in Canada since May 2003, the latest being a mature dairy cow from British Columbia reported on the 3rd May 2007, making this the 2nd case in 2007. In 2006, five cases were reported. Over the period from 2003, the average incidence rate in Canada has been about 0.4 cases per million adult (over 2 years) cattle. This assumes an average adult cattle population in Canada of 6 million. In 2006 the incidence was 0.8 per million adult cattle.

Risk assessments carried out by the CFIA (CFIA 2006 a & b) have assumed that there were a total of 10 preclinical (e.g. detectable but not showing clinical signs) or clinical cases in Canada in 2005, and that for each case there would be 10 subclinical cases. It was also assumed that 50% of the clinical or preclinical cases would be detected by the surveillance programme. These assumptions have been adopted for this assessment.

It is further assumed that almost all clinical or pre-clinical cases would occur in animals older than thirty months (OTM), and that the prevalence in UTM animals is a factor of 100 less. The prevalence in OTM animals will be factored by the average proportion of OTM animals slaughtered as given in Table 2, so that the total number of estimated cases would be the same as if the overall prevalence was applied to the total numbers slaughtered.

The assumptions on infectivity of bovine tissues will be based on the latest data from the VLA Attack rate experiments as summarised in Section 4, which are somewhat different from those used by CFIA.

2.3 Landfill Definition

There are a number of natural control landfill sites in BC that could take slaughter waste, so rather than base the study on individual sites, the study has been based on two hypothetical natural control landfills, one taking 80,000 tonnes/year of municipal solid waste (MSW) and the other taking 4000 tonnes/year of MSW. In each case these have been evaluated for two levels of slaughter waste, 2% of MSW and 5% of MSW, and for high (1000 mm/year), medium (600 mm/year) and low (300 mm/year) rainfall. In addition, a third option has been considered to reflect the position at one landfill (Big Lake) where the slaughter waste is placed in a separate cell. The main characteristics of the study sites are summarised in Table 3.

Leachate generation has been estimated using the data from SHA (2006) in which an analysis of leachate generation potential for landfill sites in BC as a function of annual rainfall was presented, showing that the Water Surplus for landfill sites in BC plot on a straight line as a function of annual precipitation (P), such that:

Water Surplus (WS) = 0.79 * Precipitation (P) – 236 (mm/year)

A Natural Control Landfill will not usually have a leachate collection system, and will rely on the natural attenuation of the underlying soils to provide adequate retention and biological treatment of any leachate generated. In British Columbia, the Landfill Criteria for Natural Control landfills (BC MOE, 1993) require that there is a minimum 2 m thick layer of low permeability soil with an hydraulic conductivity of 1×10^{-6} cm/s or less below each waste cell. The data for the landfill sites that could take SRM in BC indicate that these criteria are generally exceeded. It is proposed to start by using the minimum criteria and testing the sensitivity to these values.

Table 3: Definition of Landfill Sites for Risk Assessment

Case	A – Average MSW landfill	B – Small MSW landfill	C – 100% SW in Cell
Total MSW	80,000 tonnes/year	4,000 tonnes/year	520 tonnes/year slaughter waste
Proportion slaughter waste	2 or 5%	2 or 5%	100%
Disposal footprint (m^2)	50,000	30,000	33,400
Open footprint (m^2)	400	200	80
Rainfall (mm/yr)	1000 / 600 / 300	1000 / 600 / 300	1000 / 600 / 300
Leachate collection	No	No	No
Underlying layer Thickness (m) Hydraulic conductivity	 2 1 x 10^{-8} m/s	 2 1 x 10^{-8} m/s	 2 1 x 10^{-8} m/s
Depth to Water table (m)	1.2	1.2	1.2
Aquifer thickness (m)	6	3	6
Aquifer porosity (ratio)	0.3	0.3	0.3

The SHA (2006) report has proposed a Landfill Technical Requirements Matrix in order to determine the technical requirements of a landfill as a function of the proportion of slaughter and poultry waste disposal volumes to total MSW and the annual rainfall at the site. The matrix allows natural control landfills to be used if the slaughter and poultry waste is less than 2% of total MSW and the rainfall is less than 400 mm/yr. Natural control landfills with enhanced technical requirements may be used if the slaughter and poultry waste is less than 5% of total MSW and the rainfall is less than 400 mm/yr and for areas with an annual rainfall of 400 to 1000mm/yr if the slaughter and poultry waste is less than 2% of total MSW. For this study it will be assumed that the proportion of slaughter waste is at the top end of these ranges, i.e., either 2% or 5% of the total MSW, and that all the slaughter waste derives from cattle slaughter. The technical requirements of the landfill will then be defined according to the SHA matrix as indicated in

Table 4.

The SHA (2006) report also proposes a range technical requirements for natural control landfills taking slaughter waste. These cover a range of issues including operational procedures, buffer distances, environmental systems and environmental monitoring. These requirements include that there should be a minimum of 4m between the seasonal high water table and the bottommost waste cell.

The main difference with the enhanced technical requirements is a minimum of 8m between the seasonal high water table and the bottommost waste cell (as compared with 4m) and a minimum of 5m thick layer of low permeability soil (as compared with 2m).

Table 4: Landfill Technical Requirements

Rainfall (mm/year)	2% slaughter waste	5% slaughter waste
300	NC	ETR
600	ETR	EL
1000	ETR	EL
Key:		
NC	Natural control landfill	
ETR	Natural control landfill with enhanced technical requirements	
EL	Engineered Landfill (not considered in this study)	
Based on the proposed Landfill Technical Requirements Matrix in SHA (2006).		

2.4 Other Data

2.4.1 Drinking Water Consumption

Water ingestion rates for use in public health risk assessment studies have been presented by Roseberry and Burmaster (1992) based on statistical analysis of data from the Nationwide Food Consumption Survey of the USDA in 1977-78. Roseberry and Burmaster fitted lognormal distributions to the data for both total water intake and tap water intake for a range of age groups and a simulated balanced population. Tap water intake is defined as the sum of water drunk directly as a beverage and water added to foods and beverages during preparation. Total water intake is the tap water intake plus water intrinsic in foods as purchased.

The tap water intake 50 percentile for a simulated balanced population is given as 0.96 l/day with an arithmetic mean of 1.13 l/day. The values for total water intake are 1.8 and 1.9 l/day respectively. For this study, the lognormal distribution for tap water intake for a simulated balanced population as given by Roseberry and Burmaster (1992) is used. The intake distribution is characterized by a 2.5 percentile of 0.31 l/day and a 97.5 percentile of 2.95 l/day. These values are compatible with those proposed by Health Canada for use in human health risk assessment; see

(http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/existsub/approach/appendix-annexe_a_e.html)

2.4.2 Livestock Water Consumption

The landfill locations are mainly in remote areas that are not adjacent to pasture land. It is therefore unlikely that there would be any dairy cows in the vicinity of any of the landfill sites, although this cannot be ruled out as a possibility. The number of beef cattle would also be quite small.

Water requirements for cattle are influenced by several factors, including rate of gain, pregnancy, lactation, activity, type of diet, feed intake, and environmental temperature. These requirements are met by water consumed from wells, ponds, watering troughs, etc., as well as moisture found in feedstuffs. Data on water requirements for various grades of cattle (beef, dairy, finishing, etc) has been compiled by the North Dakota State University (http://www.ag.ndsu.edu/pubs/ansci/livestoc/as954w.htm accessed 22-02-07). This gives a range of from 11.0 to 17.5 gals per head per day for lactating beef cattle, and from 13.0 to 17.0 gals per head per day for dairy cows producing 30 lbs (13 litres) milk/day and 24.0 to 27.0 gals per head per day for dairy cows producing 50 lbs (22 litres) milk/day. For this study it is proposed to use a range of values from 11.0 to 17.5 gals per head per day (42 to 66 litres /day) to cover lactating beef cattle and all but the highest milking dairy cows. A worst case assumption of 100 litres/day will also be used to represent high milk production animals.

3.0 Infectivity of Bovine Tissues

A key input to the risk assessment is the amount of infectivity present in the material to which people or cattle may be exposed. The latest data on the infectivity of bovine tissues is summarised in the following sections in terms of:

1. The infectivity of central nervous system (CNS) tissues from an animal with clinical BSE to another bovine
2. The development of infectivity through the incubation period of the disease;
3. The total infectivity in a clinical case; and
4. The significance of exposure estimates for human exposure..

3.1 Infectivity of CNS tissues from an animal with BSE

The Veterinary Laboratory Agency (VLA) in the UK has carried out experiments to identify the effect on cattle of oral doses of BSE infected cattle brain. In this "attack rate" experiment groups of 10 calves were each fed 300g, 100g, 10g and 1g of an homogenate made from the brain stems from clinically sick animals. All animals in the two higher dose categories came down with BSE, and 7 out of 10 in both the 10 g and 1g trials. The range of incubation periods for both the 1g and 10g trials were similar (44 – 71 months). An extension of the attack rate experiment has recently been completed with doses of 1g 100mg, 10mg and 1mg, and the results are now in press (Wells *et al*, 2006). The results show 3 of 5 in the 1g trial group, 7 out of 15 animals in the 100mg group, 1 out of 15 in the 10mg group, and 1 out of 15 in the 1mg group, positive for BSE. Incubation periods for the positive results in both the 1 and 10mg groups were similar to those for the 1 g trial, but two of the animals in the 100mg group had incubation periods in excess of 90 months.

Wells et al (2007) estimate the oral ID_{50} of this clinically affected BSE brain pool for cattle to be 0.20g with a 95% confidence interval of 0.04g to 1.0g. This is equivalent to a mean infectivity of 5.0 cattle oral ID_{50}/gram with a 95% confidence range of 1 to 25. With higher titres of BSE affected brain the range could extend to 300 (EFSA, 2005).

It is proposed to model the infectivity titre in the brain of a clinically BSE infected bovine with the following distribution:

Log normal distribution with
Median (50 percentile): 5 cattle oral ID_{50}/gram
Higher 99 percentile: 100 cattle oral ID_{50} ($CoID_{50}$)/gram

This model has been used in risks assessments adopted by the European Food Safety Authority (EFSA, 2005) and others for the UK Food Standards Agency reviewed by the Spongiform Encephalopathy Advisory Committee (SEAC).

3.2 Development of infectivity through incubation period

In its Opinion and Report of the 16 May 2002 (SSC, 2002) the Scientific Steering Committee of the EC has provided an interpretation of the pathogenesis study to try and determine the time after exposure at which infectivity can be detected in the central nervous system and spinal cord. It highlights the problems in interpreting the data and concludes that the assumption made by the SSC in its opinion of the 12 January 2001, - i.e "that in general, as a reasonable worst case assumption, the dorsal root ganglia and the spinal cord are considered to pose a higher risk as from the second half of the incubation period" - remains valid.

In the pathogenesis study the first positive infectivity in CNS tissues was found at 32 months post infection, with no infectivity found at 26 months post infection. From the attack rate study the mean incubation period for animals given a similar dose was 45 months with a range from 33 to 55 (SSC, 2002). Combining these indicates that there is no detectable infectivity at 60% through the incubation period (26/45 = 0.6; range 0.5 to 0.8), and that there is detectable infectivity at 70% through the incubation period (32/45 = 0.7; range 0.6 to 0.96). For a risk assessment these results can be modelled as an exponential function with a doubling time of 2 months. This model was used in the risk assessment for the review of the Over Thirty Month (OTM) Rule in the UK (Comer and Huntly, 2004).

The model indicates that the infectivity at 50% and 70% of the incubation period is 4.5 logs and 2.5 logs less than the clinical value at the end of the incubation period.

This information is provided here for completeness, as in this study, the infectivity for clinical or preclinical cases has been assumed to be as for clinical cases, and for the sub-clinical cases the same assumption as used in the CFIA risk assessments has been adopted; i.e. that the infectivity in a sub-clinical case is 0.03 of a clinical case (a 1.5 log reduction).

3.3 Total Infectivity in Clinical case

The total infectivity in a clinical case of BSE is summarised in Table 5. The weights of the various tissues are taken from the LFRA (1997) report and the infectivity values are as discussed above, with the infectivity for whole brain taken to be the median value of 5 bovine oral ID_{50}/g. From the results of the pathogenesis experiment the infectivity in the ileum is taken to be one log (a factor of 10) less than that in the CNS and the infectivity in the tonsil four logs less (Wells *et al*, 2005). It can be seen that 90% of the infectivity is associated with central and peripheral nervous system tissues, with about 10% associated with the distal ileum.

Table 5: Infectivity in a Clinical Case of BSE (Bovine oral ID_{50}) Median values

Tissue	Weight	Infectivity		%
	kg/animal	ID50/g	ID50/animal	
Brain	0.5	5	2500	60.2%
Spinal cord	0.2	5	1000	24.1%
Dorsal root ganglia	0.03	5	150	3.6%
Trigeminal ganglia	0.02	5	100	2.4%
Tonsil	0.05	0.0005	0.025	0.0%
Distal ileum	0.8	0.5	400	9.6%
TOTAL	**1.6**		**4150**	

3.4 Significance of Exposure Estimates for human exposure

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 in order to have a similar probability of infecting a man compared to a bovine. There is little data on the cattle to human species barrier and previous risk assessments have made broad assumptions (SSC, 2000). However, an indication of the species barrier appropriate for the exposure estimates in this study can be gained from the experience in the UK as outlined below.

As part of the work for the review of the Over Thirty Month rule, Comer and Huntly (2004) estimated the total exposure of the UK population to BSE infectivity through food. They estimated that a total of 54 million bovine oral ID_{50} units entered the human food chain from 1980 to 2001. However, at the time of that study the latest data from the attack rate experiment was not available and a different assumption for the infectivity of bovine tissues was used that was a factor of 10 higher. Thus to be consistent with this present study the estimate should be divided by 10 and a value of 5 million bovine oral ID_{50} units consumed by the UK population should be used. This would indicate that the average exposure of the population (assumed to be 60 million) over the 20 year period would have been 0.004 bovine oral ID_{50} units per person per year.

There have been a total 165 cases of vCJD in the United Kingdom (February 2007), and it now seems that the epidemic reached a peak in 2000 and there has been a subsequent decline in the numbers of vCJD cases (CJD Surveillance Unit, 14th Annual Report, 2005). Current estimates of the total size of the vCJD epidemic have reduced significantly from the high numbers thought possible a few years ago to an upper limit of 550 in a recent report (Clake & Ghani, 2005). In fact Clarke and Ghani give a best estimate of 70 future deaths, and state that *"even in the worst case scenario, when non-MM homozygous individuals are equally susceptible but have longer mean incubation period than MM homozygous individuals, the best estimate of the potential scale of the epidemic is unlikely to exceed 400 future cases."*

An indication of the significance of the exposure estimates may then be obtained by comparing the total exposure estimate over the BSE epidemic (5 million bovine oral ID_{50} units) with the upper limit of 550 total cases of vCJD. If the exposure is factored by 40% to allow for the proportion of methionine homozygous individuals then it is calculated that the estimated exposure per expected vCJD case is in the order of 4,000 bovine oral ID_{50} units.

4.0 Risk Assessment Method

4.1 Overview

The risk of exposure of domestic ruminants and humans to the BSE infective agent resulting from the disposal of SRM in naturally contained landfills has been assessed using a classical risk assessment approach that has involved the following key steps:

1. Scenario definition
2. Assessment of exposure pathways
3. Model development together with assumptions and parameters for the model
4. Model execution.

The Scenario definition has already been described in Section 2.0 and this section will review the exposure pathways and summarise the model approach and assumptions. The model itself is built in Excel and is evaluated using @RISK, a probabilistic risk assessment tool that enables some of the uncertainty in the input parameters to be modelled.

The exposure estimates, for both people and cattle, are given in terms of bovine oral ID_{50} units. This is amount of infectivity that would, on average, infect 50% of an exposed population of cattle. When considering the risk to people, the potential magnitude of the cattle to human species barrier, as outlined in Section 3.4, should be taken into account.

4.2 Exposure Pathways

The potential pathways by which domestic ruminants or humans could be exposed to the infective agent of BSE following disposal of SRM in a landfill have been considered. The evaluation of the exposure pathways has been based on previous studies and experience. From this evaluation only one pathway (Pathway 1) has been selected for detailed evaluation in the risk assessment.

1. Ingestion of groundwater contaminated by leachate from the landfill.

The volume and character of the leachate generated from the landfill will depend on a range of factors, including the volume and character of the waste deposited, the rainfall at the site, the open area, the type of cover and drainage management. With a natural control landfill the leachate will percolate into the underlying ground and eventually migrate to any underlying aquifer. The degree to which prions may be present in leachate is not known, but it has to be assumed that some infectivity could be present in leachate.

The potential for exposure will then depend on the proximity of any well or borehole and whether the water is used for drinking water or for livestock. For the purpose of this study it is proposed to assume as a worst case that water will be extracted adjacent to the landfill.

2. Ingestion of surface water contaminated by leachate from the landfill.

Contamination of surface water from a landfill will usually result from failure of leachate treatment systems, where the treated effluent is discharged to a water course. For naturally controlled landfills there is no leachate collection or treatment, so there should be no direct pathway for the leachate into surface water. Surface water run-off from the landfill surface should not be contaminated with any deposited material. The Landfill Criteria for Municipal Solid Waste (BC MOE, 1993) requires surface water diversion to restrict storm water runoff from contacting the wastes. It is possible that contaminated groundwater could come to the surface and flow into an adjacent river or stream. However, this would increase the dilution, so that the worst case would be covered by the groundwater pathway.

3. All airborne/inhalation pathways

Inhalation of prions has not been shown to be a risk factor for vCJD, or for BSE in cattle. In addition, the prion is too heavy a molecule to exist in a vapor state under atmospheric conditions. Decomposition of organic matter, both in the waste and in the infected carcasses, generates gases. The prion agent is a large molecule and could not be present in gaseous form. Further, landfill gas will not entrain any particulate matter (for example as in a chimney flue) as the gas velocity from the landfill surface will be very low. There is therefore no risk from the BSE infective agent associated with landfill gas.

In the UK, there have been public concerns related to airborne prion particulates that might result from open burning of carcasses, but this is not part of the landfill disposal option being considered in British Columbia.

4. Ingestion of contaminated soil/particulates

It is assumed that the material would be handled and the disposal managed so that it is buried at a reasonable depth and covered daily to prevent any disturbance of the site by scavengers. It is understood that loads of slaughter waste would normally be covered as soon possible with a load of MSW. The slaughter waste is wet and so would not generate dust. Domestic ruminants would not have access to the site and could not be exposed. Site workers will ingest a certain amount of dust working on the landfill site, but again as the slaughter waste is wet and covered immediately the potential for human exposure should be minimal. This pathway is not considered further.

5. Incidental ingestion of contaminated surface water

Pathway 5 and 6, discussed below, are in effect subsets of pathway 2, in that they are alternative routes of exposure for infectivity in surface water. Rivers may be used for a variety of water sport activities including angling, boating, canoeing and sail boarding. These activities involve varying degrees of contact with the water. The amounts of water incidentally ingested as a result of water sport activities would be very small, certainly much less than that estimated for normal drinking water consumption. This reduced potential of exposure related to incidental ingestion coupled with the conclusion of increased dilution of infectivity on leachate entering surface water made for pathway 2, would eliminate pathway 5 from further consideration.

6. Consumption of fish

There is a potential for infectivity in solid particles suspended in surface water to be ingested by fish, which may later be caught and used for human food. There is no information on the potential for infectivity to be transmitted in this way, but it is thought to be highly unlikely that infectivity could accumulate in the flesh of fish. In previous studies (DNV, 1997a), the potential for infectivity in fish was assessed to be the same as for drinking water consumption and thus this risk is not considered further.

Selection of Pathway for Detailed Assessment

From the above evaluation it is concluded that only one exposure pathway should be included in the risk assessment: Ingestion of groundwater contaminated by leachate from the landfill.

4.3 Source Definition

The source term for the model requires an estimate of the amount of BSE infective material (expressed as bovine oral ID_{50} units) deposited in the landfill. This in turn depends on the amount of slaughter waste accepted by the landfill which is converted into an equivalent number of cattle slaughtered.

This will be based on the following assumptions:

- Landfill accepts the maximum quantity of slaughter waste (as % of total MSW);
- All slaughter waste is derived from slaughter of cattle; e.g., no dilution with poultry or other species;
- Proportion of OTM reflects the range for BC (see Table 2)
- Quantity of slaughter waste and SRM per animal as given in Table 1.

The resulting values for the two landfill cases are given in Table 6.

Table 6: Estimated numbers of cattle slaughtered for study landfill sites

	2% slaughter waste		5% slaughter waste		100% slaughter waste
Annual Waste Stream (MSW) (tonnes/year)	80,000	4,000	80,000	4,000	
Slaughter waste (tonnes/year)	1,600	80	4,000	200	520
Numbers of cattle slaughtered					
UTM	4,548	227	11,369	568	1,478
OTM	2,106	105	5,266	263	685
Total	6,654	333	16,635	832	2,163

These values are combined with the BSE prevalence (Section 2.2) and infectivity data (Section 3.1) to estimate the amount of infectivity that may be deposited in the cell. Note that in this study it has been assumed that the level of infectivity in a clinical or pre-clinical animal would be the same as for a clinical case for both OTM and UTM animals and that the infectivity in an animal with sub-clinical infection is 0.03 of a clinical case, as used in the CFIA risk assessments (CFIA, 2006 a & b). The resulting estimates are given as median and 95 percentile range values in Table 7.

Table 7: Infectious load to Landfill (bovine oral ID_{50} per year)

	2% slaughter waste		5% slaughter waste		100% slaughter waste
Annual Waste Stream (MSW) (tonnes/year)	80,000	4,000	80,000	4,000	
Source term (bovine oral ID_{50} per year)					
Median	37	2	93	5	12
2.5 percentile 97.5 percentile	3 464	0.15 23	7 1159	0.37 58	1 151

4.4 Behaviour of Material in Landfill

Once the slaughter waste has been deposited in a landfill it will start to decay. The rate of decay will depend on a range of factors, including moisture content, pH and the level of microbiological activity present. As the material decays, the BSE infective agent may be released into the surrounding material.

The putative infectious agent for TSEs is a misfolded isoform of a normal cellular protein (PrP^c), normally designated as PrP^{Sc} or PrP^{TSE} [1] and called a prion by Stanley Prusiner (1998). The term prion was derived from **pro**teinaceous and **in**fectious and is defined by Prusiner (1998) as a proteinaceous infectious particle that lacks nucleic acid. The normal isoform (PrP^c) is soluble and primarily monomeric in solution, whereas PrP^{TSE} forms insoluble aggregates.

There is no data on what might happen to the infective agent in an environment such as a landfill, although some studies are now in progress. The only limited data on the behaviour of a TSE agent when buried in the ground is from a single experiment reported by Brown and Gajdusek (1991) that has been used to support the assumption that TSE infectivity will degrade in the ground and the value of 98% over 3 years (or longer) has been used (Comer *et al*, 1998; Gale *et al*, 1998). The results also showed that there was only limited leaching with most of the residual infectivity remaining in the originally contaminated soil.

Johnson *et al* (2006) have studied the interaction of PrP^{TSE} with common soil minerals and soils. They showed that PrP^{TSE} can bind strongly to soils and could be difficult to desorb. However, they also found that the PrP^{TSE} bound to the soil particles remained infectious.

A major study is also underway at the Institute for Animal Health in Edinburgh, in which the behaviour of infectivity in carcasses buried in the ground is being studied. An initial report was

[1] The infectious form of the prion protein has commonly been labelled as PrP^{Sc}, where Sc stands for Scrapie. This may be confusing when it is used to refer to the infectious agent for other TSEs. For this reason the WHO have used the term PrP^{TSE} for all abnormal misfolded PrP associated with TSEs (WHO Guidelines on Tissue Infectivity Distribution in Transmissible Spongiform Encephalopathies, WHO 2006).

given at Prion 2006 (Fernie, *et al,* 2006) in which it was stated that TSE infectivity may bind strongly to soil components and has very limited mobility in soils with controlled rates of water percolation.

These results and the biophysical properties of the prion protein suggest that any infectivity released from decaying bovine material is likely to remain bound to solid matter in the landfill and thus unlikely to be present in the leachate. However, with current knowledge it is not possible to be certain that BSE infectivity could not be present at some level in leachate. For this reason it is necessary to make some assumption about the maximum credible level of infectivity that could be present in leachate.

For the purpose of this study, it is assumed that there would be no retention of the infectivity deposited in the landfill. In addition, it is assumed that there would be a period of hold-up in the landfill, long enough to allow for the possibility of degradation of the infectivity, but then the infectivity would migrate out of the landfill with the leachate at a rate to balance the input, after any degradation, such that there is no build up of infectivity in the landfill. Degradation of infectivity of 98% is assumed for hold ups of 3 years or more.

4.5 Movement of leachate from Landfill

Leachate will percolate out of the landfill through the underlying layer. The rate of percolation will depend on the hydraulic conductivity of the layer and the depth of leachate in the cell. The leachate level will tend to rise in the cell until the flow out balances the flow in. If the flow out was not able to balance the flow in, then the leachate level would rise too high and cause break outs at the surface. The time for the leachate to move through the underlying layer will then depend on the flux and the depth of the layer.

Estimates of the head required to generate a flux out to balance the water surplus are given for the three rainfall levels used in Table 8. This shows that the flow out would balance the water surplus with no head for 300 or 600mm/year and with a head of 1.5m for a rainfall of 1000mm/year. The time taken for the leachate to traverse the underlying layer is also given for the minimum requirement of 2m. Even at the higher flux there would still be a hold up of 3.6 years, which would clearly double if the requirement for a 4m underlying layer was applied. Thus, even if the infectivity were to move out of the cell with the leachate, there would still be a significant hold up in the landfill that would allow time for degradation processes to occur.

Table 8: Movement of Leachate from Landfill Cell

Rainfall (mm/year)	300	600	1000
Water surplus (mm/year)	1	238	554
Depth of leachate in cell (m)	0	0	1.5
Time to traverse underlying layer (years)	2000	8.4	3.6
2 m underlying layer with hydraulic conductivity of 1 x 10^{-8} m/s			

4.6 Aquifer Assumptions

The leachate that passes through the underlying layer of the landfill will continue to migrate to any underlying aquifer. For this study it is assumed that there is an aquifer below the landfill with characteristics as given in Table 3. A very simple view has been taken for leachate mixing in the aquifer: leachate from the cell taking slaughter waste is assumed to mix completely with the water available in the aquifer directly below the footprint of the cell. No credit is taken for any additional dilution from flow rates of the aquifer, and no additional degradation of infectivity in the aquifer is accounted for.

The extraction point for water, whether for human or animal consumption, is presumed to be located adjacent to the landfill so that it is in effect drawing water from directly beneath the landfill. The modelling of the aquifer, whilst simple, represents very conservative assumptions, both from not taking account of aquifer flow and the fact that any water extraction point would be located some distance from the landfill so the draw of the well would incorporate aquifer water that did not contain leachate.

5.0 Risk Assessment Results

The risk assessment model has been evaluated using @RISK for a range of input scenarios covering two sizes of natural control landfill taking 2% or 5% slaughter waste combined with three levels of rainfall. In fact with the restrictions proposed for the use of natural control landfills, see

Table 4, 5% of slaughter waste is only allowable with the lowest rainfall level (300 mm/yr); however, all the possible combinations have been evaluated. A summary of the input data used in the model is given in Appendix I.

The results are presented in

Table 9 for exposure to humans and Table 10 for exposure to cattle from TSE infectivity that may be present in ground water. In both cases the results are given in terms of bovine oral ID_{50} units and are presented a) for the estimated daily exposure, and b) for the total exposure over one year, assuming that the person or animal gets all their drinking water from the one supply. For each scenario the results are given as a median (50 percentile) value and the 2.5 and 97.5 percentile, representing the range that would include 95% of values. The median daily exposure estimates are also presented in Figure 1 and Figure 2. In addition the cumulative frequency distribution for the annual human exposure for one scenario is given in Figure 3.

Table 9: Summary Results – Human Intake from Ground Water

a) Daily exposure - Bovine oral ID_{50} per day

Scenario			Average MSW Landfill		Small MSW Landfill		100% SW Cell	
	Rainfall mm/yr	Slaughter Waste	Median		Median		Median	
			2.5%ile	97.5%ile	2.5%ile	97.5%ile	2.5%ile	97.5%ile
1	300	5%	2.4E-06		4.8E-07		1.6E-06	
			1.E-07	5.E-05	3.E-08	9.E-06	9.E-08	3.E-05
2	600	5%	2.1E-06		3.8E-07		1.4E-06	
			1.E-07	4.E-05	2.E-08	7.E-06	8.E-08	3.E-05
3	1000	5%	1.8E-06		3.0E-07		1.2E-06	
			1.E-07	3.E-05	2.E-08	6.E-06	7.E-08	2.E-05
4	300	2%	9.6E-07		1.9E-07			
			5.E-08	2.E-05	1.E-08	4.E-06		
5	600	2%	8.5E-07		1.5E-07			
			3.E-06	2.E-05	8.E-09	3.E-06		
6	1000	2%	7.3E-07		1.2E-07			
			4.E-08	1.E-05	7.E-09	2.E-06		

b) Annual exposure - Bovine oral ID_{50} per year

Scenario			Average MSW Landfill		Small MSW Landfill		100% SW Cell	
	Rainfall mm/yr	Slaughter Waste	Median		Median		Median	
			2.5%ile	97.5%ile	2.5%ile	97.5%ile	2.5%ile	97.5%ile
1	300	5%	8.7E-04		1.7E-04		5.7E-04	
			5.E-05	2.E-02	1.E-05	3.E-03	3.E-05	1.E-02
2	600	5%	7.7E-04		1.4E-04		5.0E-04	
			4.E-05	1.E-02	8.E-06	3.E-03	3.E-05	1.E-02
3	1000	5%	6.7E-04		1.1E-04		4.3E-04	
			4.E-05	1.E-02	6.E-06	2.E-03	2.E-05	8.E-03
4	300	2%	3.5E-04		7.0E-05			
			2.E-05	7.E-03	4.E-06	1.E-03		
5	600	2%	3.1E-04		5.5E-05			
			2.E-05	6.E-03	3.E-06	1.E-03		
6	1000	2%	2.7E-04		4.3E-05			
			1.E-05	5.E-03	2.E-06	8.E-04		

Table 10: Summary Results – Cattle Intake from Ground Water

a) Daily exposure - Bovine oral ID_{50} per day

Scenario	Rainfall mm/yr	Slaughter Waste	Average MSW Landfill Median	Average MSW Landfill 2.5%ile	Average MSW Landfill 97.5%ile	Small MSW Landfill Median	Small MSW Landfill 2.5%ile	Small MSW Landfill 97.5%ile	100% SW Cell Median	100% SW Cell 2.5%ile	100% SW Cell 97.5%ile
1	300	5%	1.3E-04	9.E-06	2.E-03	2.7E-05	2.E-06	4.E-04	8.7E-05	6.E-06	1.E-03
2	600	5%	1.2E-04	8.E-06	2.E-03	2.1E-05	1.E-06	3.E-04	7.7E-05	5.E-06	1.E-03
3	1000	5%	1.0E-04	7.E-06	2.E-03	1.7E-05	1.E-06	2.E-04	6.7E-05	4.E-06	1.E-03
4	300	2%	5.4E-05	3.E-06	8.E-04	1.1E-05	7.E-07	2.E-04			
5	600	2%	4.7E-05	3.E-06	7.E-04	8.5E-06	5.E-07	1.E-04			
6	1000	2%	4.1E-05	3.E-06	6.E-04	6.7E-06	4.E-07	1.E-04			

b) Annual exposure - Bovine oral ID_{50} per year

Scenario	Rainfall mm/yr	Slaughter Waste	Average MSW Landfill Median	Average MSW Landfill 2.5%ile	Average MSW Landfill 97.5%ile	Small MSW Landfill Median	Small MSW Landfill 2.5%ile	Small MSW Landfill 97.5%ile	100% SW Cell Median	100% SW Cell 2.5%ile	100% SW Cell 97.5%ile
1	300	5%	4.9E-02	3.E-03	7.E-01	9.8E-03	6.E-04	1.E-01	3.2E-02	2.E-03	5.E-01
2	600	5%	4.3E-02	3.E-03	6.E-01	7.8E-03	5.E-04	1.E-01	2.8E-02	2.E-03	4.E-01
3	1000	5%	3.8E-02	2.E-03	6.E-01	6.1E-03	4.E-04	9.E-02	2.4E-02	2.E-03	4.E-01
4	300	2%	2.0E-02	1.E-03	3.E-01	3.9E-03	3.E-04	6.E-02			
5	600	2%	1.7E-02	1.E-03	3.E-01	3.1E-03	2.E-04	5.E-02			
6	1000	2%	2.7E-04	1.E-05	5.E-03	2.4E-03	2.E-04	4.E-02			

Figure 1: Human Exposure from Groundwater
Median Value – Bovine oral ID_{50} per day

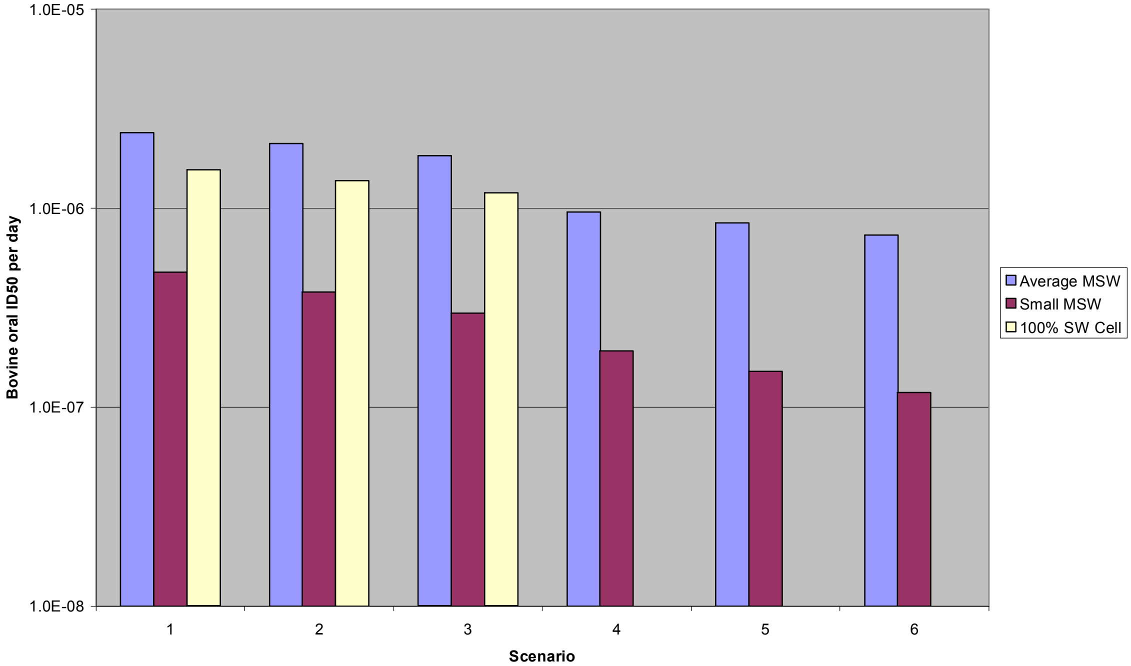


Figure 2: Cattle Exposure from Groundwater
Median Value – Bovine oral ID_{50} per year

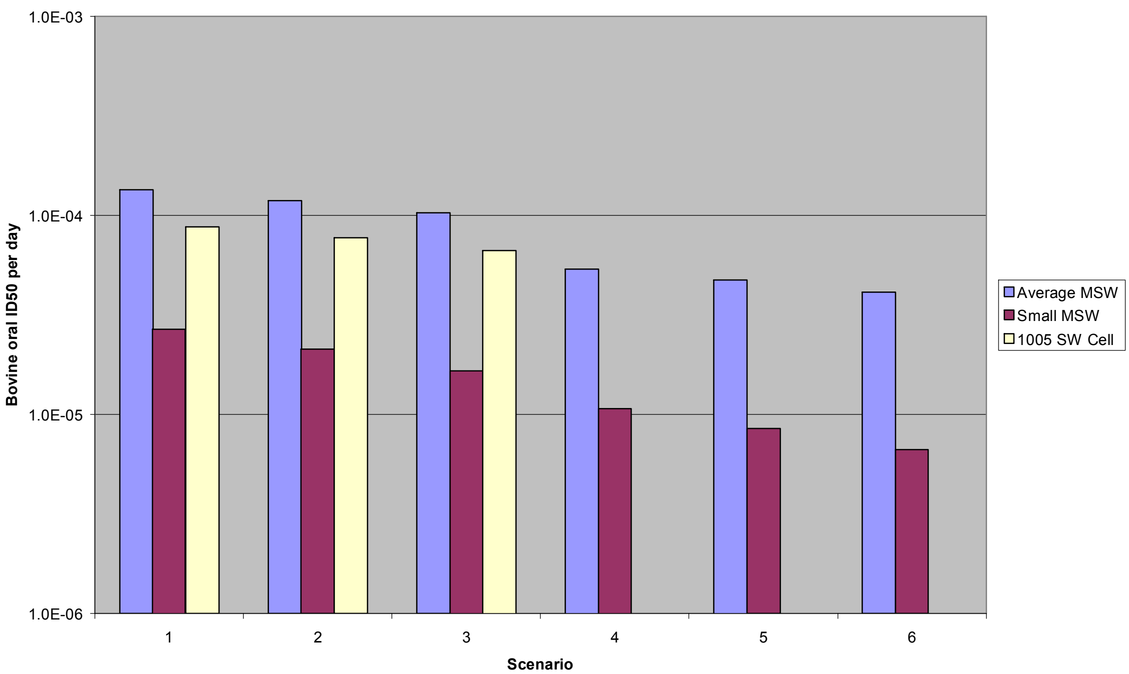
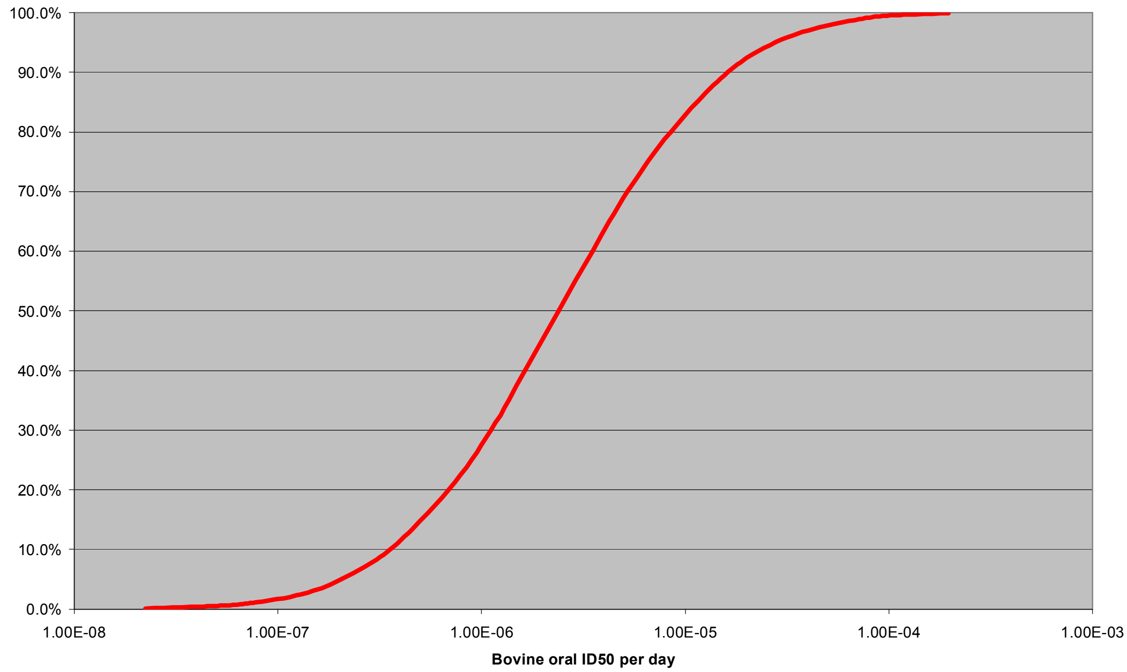


Figure 3: Cumulative Frequency Distribution for Human Exposure
Average MSW; 5% slaughter waste; 300 mm/yr rainfall
Bovine oral ID_{50} per day



6.0 Findings and Conclusion

6.1 Human Exposure

The results for both human and cattle exposure have been presented in terms of ingestion of bovine oral ID_{50} units. This is amount of infectivity that would, on average, infect 50% of an exposed population of cattle. The amount of infectivity in an animal with BSE was given in Section 3.3. Ideally, the exposure to humans would be presented in terms of human oral ID_{50} units, but as explained in Section 3.4 there is little data on the magnitude of the cattle to human species barrier resulting in great uncertainty in the infective dose for people. However, when interpreting the results for exposure to people it must be borne in mind that there certainly will be a species barrier that would reduce the effective exposure, probably by a factor of 1000 or more (see Section 3.4).

There has been limited work done on the effect of cumulative oral doses. Diringer *et al* (1998) showed that repeated dosing caused disease at a higher incidence than a single exposure to that dose, but at a lower incidence than if the total dose had been given as a single exposure. The study also showed that the risk of infection was higher if the time interval between repetitive dosing was short and that there was evidence of clearance of infectivity with time. Diringer's data has been re-evaluated by Gravenor *et al* (2003) who demonstrated that the risk of infection does not simply increase in line with the cumulative dose; for example, the rate of infection when a total dose is divided into 10 separate doses and given at daily intervals or four daily intervals was 36% and 25% respectively of the rate of infection if the total dose is given as a single dose. For this reason the prime results for this study are those for a daily exposure. Nevertheless, results for the cumulative exposure over one year have also been presented as an indication of an upper limit.

The results in

Table 9 and Figure 1 shows that the maximum estimated exposure to TSE infectivity for a person who takes all their drinking water from a source adjacent to a landfill that is taking bovine slaughter waste would be a median value of 2.4×10^{-6} bovine oral ID_{50} units per day (95% range of 1×10^{-7} to 5×10^{-5}). This is for the average MSW landfill, taking a total of 80,000 tonnes of MSW per year with 5% of slaughter waste and with a low annual rainfall of 300 mm/year. If the proportion of slaughter waste is 2%, then the exposure is reduced by a factor of 2.5 (the exposure is directly proportional to the amount of slaughter waste accepted). The exposure reduces slightly as the rainfall increases, but the difference is minimal. For the small landfill, taking 4000 tonnes of MSW per year, the exposures are estimated to be about a factor of 5 less, with a median value of 5×10^{-7} for 5% slaughter waste and a 300 mm/year rainfall. In some landfills, slaughter waste is placed in a separate cell with no MSW. This is represented by Case C, and the exposures are estimated to be 1.6×10^{-6} bovine oral ID_{50} units per day for the low rainfall situation. Thus the exposure is less than for the Average MSW case, though the risk per tonne of slaughter waste is slightly higher.

The annual exposures have also been calculated and shown in part b of Table 9. This shows that the total estimated annual exposure for the worst case (i.e. the Average MSW with 5% slaughter waste and low rainfall) is 9×10^{-4} bovine oral ID_{50} units per year. As indicated above, the effective exposure would be much less than this for a cumulative dose over a long period of time (Gravenor *et al,* 2003). In addition, it is highly unlikely that any one person would receive most of their water intake over a year from a single source.

These would be very low levels of risk, even without taking account of the species barrier. At such low levels of exposure the most likely outcome would be no infections, even if a large population was exposed.

6.2 Cattle Exposure

The results for exposure to cattle are given in Table 10 and Figure 2. These are also given as exposure to bovine oral ID_{50} units, but in this case there will be no species barrier. The results indicate the potential exposure for cattle drinking water extracted adjacent to a landfill site that is taking bovine slaughter waste. As indicated in Section 2.4.2 the water consumption range used for cattle will cover all beef cattle, lactating beef cattle and all but the highest yielding dairy cows. The latter would be most unlikely to be located in the vicinity of any of the landfill sites under consideration. It is estimated that the maximum exposure, for the average MSW landfill taking a total of 80,000 tonnes of MSW per year with 5% of slaughter waste and with a low annual rainfall of 300 mm/year, would be a median value of 1.3×10^{-4} bovine oral ID_{50} units per day (95% range of 9×10^{-6} to 2×10^{-3}). If a worst case water consumption figure of 100 litres/day is used than the median exposure for this case increases to 2.5×10^{-4} bovine oral ID_{50} units per day. This level of exposure would be very unlikely to result in any new infections of cattle with BSE.

6.3 Summary of Conservative Assumptions

The assessment has included a number of conservative assumptions that together will mean that the results will tend to over estimate the exposures rather than under estimate them. Some of the main conservative assumptions include:

1. All the slaughter waste deposited is derived from bovine slaughter.
2. The TSE infective agent, PrP^{TSE}, does not stay bound to solid material in the landfill, but will migrate with the leachate.

3. Any flow of water through the aquifer is not taken into account

4. Water is extracted adjacent to the landfill so that there is no additional dilution from clean water.

5. Animals and people are assumed to take all their drinking water from the source adjacent to the landfill.

6.4 Impact of Landfill characteristics

In a naturally controlled landfill there is no leachate collection or treatment system, so that the landfill is designed to provide a period of hold-up to allow the processes of decay to take place, but ultimately the leachate generated from the deposited material and water surplus will migrate through the underlying layer. In this study it is assumed that TSE infectivity will decay to some extent, but that this is assumed to occur over a period of 3 years or longer, so that additional time in the landfill (resulting from a thicker underlying layer or low permeability material) will not result in any additional reduction in TSE exposure.

Provided the depth of the underlying layer is sufficient to give at least 3 years hold-up, the important characteristics then become those that will ensure that the material is contained as intended and that there are no additional pathways of exposure. In terms of physical characteristics, separation between the seasonal high water table and the waste cells is important as this will minimise the risk of influx of water into the waste cells that could lead to surface water contamination. It is then important that the operational procedures are followed, in terms of the way the slaughter waste is deposited, maintenance of daily cover, control of surface water and run-off, etc. These will ensure that the assumptions about exposure pathways remain valid.

6.5 Conclusion

The risk of exposure to BSE infectivity of both domestic cattle and people in the vicinity of naturally contained landfill sites taking bovine slaughter waste has been assessed using a quantitative risk assessment approach. The assessment has covered a range of landfill sizes and rainfall levels to represent the spectrum of possible sites in British Columbia rather than consider any specific site. Alternative exposure pathways were reviewed qualitatively, and it was concluded that the only credible exposure pathway was through infectivity moving from the landfill site with leachate and contaminating the groundwater. The potential exposure for this pathway has been shown to be very low for both people and cattle. It is therefore concluded that the disposal of bovine slaughter waste in naturally contained landfills would not pose any significant risk to either cattle or people provided that the risk management factors assumed in this risk assessment are valid.

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Appendix I - Summary of Model Input Parameters

1. Run Options

Parameter	Values
Landfill Type	A – Average MSW; B – Small MSW; C - !00% SW Cell
Proportion Slaughter Waste	5% or 2%; or 100% for Case C
Rainfall	300, 600 or 1000 mm/yr

2. BSE Prevalence and Infectivity

Parameter	Distribution	Value
BSE Prevalence	Fixed	1.67 per million; 10 clinical or pre-clinical cases per 6 million adult cattle
Proportion of cases detected	Fixed	50%
No of sub-clinical cases	Fixed	10 per clinical case
Relative infectivity of sub-clinical cases	Fixed	0.03
Factor for prevalence in UTM	Fixed	100
Infectivity of CNS tissues in clinical case	Log normal	Median – 5 bovine oral ID_{50} per g 99 percentile - 100

3. Slaughter and Landfill

Parameter	Distribution	Value
Proportion of OTM cattle	Discrete	0.10 – 6% 0.21 – 46% 0.45 – 48% Based on values in Table 1. Mean = 0.32
Weight of SRM	Fixed	UTM – 224 kg OTM – 276 kg
Degradation of Infectivity	Normal	Mean 0.98 Standard deviation 0.01
Water surplus	Formula	Rainfall * 0.79 - 236

4. Landfill Definition

		Average MSW Site	Small MSW Site	100% SW Cell
Annual Waste Stream	tonnes/year	80,000	4,000	520
Disposal footprint	hectares	5	3	3.3
Open footprint	hectares	0.04	0.02	0.008
Aquifer thickness	m	6	3	6
porosity of aquifer	ratio	0.3	0.3	0.3

5. Water consumption

Parameter	Distribution	Value
Human tap water intake	Log normal	2.5 percentile – 0.31 97.5 percentile – 2.954
Bovine consumption	Uniform Worst Case	42 – 66 litres / day 100 litres / day

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