LEACHATE CHARACTERISTICS ARISING FROM THE FOOT AND MOUTH MASS BURIAL SITE IN SCOTLAND

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SUMMARY: The 2001 outbreak of Foot & Mouth Disease (FMD) affected many rural areas throughout the United Kingdom. Premises found to be infected with the disease had their stock slaughtered and disposed by incineration on-farm in order to prevent further spread of the disease. Similarly, in Cumbria and Dumfries and Galloway premises adjacent to, or within 3km of, an infected premise were also culled. In the majority of cases these stock were either rendered, incinerated or buried at centralised off-farm facilities. In Scotland, the mass burial site was located at Birkshaw Forest near Lockerbie in Dumfries and Galloway. This site contains over 400,000 carcasses and this paper describes the character of the Leachate, discusses the potential of the FMD virus surviving in leachate, and methods available for inactivating the virus in leachate during the initial period of infectivity.

1. INTRODUCTION

Birshaw Forest is situated on top of a hill overlooking the Annan River valley near Lockerbie in Dumfries and Galloway. The site contains in excess of 400,000 carcasses that were disposed in six engineered pits during April and May of 2001. The carcasses were disposed of under the provisions of the Animal Health Act and as such it is not a licensed facility. However, from the outset the site was designed, operated and managed as a waste management licensed merchant landfill. The primary objective was to maintain a disposal route at all times throughout the preventative cull in order to minimise the risk of spreading FMD to other regions. This led to operational challenges on site including the management and disposal of leachate arising from the initial, rapid decomposition of the carcasses.

The site is in effect a mono-disposal facility that produces a leachate that has its own individual character and is remarkably strong in comparison to other leachates found at more conventional facilities. Initially, the chemical oxygen demand (COD) values started at around 160,000 mg l^{-1} with little or no ammoniacal-N. The COD values rapidly fell to around 20,000 – 40,000 mg l^{-1} with the ammoniacal-N rising to around 2,000-4,000 mg l^{-1}.

All this was occurring within a very short period and it was clearly neither practical nor possible to set up either on-site pre-treatment or full treatment of the leachate within the time scale available. Off-site disposal was the only practical option with temporary on-site storage to reduce the loadings at the selected disposal point.

2. ON-SITE DISPOSAL OPERATIONS

Disposal operations at Birkshaw commenced at the end of March 2001 and were substantially complete by the middle of May 2001 with all the carcasses coming from premises where no clinical signs of FMD were identified. However, because of the proximity of the premises to infected farms it is likely that some of the animals would have either been exposed to or be incubating FMD.

2.1 Animal Disposal Statistics

Sheep were the predominant livestock disposed at Birkshaw and although the region has a large beef and dairy industry, very few cattle were disposed this way. In line with advice provided by Spongiform Encephalopathy Advisory Committee (SEAC) the only cattle buried on site were under 18 months old, and then, only if disposal by rendering or incineration was unavailable. A breakdown of the type and quantity of livestock disposed at Birkshaw from data supplied by the State Veterinary Service (SVS) is detailed in Table 1 below.

2.2 Carcass Processing

One of the major disposal difficulties encountered was that the carcasses very soon formed an unstable waste mass within the pits. Following death of an animal, gases soon form within the body as part of the decomposing process leading to bloating of the carcass that leads to considerable uplift forces allowing the carcass to rise to the surface. Shortly afterwards, the carcass will rupture with the potential for spreading the disease and other pathogens in aerosol form to atmosphere. To counter this a system was devised following a series of assessments and trials on various options to prevent bloating as detailed below.

2.2.1 On-farm puncturing of the carcass

Professional slaughterers that had the necessary skills to puncture the carcasses to prevent bloating carried out the cull. However, there were a number of concerns against the adoption of this method including the increased time needed on-premise causing a significant delay to the overall cull process, the potential for releasing body fluids and spreading the disease during transportation, and the potential for the carcass to 'self-seal' by movement of internal organs during transportation thus negating the exercise.

Table 1 – Animal Disposal Statistics (SVS Cull Statistics, Ayr Divisional Office)

Type	Dumfries & Galloway	The Scottish Borders	Total Number of Carcasses
Sheep	397,331	37,300	434,631
Cattle	45	2,000	2,045
Pigs	287	1	288
Goats	151	-	151
Deer*	1	-	1
Total	397,815	39,301	437,116

Note: *Road kill found on nearby motorway

2.2.2 On-site slaughter and puncturing of the carcass

This option was never pursued in Scotland but would involve the transportation of live animals to the burial site for on-site slaughtering and puncturing. This would raise a number of concerns including the potential to spread disease during transportation in 'open' livestock vehicles, increased activities and facilities on-site and the potential delay to the on-site disposal operation.

2.2.3 On-site puncturing of the carcass

This was the adopted method for the disposal operation comprising the transportation of carcasses to site in 'sealed' vehicles, tipping into a reception pit and carrying out four passes of a waste compactor. This was found to be the most effective way of rupturing the carcass and breaking up the skeletal frame whilst still leaving the carcass in a manageable form. This method worked well on all types of livestock except cattle where the system had to be developed in order to achieve the same effect by using two excavators to initially separate the carcass into two or three sections.

This system resolved the issue of bloating and, whilst the waste mass still had poor bearing capacity, it enabled the burial pits to be capped with clay without the risk of carcasses breaking through. Another advantage of the system was that it enhanced the initial decomposition of the carcasses in particular by breaking up the skeletal frame it enabled the early exposure of the marrow in the bones.

2.3 Leachate Management

Initial leachate management proved problematic with open clay burial pits in an area of high rainfall, in excess of 1m per year, and no available disposal route for the high strength leachate generated on site. To manage the leachate within the pits longitudinal drains, comprising slotted pipework with 40mm single size stone surround, were fitted or retrofitted in the waste mass leading to sumps comprising 600mm slotted pipes with 60mm single size stone surround. The large stone size was utilised to limit the effect of fats and fleece blocking the drainage pathways.

Temporary leachate storage was provided using 40 ISO containers (each having a 20,000 litre capacity) even so the leachate levels built up in all the pits prior to establishing a suitable disposal route. Subsequent calculation and measurement of the leachate quantities indicate that around 4,000m^3 of leachate was generated during the disposal period.

3. FMD LEACHATE

As the burial pits are in effect mono-disposal facilities, they will generate a leachate with a specific character. The nature of the waste will generate a high strength leachate that in all probability will contain the FMD virus that could survive for at least 180 days following disposal of the carcasses. During this period the leachate will require disinfection to prevent the risk of further spread of disease.

3.1 Quality

During the operational phase, it was not possible to obtain systematic and reliable analyses of the leachate. An initial sample taken after the first week suggested that the chemical oxygen demand (COD) was in excess of 160,000 mg l^{-1} with little or no ammonia, which would be compatible for a waste of this nature in its early aerobic phase of decomposition. Subsequent samples taken from the pits when they were exposed and following periods of heavy rain provided inconsistent and unreliable results.

Therefore, the data presented are for the periods following interim capping and final restoration where leachate generation rates have stabilised thus producing more consistent chemical analyses. Even so, during the period of interim capping and construction of the permanent capping, between July 2001 and March 2002, fluctuating results were still encountered due to elevated and rapid infiltration rates of rainfall.

The results given in Table 2 show the summary of all the leachate samples taken on site during the period July 2001 and April 2003 from the 9 leachate sumps taken on a monthly programme. They show large fluctuations in the key determinands of COD and ammonia. This is partially due to the changing character of the leachate but also reflects different sizes, infiltration rates and generation rates of the individual pits. Table 3 sets out the average strength of all the samples for each month with Table 4 detailing the monthly leachate quality for Pit 3.

Pit 3 was selected as this has the most consistent infiltration and generation rates through the year and clearly shows the decline in strength of the leachate through the period as shown in Figure 1. This is not so apparent in the average leachate strength as some of the pits still show fluctuating levels in the key determinands. However, based on site observations during leachate extraction, it is suggested that pockets of leachate are withheld in the waste mass by fats and fleece and following further decomposition, allows the release of 'aged' leachate thus leading to episodic elevated levels of the organic elements.

Also noted are the significant odours associated with the leachate that require careful management both on site and at the disposal point. Overall, the results show the continued high strength of the leachate in comparison with other leachates such as those encountered at Municipal Solid Waste (MSW) sites in the UK that pose difficulties in treatment and disposal.

Table 2 – FMD leachate analyses

Determinand	Nº of Samples	Maxima	Minima	Mean	Median	Standard Deviation
pH	199	8.0	5.9	6.9	6.9	-
Calcium (Ca) mg l^{-1}	194	700	2	208	183	132
Iron (Fe) mg l^{-1}	193	335	0	52	33	53
Phosphate soluble reactive (as P) mg l^{-1}	198	476	1	55	25	77
Ammonia (NH_3-N) mg l^{-1}	199	19,200	28	3,294	2,700	2,702
Total Oxidised Nitrogen (TON) mg l^{-1}	9	10.0	0.2	2.1	0.6	3.2
Biochemical Oxygen Demand (BOD) mg l^{-1}	9	38,500	300	12,700	11,600	12,875
Chemical Oxygen Demand (COD) mg l^{-1}	199	134,200	500	20,414	16,000	20,216
Electrical Conductivity (EC) µS	194	45,000	5	11,210	10,985	7,435
Alkalinity to pH 4.5 (as $CaCO_3$) mg l^{-1}	199	88,200	152	11,935	9,400	10,233
Suspended Solids (Ss) mg l^{-1}	199	5,432	10	389	260	486
Dry Residue (Dr) mg l^{-1}	108	82,400	470	6,866	4,960	8,498

Note: BOD:COD ratio determined on average leachate results equates to 1:2

Table 3 – Average monthly FMD leachate results

Date	pH	Ca mg l^{-1}	Fe mg l^{-1}	P mg l^{-1}	NH_3-N mg l^{-1}	TON mg l^{-1}	BOD mg l^{-1}	COD mg l^{-1}	EC µS	$CaCO_3$ mg l^{-1}	Susp.s. mg l^{-1}	Dry r. mg l^{-1}
Jul '01	6.4	292	79	79	1,838	n.a.	n.a.	31,801	4,420	12,326	370	n.a.
Aug '01	6.5	n.a.	n.a.	81	2,546	n.a.	n.a.	75,340	n.a.	16,230	226	n.a.
Sep '01	6.2	192	58	76	2,036	n.a.	n.a.	7,188	9,605	7,916	695	n.a.
Oct '01	6.3	88	93	240	1,173	n.a.	n.a.	8,487	10,422	2,825	769	n.a.
Nov '01	6.6	273	15	188	2,356	n.a.	n.a.	30,267	9,669	12,542	696	n.a.
Dec '01	6.8	164	18	106	2,423	n.a.	n.a.	17,298	9,972	21,568	621	n.a.
Jan '02	6.9	205	12	107	2,482	n.a.	n.a.	11,958	9,382	8,616	733	n.a.
Feb '02	6.9	171	58	27	4,567	n.a.	n.a.	26,444	11,952	8,167	233	n.a.
Mar '02	6.9	64	29	16	6,133	n.a.	n.a.	26,667	8,842	19,856	271	n.a.
Apr '02	6.5	234	108	42	7,167	n.a.	n.a.	30,000	16,689	13,244	338	n.a.
May '02	6.8	239	76	24	2,737	n.a.	n.a.	25,778	13,867	14,611	160	8,688
Jun '02	7.2	229	68	24	3,386	n.a.	n.a.	24,000	10,822	10,841	265	6,489
Jul '02	6.9	188	62	22	2,061	n.a.	n.a.	12,889	13,801	8,833	416	6,267
Aug '02	6.9	330	69	29	4,132	n.a.	n.a.	10,944	14,154	9,340	175	6,242
Sep '02	7.1	205	58	23	4,647	n.a.	n.a.	16,667	11,942	9,451	99	5,977
Oct '02	7.1	315	69	30	4,708	n.a.	n.a.	13,222	14,718	11,764	568	4,827
Nov '02	7.3	164	40	22	2,403	n.a.	n.a.	12,278	12,968	22,469	301	6,427
Dec '02	7.5	173	35	23	2,823	n.a.	n.a.	14,444	10,732	7,962	433	6,206
Jan '03	7.3	221	35	14	2,829	n.a.	n.a.	15,056	3,610	8,437	323	6,244
Feb '03	7.2	195	47	18	3,641	n.a.	n.a.	9,278	19,611	16,823	211	5,517
Mar '03	7.5	178	16	3	3,528	n.a.	n.a.	28,833	10,568	9,388	304	6,148
Apr '03	7.5	176	16	4	3,774	0.3	12,600	30,000	11,217	10,336	358	6,448

Note: n.a. = not analysed

Table 4 – Pit 3 monthly FMD leachate results

Date	pH	Ca mg l^{-1}	Fe mg l^{-1}	P mg l^{-1}	NH_3-N mg l^{-1}	TON mg l^{-1}	BOD mg l^{-1}	COD mg l^{-1}	EC µS	$CaCO_3$ mg l^{-1}	Susp.s. mg l^{-1}	Dry r. mg l^{-1}
Jul ‘01	6.4	418	56	6	1,825	n.a.	n.a.	1,939	22,000	6,393	272	n.a.
Aug ‘01	6.2	n.a.	n.a.	46	44	n.a.	n.a.	53,700	n.a.	11,930	155	n.a.
Sep ‘01	6.1	377	41	8	1,860	n.a.	n.a.	1,807	20,000	6,117	570	n.a.
Oct ‘01	6.2	139	92	164	1,321	n.a.	n.a.	18,932	10,719	1,719	76	n.a.
Nov ‘01	6.5	643	11	137	3,402	n.a.	n.a.	39,000	11,504	15,165	770	n.a.
Dec ‘01	6.6	233	21	68	2,790	n.a.	n.a.	13,114	9,946	20,726	560	n.a.
Jan ‘02	6.9	377	28	126	3,391	n.a.	n.a.	17,950	14,385	14,761	900	n.a.
Feb ‘02	6.6	280	125	11	6,700	n.a.	n.a.	14,000	12,250	9,400	260	n.a.
Mar ‘02	6.8	140	40	7	7,400	n.a.	n.a.	30,000	9,600	14,000	220	n.a.
Apr ‘02	6.3	425	130	21	5,200	n.a.	n.a.	20,000	16,360	11,100	240	n.a.
May ‘02	6.6	390	145	23	2,170	n.a.	n.a.	32,000	14,000	13,250	10	10,130
Jun ‘02	7.0	410	162	21	3,950	n.a.	n.a.	21,000	12,900	16,200	230	9,800
Jul ‘02	6.9	290	81	10	1,900	n.a.	n.a.	11,000	13,280	9,600	390	6,900
Aug ‘02	7.0	370	67	12	3,350	n.a.	n.a.	12,000	12,910	8,800	260	5,100
Sep ‘02	7.0	305	120	13	4,780	n.a.	n.a.	20,000	15,470	11,600	140	8,760
Oct ‘02	6.9	365	67	23	5,200	n.a.	n.a.	12,000	18,270	11,910	220	9,270
Nov ‘02	7.4	285	70	14	2,500	n.a.	n.a.	16,000	14,760	25,170	250	7,367
Dec ‘02	7.7	190	33	4.5	2,250	n.a.	n.a.	7,000	9,520	6,540	435	4,950
Jan ‘03	7.5	215	77	8	2,180	n.a.	n.a.	8,500	3,370	5,350	340	4,500
Feb ‘03	7.2	230	88	14	2,430	n.a.	n.a.	9,500	12,400	7,030	165	4,250
Mar ‘03	7.6	205	37	<1	2,560	n.a.	n.a.	9,000	8,160	7,570	200	4,170
Apr ‘03	7.5	165	3	1	1,900	0.2	5,500	6,500	10,350	5,460	170	3,770

Note: n.a. = not analysed

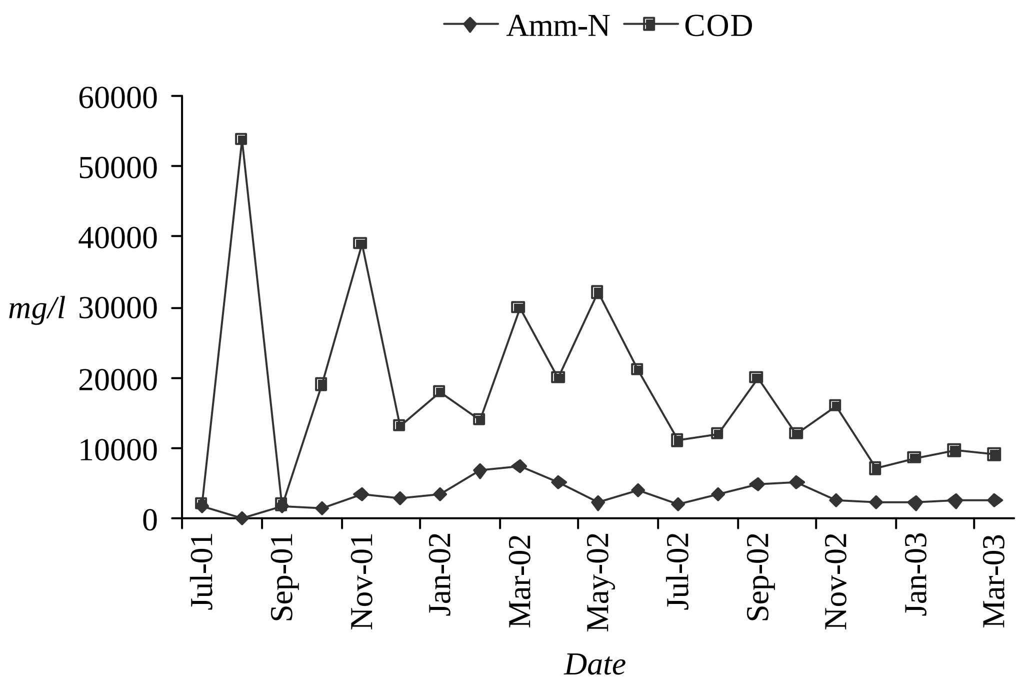

Figure 1. Pit 3 trends

3.2 Disinfection

It has already been identified that the leachate may well contain an active FMD virus during the initial period of the site and active measures must be taken to ensure that the virus is inactivated in order to prevent the spread of further disease and therefore a clear understanding of the disease and the process of inactivation must be known.

3.2.1 FMD Virus

FMD is a highly communicable disease that affects domesticated ungulates, i.e. cattle, sheep, goats and pigs, but also affects a number of other mammalian wildlife specie, around 70 specie. The virus is from the Picornaviridae family with 7 serotypes:

Types: O, A, C, SAT1, SAT2, SAT3 and Asia1

There are also many strains within each of the serotypes all of which cause disease that is clinically indistinguishable, but immunologically distinct so that there is no cross protection between types. The disease is infectious by direct and indirect contact, normally by inhalation or ingestion, and the virus is normally inactivated within minutes at a pH <6.0 or >12.5. Healthy sheep tend not to die of the disease with only sick or weak animals succumbing, although spontaneous abortion of lambs can occur.

In respect to survivability, following the death of an infected animal, rigor mortis is accompanied by glycolysis producing lactic acid thus lowering the pH of the internal organs, tissues and musculature to less than 6.0 that will inactivate the virus. This process commences after 18 hours and reaches its maximum between 48-72 hours post mortem. However, in Scotland where all the animals were buried within 24 hours this process was interrupted within the burial pits by infiltration of rain and groundwater preventing the reduction in pH thus enabling the virus to survive. Figure 2 shows the pH of the leachate within Pit 3 that clearly demonstrates the pH remaining above 6.0 and so it has to be assumed that the virus would have survived in this environment and demonstrates the need for the leachate to be disinfected prior to leaving the site.

3.2.1 FMD Inactivation

The virus may be inactivated in a number of ways including thermal, filtration, complex combination disinfectants and chemical methods. Thermal inactivation would require elevating the leachate to a temperature greater than 50^o C, but organic matter can interfere with the process and to ensure complete inactivation the temperature would have to be raised to 90^o C for at least 90 minutes. This would be both a costly and difficult operation to carry out on site and in all likelihood could not have been established in the timescale available.

Filtration would require the leachate to be passed through a 20 nm filter that would remove the virus from the leachate. The concentrate and filter would retain the virus so would require inactivation by chemical or thermal means prior to disposal. With the elevated COD and suspended solids and the quantity of leachate generated this system would not have been practical.

Complex combination disinfectants include idofors, acids, hypochlorites and alkylating agents that are highly effective but are expensive and have their own environmental concerns that would require the treated leachate to be neutralised prior to discharge.

Chemical methods were adopted on-site for the disinfection of the leachate as this was the simplest and most cost effective method. This involves the addition of acids or alkalis as a method of pH control and Table 5 details the survival times of the virus at relevant pH levels. Because the likely disposal route would be through an existing landfill treatment plant, where consent levels for pH would be between pH 6.0 and 11.0, and that acids can be difficult to handle in the operational conditions found on site, it was decided to elevate the pH using sodium hydroxide pellets for the virus inactivation. The sodium hydroxide pellets had the benefit that this form of alkali came in sealed bags and was relatively easy to handle.

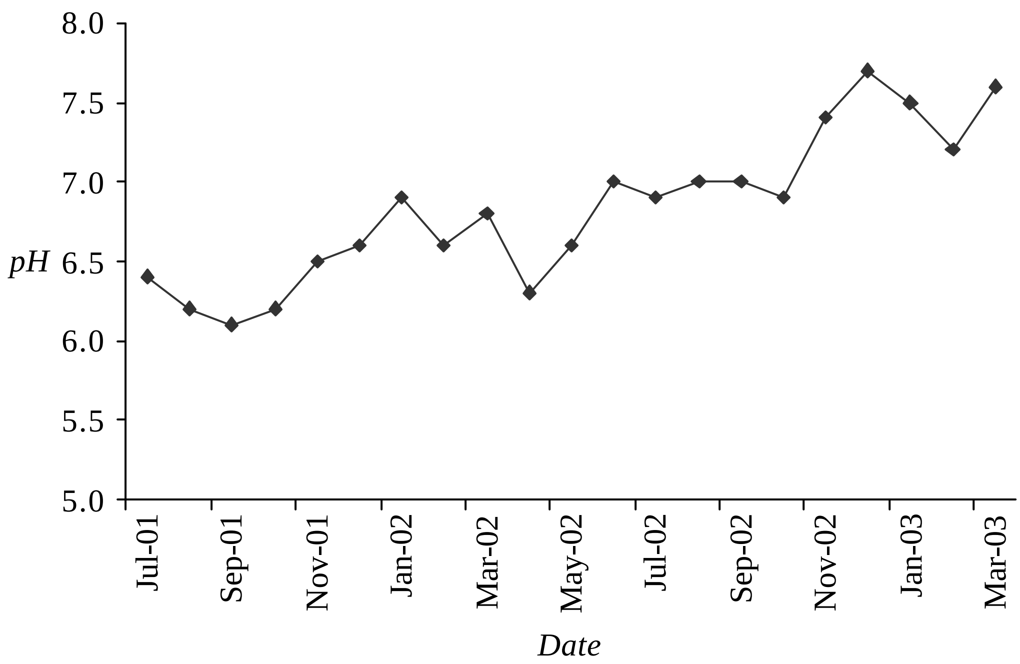

Figure 2. Pit 3 pH levels

Table 5 – FMD survival times relative to pH in tissue culture medium

pH	Time
2.2	15 seconds
4.0	15 seconds
6.0	2 minutes
7.0	Several weeks
9.0	1 week
10.0	14 hours
12.5	15 seconds

Following veterinary advice, it was agreed to raise the pH to 10.5 for at least 4 hours as a method of significantly reducing the risk of virus survivability.

3.3 Treatment

For this particular leachate with a high strength, a sustainable disposal route through a treatment plant was difficult to determine. No wastewater plants capable of handling the leachate were found in either Scotland or the north of England. Eventually, a landfill was located in the north-west of England with an existing industrial wastewater and leachate treatment plant that could take the leachate at the quantities generated. Even so, the treatment plant required extensive refurbishment and upgrade before they could start treatment. Fortunately, there was sufficient storage capacity at the landfill whilst the works were underway.

The treatment process comprises a large, sealed storage tank that allows the delivery tankers to directly discharge the leachate into the treatment process. This tank also takes the leachate from their operational landfill. The combined leachate then goes into a dissolved air flotation (DAF) plant for pre-treatment, essentially fine bubble aeration and chemical dosing is used to encourage a ‘scum’ or sludge which contains between 30 and 50% of the organic material within the leachate. The sludge from the DAF plant is pressed in a fully enclosed press, to form a cake prior to disposal back into the landfill. The filtrate from the DAF plant then goes to the biological treatment lagoons, that have been increased in size to a total of 2,400m^3, comprising aeration with liquid oxygen. The treated effluent is then discharged to an upgraded primary sewage treatment facility prior to final discharge to sea via a 5km long outfall.

4. DISCUSSION

Current contingency plans for future outbreaks of FMD have identified the primary disposal routes as commercial incineration and rendering plants. However, both methods will have a limited capacity that may well be unable to cope with the pace of any future major operations as encountered in 2001. The next tier in the hierarchy are merchant landfills where existing leachate treatment plants are unlikely to be able to cope with the strength of leachate arising from animal carcasses. Similarly, with the implementation of the EU Landfill directive and the diversion of active waste from landfill, future leachate treatment plants are likely to have limited facility for biological treatment so this disposal route will need to recognise the implications of high strength and possibly infected leachate arising from disposal operations.

5. CONCLUSION

Prior to the 2001 outbreak of FMD, the last major outbreak was in the 1960s where the majority of livestock was disposed on-farm. As such, there is very little information regarding the environmental impacts arising from burials and no data regarding the characteristics of a leachate arising from such an operation and the aim has been to identify the nature of the leachate and the associated difficulties that will be encountered in respect to onward disposal and treatment including:

- High BOD, COD and ammoniacal nitrogen loadings
- Significant odours
- Disinfection required for virus inactivation during the early stages

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