AMENDMENT

‘Pollution potential of cemeteries’ - R&D P223

In early 2004 a number of errors were noticed in the report on the ‘Pollution potential of cemeteries’ R&D P223, which is available from the Agency’s National Customer Contact Centre (NCCC). These errors were in the calculations given as worked examples of pollutant loading in 3 hypothetical cemeteries. The errors are therefore largely confined to Appendix B of the report. A new edition of the report is now being sold as before by the NCCC however, for those who have already purchased a copy the revised Appendix B and a short excerpt from Section 3. The main changes from the original version are highlighted in red.

The risk assessment methodology provided in the main report was not affected by these errors, however readers are advised that the examples and calculations below can offer only a flavour of the subject. In view of the increased availability of contaminant transport models since this report was prepared, site-specific model use is to be preferred where this is appropriate.

Copies of the revised Appendix B and Section 3 will be made available soon for download from the Agency’s Science & Research Publications web site:
http://www.environment-agency.gov.uk/science/454158/110943/?version=1&lang=_e

Science Group: Air, Land and Water - March 2004

3. CHARACTERISTICS OF CEMETERIES AS SOURCES OF POTENTIAL POLLUTION

3.1 Introduction

This section examines the possible contaminant loading that may be derived from burials in the United Kingdom. The processes controlling the release of potential contaminants are complex, involving the interaction of hydrogeological and climatic factors, cemetery management practices and variations in practices associated with the preparation of bodies for burial, for example coffin manufacturing and embalming processes.

In considering human interments, it is assumed that current UK practices are followed regarding the preparation of the body and in the method of burial. In particular:

- Embalming - that no toxic metals or alkaloid substances have been used in preparation of corpses since 1951, when their use was banned. Half of all human burials having undergone some embalming with a formalin solution;
- Coffins - constructed predominantly of chipboard or MDF with a paper veneer;
- Depth of single burial 1.8 m (bottom of coffin 1.8 metres below ground level).

For other interments it is assumed that:

- Burial of farm stock follows the Code of Good Agricultural Practice for the Protection of Water (MAFF 1998);
- Commercial burial of pets (pet cemeteries) is in accordance with the voluntary code of conduct advanced by the Association of Private Pet Cemeteries and Crematoria;
- At green burial site the corpse is enclosed in a readily degradable coffin, or only shrouded in woollen cloth. Burial at depth of 1.3 metres. Grass or shrub cover to grave.

3.2 Potential pollution loads from human and animal burials

3.2.1 Composition of corpses and accompanying burial material

Table 3.1 illustrates that the composition of human and animal bodies is very similar, although there will be some variation as a consequence of differences in build between individuals. Forbes (1987) estimated the broad elemental composition of the human body. The composition, shown in Table 3.2, is consistent with the range of principal chemical contaminants found at cemeteries, as described in Chapter 2.

Table 3.1 Comparison of composition of human and bovine bodies (percentage weight).

Component	Human[1]		Bovine[2]
Water	64		56
Protein +	20	)	
Carbohydrate +	1	)	28 (as Meat and
Mineral salts	5	)	Bone Meal)
Fat	10		16 (as Tallow)

[1] van Haaran (1951)
[2] Taylor, Woodgate and Atkinson (1995)

Table 3.2 Elemental composition of a human body based on a standard or reference man of 70kg body weight

Element	Mass (g)
Oxygen	43000
Carbon	16000
Hydrogen	7000
Nitrogen	1800
Calcium	1100
Phosphorus	500
Sulfur	140
Potassium	140
Sodium	100
Chlorine	95
Magnesium	19
Iron	4.2
Copper	0.07
Lead	0.12
Cadmium	0.05
Nickel	0.01
Uranium	0.00009
Total body mass	70000

The balance of elements in the table is consistent with the observation that the principal pollutants which derive from corpses are dissolved and gaseous organic compounds and dissolved nitrogenous forms (particularly ammoniacal nitrogen), with a potential for increased pH resulting from the high proportion of calcium ions.

3.2.2 Factors affecting the rate of release of contaminants from burials

The process which controls the production, release and potential migration of pollutants from buried corpses is microbial decay and is essentially the same as that which controls the stabilisation of wastes in landfills. Landfill decay processes are described in some detail in Appendix A of Waste Management Paper No 26A (Department of the Environment, 1993). In the case of landfilled wastes, the initial aerobic phase is completed rapidly and, because the input of wastes exceeds the rate at which oxygen may gain access to the degrading mass, the greater part of decomposition takes place under anaerobic conditions. The analogy with landfilled putrescible waste is useful in assessing potential impacts and Dent and Knight (1998) have remarked - "Cemeteries are best thought of as special kinds of landfill in that they mostly comprise a limited range of organic matter covered by soil fill". However, a comparison of the elemental compositions of vertebrate bodies with typical domestic waste highlights some important contrasts:

- The water content of a human body is about twice that of domestic refuse (65-70% in a corpse, compared to 34% in domestic waste). Lack of available moisture may inhibit both aerobic and anaerobic decay (Department of the Environment, 1993).

- The C:N:P ratio in vertebrate cadavers (about 30:3:1) provides a good balance between the principal microbial nutrients; whereas the ratios in domestic wastes show a deficiency in terms of phosphorus.

Both these factors encourage rapid and complete degradation of corpses, when compared with domestic waste. The relative rate of degradation of different types of carbon compounds has been estimated by the Environment and Industry Research Unit, Polytechnic of East London (1992). This indicates that 70% of the weight (including water) comprises rapidly degradable protein, carbohydrates and lipids, with some 30% comprising resistant bone, enamel (teeth) and keratin (nails and hair). Allowing for a 70 kg corpse, buried in a 10 kg chipboard coffin, the proportions of readily to slowly degraded matter are recorded in Table 3.3.

Table 3.3 Proportions of readily and slowly degraded matter in a coffined human corpse

Component	Category %			
	Readily degradable	Moderately degradable	Slowly degradable	Inert (Non-degradable)
Human corpse	60	15	20*	5*

Note * Assumes mineral salts (ashes) represent final stable residue; slowly degradable component of bones may be considered essentially inert for practical purposes.

Farm or domestic animals and poultry corpses show degradation characteristics either comparable to those of a human or with increased proportions of less rapidly degraded tissues, particularly poultry feathers.

In human corpses that are not embalmed, aerobic bacteria are initially inhibited due to changes in body tissues. The only exception is the skin surface which is exposed to the atmosphere. The principal agents of putrefaction are therefore anaerobic bacteria essentially akin to those found in solid waste degradation processes. However, the analogy with landfill is likely to cease as the decay products migrate from the grave, where they may encounter aerobic conditions within the ground. At a normal burial density the volume of soil adjacent to, and overlying, each coffin will be equal to some eight times the volume of the burial (see Assumptions in Appendix B1).

Consequently, the zone in which anaerobic conditions persist during decay of the body is likely to be restricted to the immediate vicinity of the grave, particularly in the case of free draining soils. Subsequent transformations of initial degradation products will be essentially aerobic. At sites where poor drainage causes waterlogging, rather more extensive anaerobic conditions may develop. The extent will, however, be a function of the rate of burials and the initial oxygen content of the water accumulating in the ground. In contrast, at landfill sites the large relative mass and loading rate of decomposing waste creates long-term anaerobic conditions.

Manufacturers of embalming fluids claim that high index cavity and arterial embalming may inhibit “wet” anaerobic degradation. Instead, dry aerobic decay is believed to take place.

Coffins and shrouds are composed of less rapidly degraded materials than the corpses which they enclose. Nevertheless, in modern burial practice chipboard and MDF coffins may begin to disintegrate rapidly in the ground compared with solid wooden boxes. Decay and collapse of chipboard coffins is reported to be evident within one month of burial, compared with 15 to 20 years in the case of pine or over 60 years for elm boxes, whilst cardboard coffins are reported to collapse onto the cadaver almost immediately on infilling the grave (West, 1998).

The rate of decay is also influenced by climatic and physical factors, including:

(a) Climate - warm temperatures accelerate decomposition, whilst freezing will inhibit or suspend the process;

(b) Soil lithology- a well drained soil, such as a coarse sand, will accelerate decomposition, whereas a poorly drained soil has the reverse effect. Peat bogs have been found to inhibit bacterial growth and bodies may remain preserved for thousands of years.

(c) Burial practice - including the depth of burial and construction of the coffin. Both these factors control the ease with which invertebrates and vertebrates may gain access to the corpse and hasten its decay.

Table 3.4 illustrates the effects of burial conditions on the rate of decay.

Further details are given in Section 5.6 of the Project Record (P2/024/1).

Table 3.4 Condition of burial affecting decay rate

Condition of burial	Timescale to skeleton	Comment
Body unburied, without clothes	3 to 4 months	Destruction by bacteria and scavengers
Body unburied, fully clothed	considerably shorter than 3 to 4 months.	Agents of decay work faster under cover.
Uncoffined body buried 2 metres deep - in friable soil and body not embalmed	10 to 12 years	Analogous to many modern burials, with rapid collapse of coffin
Bodies buried deep outlast those in shallow graves: 0.5 m deep 1.5 m deep	 <1 year (months even) many years	Any increase in depth makes a body less accessible to worms and maggots.
Body wrapped in polythene	Increases time to decompose	

3.2.3 Potential contaminant release rates

Humans

A human corpse normally decays within a period of 10 to 12 years (Table 3.4). It is estimated that over half of the loading will be leached within the first year. In successive years there will be a declining source term, in which half the residual loading is leached. After 10 years less than 0.1% of the original loading may remain. An example of such a potential release rate is given in Table 3.5.

A similar estimate of the release rate for formaldehyde can be made using figures from Davies (1998) and Soo Chan *et al* (1992). This would result in a potential total release of approximately 90g of formaldehyde per body. If all were leached in the first year it would result in an effluent containing approximately 80 mg l^{-1} formaldehyde. Following the source depletion term model, the concentration after 10 years would be estimated to be less than 20 mg l^{-1}. These estimates take no account of the natural degradation of formaldehyde in the ground. The absence of reports of widespread groundwater contamination by formaldehyde leads to the conclusion that natural attenuation processes in the ground prevent contamination.

The embalming of bodies for green burial is discouraged. In view of the positive choice that is made by persons wishing green burial (or on their behalf by relatives) it is concluded that such burial sites do not provide a significant potential source of formaldehyde release.

Table 3.5 Potential annual release (kg) of principal components from a single 70 kg burial

Year	TOC	NH_4
1	6.0	0.87
2	3.0	0.44
3	1.5	0.22
4	0.75	0.11
5	0.37	0.05
6	0.19	0.03
7	0.10	0.01
8	0.05	<0.01
9	0.02	<0.01
10	0.01	<0.01

The discussions in the previous section have focused on single burials, or possibly the interment of a second body in a family grave (currently second burials in a family grave may account for up to 40% of interments in large municipal cemeteries (Nash, 1997). In addition, common graves are still prepared in large cemeteries, in which such burials may represent 2 or 3% of annual interments. Common graves are typically dug to 2.7 metres (9 feet), to contain three coffins, each covered by 150 mm of soil above the lid before the next is placed. In some areas common graves may be extended to 3.4, 4.0 or 4.6 metres (11, 13 or 15 feet) to accommodate 4, 5 or 6 burials. Common graves are normally completed (filled to the top) within one year of opening and the potential pollution load may be assessed by scaling from that associated with a single interment.

Animals

With respect to animal carcasses, it is suggested that the potential release rates are estimated by the use of multiplier factors to account for the differences in body weight and burial practices. Suggested conversion factors are given in Table 3.6

Table 3.6 Factors to modify human cadaver pollution indices to animal corpses

Animal type	Weight factor (x human value)	Infiltration factor (x human grave size)
Cattle and horses	8 – 10	4
Pigs	1	1
Sheep	0.8	1
Dog	0.15	0.25
Cat	0.03	0.1

Estimation of pollutant flux

The time taken to flush out contaminants will be directly related to the effective rainfall and soil infiltration rate for the burial site. As a worst case, it could be assumed that infiltration capacity exceeds effective rainfall at all times, so that surface evapo-transpiration determines the net infiltration rate. This will vary according to how the grave is restored after burial. Four principal restoration conditions will exist:

1. Paved surface to grave (grave slab) - slight evaporative loss, but rainfall likely to run-off around perimeter and infiltrate surrounding grass.

2. Surface of grave covered by stone chippings - evaporative losses only, similar to bare soil evaporation.

3. Surface of grave grassed - evapotranspirative loss appropriate to short rooted vegetation.

4. Shrub or tree planted on grave (green burial) - evapotranspirative loss appropriate to long rooted vegetation.

The first three conditions predominate in the majority of municipal cemeteries. Many Diocesan authorities now prohibit the erection of grave slabs or chipping surfaces in churchyards. Pet cemeteries are similar to human burial grounds in this respect. The fourth condition is found at all green burial or woodland burial sites.

The annual rate of burial will influence both the potential volume of contaminated water which may form by leaching from graves and the composition and strength of the effluent. In order to illustrate the influences, worked examples of the estimation of water fluxes and effluent (leachate) composition are included in Appendix B, for three model burial sites:

1. a small churchyard, 10 burials per year;
2. a large municipal cemetery, 350 burials per year; and
3. a green burial site, 30 burials per year.

The results of estimates of the potential average concentration of ammoniacal nitrogen in the drainage, the volume of drainage and the annual nitrogen load at one and ten years after the start of burial at each of the model sites are summarised in Table 3.7.

Table 3.7 Potential ammoniacal nitrogen concentrations, volumes and loads leached from model cemeteries.

	NH_4 mgl^{-1}		Volume m^3 yr^{-1}		Load kg yr^{-1}	
	1 year	10 years	1 year	10 years	1 year	10 years
Small churchyard	870	174	10	100	8.7	17.4
Municipal cemetery	773	155	394	3938	304.5	608.4
Green burial	861	172	30	303	26.1	52.1

Comparison of the estimates for the three scenarios indicates only a small difference in predicted average effluent concentrations, apparently suggesting comparable threats to water quality. However, if for the three scenarios, the total mass loadings of nitrogen are considered in terms of in terms of kg NH_4 yr^{-1} (Table 3.8) the greater potential impact of the large cemetery is clearly illustrated.

Table 3.8 Changes in ammonia release (kg (NH_4) yr^{-1}) from model cemeteries during first ten years operation

Year	1	2	3	4	5	6	7	8	9	10
Small cemetery	8.7	13.1	15.3	16.4	16.9	17.1	17.2	17.3	17.4	17.4
Large cemetery	305	459	532	571	590	600	604	607	608	608
Green burial	26	39	46	49	51	51	52	52	52	52

Notes: Times for model cemeteries to cover 1 hectare: small churchyard 198 years; large municipal cemetery 5.6 years; green burial site 52.7 years.

APPENDIX B ESTIMATION OF POLLUTION LOAD FROM BURIALS

NOTE: In early 2004 a number of errors were noticed in the previous version of this appendix and in Tables 3.5, 3.7 and 3.8 in the main text. As a result this new version was written to correct the errors and provide a minimal re-write of the text. The methodology provided in the main report was not affected by these errors, however substantial changes to the worked examples will be noticed.

In addition, since this report was first published the availability and use of contaminant transport models has increased greatly. Readers are advised that the examples and calculations below can offer only a flavour of the subject and that site-specific model use is to be preferred where this is possible.

B1 Background information and calculations

The detailed elemental composition of the human body is well reported (see for example Forbes 1987) and set out below in Table B1. Clearly, the water content of a human body is very significant accounting for around 70% of the total mass. Also, the mass and composition does vary between individuals and with age, sex and other factors.

Table B1a Elemental composition of a human body based on a standard or reference man of 70kg body weight.

Element	Mass (g)
Oxygen	43000
Carbon	16000
Hydrogen	7000
Nitrogen	1800
Calcium	1100
Phosphorus	500
Sulfur	140
Potassium	140
Sodium	100
Chlorine	95
Magnesium	19
Iron	4.2
Copper	0.07
Lead	0.12
Cadmium	0.05
Nickel	0.01
Uranium	0.00009
Total body mass	70000

Table B1b Structural composition of a human body based on a standard or reference man of 70kg body weight.

Tissue	Mass (g)
Total body mass	70000
Skeletal muscle	28000
Adipose tissue	15000
Bone	5000
Cartilage	1100
Periarticular tissue	900
Marrow	3000
Skin	4900
Liver	1800
Brain	1400

Unsurprisingly then much of the human corpse is very amenable to biological degradation by both micro-organisms and scavengers. This is promoted by:

- an attractive elemental composition with macro- and micro- nutrients
- a readily utilisable chemical composition (e.g. protein, fats, fixed nitrogen and water)
- a relatively small proportion of slowly degradable or inert material (e.g. bones, enamel).

Table B2 Proportions of degradable material of a coffined human body

Degradability	Percentage
High	60
Moderate	15
Slow	20
Inert	5

Estimation of the potential pollution which may result from an interment may be made based on the data above and in the main body of this report and, crucially by making a range of assumptions about the release of chemicals to the wider environment.

Assumptions

Burials areas:	800 burials per acre = 1976 per ha = 5.06 m^2 per burial plot	
Green burials areas:	1580 per hectare	= 6.33m^2 per burial plot
Burials volumes:	As above to a depth of 1.8m	= 9.10m^3 per burial
Grave dimensions:	2.1 x 1.2 x 1.8m	= 4.54m^3 per grave dug
Coffin dimensions:	a) 2.1 x 1.2 x 0.4m	= 1.01m^3 – rectangular casket
	b) 2.1 x 0.75 x 0.4m	= 0.63m^3 – tapered coffin
Body mass	70kg	
Coffin mass	10kg	
Interred mass:	70kg body plus 10kg coffin	= 80kg
Soil density:	1.6 tonnes per m^3	

Comparisons

These are included here for completeness as such calculations were part of the original version of this Appendix.

Volume comparison

Burial volume:	a) 1976 x $1.01m^3$	= $1995m^3$
	b) 1976 x $0.63m^3$	= $1245m^3$
(green burials):	b) 1580 x $0.63m^3$	= $995m^3$
Land volume:	100 x 100 x 1.8m	= $18000m^3$
Soil volumes:	a) 18000 – $1995m^3$	= $16005m^3$
	b) 18000 – $1245m^3$	= $16755m^3$
(green burials)	b) 18000 – $995m^3$	= $17005m^3$

Mass comparisons

Burial mass:	1976 x 80kg	= 158 tonnes
(green burials):	1580 x 80kg	= 126t
Soil mass:	a) 16005 x 1.6	= 25608t
	b) 16755 x 1.6	= 26808t
(green burials)	b) 17005 x 1.6	= 27208t

Hence burials represent between 5% and 11% of a cemetery volume to the 1.8m burial depth and about 0.6% of the mass.

B2 Potential releases from a single human burial

Table 3.4 (p25 of main report) notes that modern burials would degrade to skeleton in 10 –12 years. Assuming that 75% of the *carbonaceous* body mass is readily degraded (Table B2) and hence that this represents the ten-year leachable fraction a simple one year half-life representation of leach masses per year is calculated in Table B3 below. Note that the table addresses Nitrogen as ammoniacal and Sulfur as sulfate for ease of comparison with normal site analytical data. Note also that this table in effect provides a simple reference but that the reader may prefer to use a structured contaminant transport model instead such as CONSIM.

Table B3 Example annual potential releases from a single human burial

Year	Potential mass release (g)					
	C	NH4	P	SO4	Cd	Ni
1	6000.0	870.0	250.0	210.0	0.01875	0.00375
2	3000.0	435.0	125.0	105.0	0.009	0.002
3	1500.0	217.5	62.5	52.5	0.005	0.001
4	750.0	108.8	31.3	26.3	0.002	0.000
5	375.0	54.4	15.6	13.1	0.001	0.000
6	187.5	27.2	7.8	6.6	0.001	0.000
7	93.8	13.6	3.9	3.3	0.000	0.000
8	46.9	6.8	2.0	1.6	0.000	0.000
9	23.4	3.4	0.98	0.82	0.000	0.000
10	11.7	1.7	0.49	0.41	0.000	0.000

B3 Estimation of flux of water

Assuming a mean annual rainfall of 650 mm (typical of much of central and southern lowland England) typical annual evapotranspirative losses and infiltration values would be:

Surface type	Evapotranspiration ($mm\ yr^{-1}$)	Infiltration ($mm\ yr^{-1}$)
Chippings	350	300
Grass	450	200
Trees / shrubs	550	100

The dimensions of a standard grave are 1.2 by 2.1 metres (2.5 m^2), so that in one year the volume of infiltrating water based on the above would be as below.

Surface type	Annual volume, litres
Chippings	750
Grass	500
Trees/shrubs	250

Application of such infiltration estimates to the release of ammonia predicted from consideration of the elemental composition of the human body and table B3 suggests initial concentrations of the order of 1.17 to 3.5 $g\ l^{-1}$ of ammonia in the effluent. Clearly, a significant concentration comparable to landfill leachate.

However, lateral flows and dispersion within the unsaturated zone is likely to mix the products of decay with water infiltrating through the areas separating individual graves. A grave population of 2470 per hectare (1000 per acre) is commonly assumed, but in practical terms, making allowance for driveways, paths etc., then for municipal cemeteries the value is closer to 1976 per hectare (800 per acre). Hence, each grave may be considered to be centred in an area of about 5.06 m^2. For green burial sites usage is about 80% of that at typical lawn (municipal) cemeteries, that is about 1580 per hectare (640 per acre), so each has a contributing area of 6.32 m^2. The annual infiltration volume for each grave area may then be estimated assuming that the areas between graves are grass covered):

Grave cover	Surface infiltration (l yr^{-1})	Infiltration from grass surrounds (l yr^{-1})	Total (l yr^{-1})
Chippings	750	500	1250
Grass	500	500	1000
Green burial	250	760	1010

B4 Estimation of pollutant load from cemeteries

The approximations above may then be used to estimate the potential composition of effluent reaching the water table beneath a burial ground. Three scenarios are examined below, based on the assumptions with respect to timing and rate of contaminant release (Table B3) and for the model values of rainfall and evapotranspiration employed above. The scenarios are:

1. Small churchyard, 10 burials per year, graves and surrounds all grass covered;

2. Large municipal cemetery 350 burials per year, grave cover of half grass cover/half chippings and surrounds all grass;

3. Green burial site, 30 burials per year. Grave cover of shrubs and surrounds as grass.

Note that the assumptions regarding the rate and duration of release of potential contaminants imply that after ten years, at a constant annual burial rate, the annual release of contaminants will reach equilibrium. However, since the area of burials will continue to expand, the predicted concentrations **averaged over the whole burial ground** will continue to decrease.

Country churchyard

The predicted burials area, annual volume of effluent produced and predicted concentrations for ammonia in the effluent for a burial ground accepting 10 per year are listed in Table B4.

Table B4 Example of estimates of effluent concentrations, small burial ground

Year	Cumulative burials	Cumulative burials area (m^2)	Annual effluent production (l)	Annual leached mass NH_4 (g)	Mean concentration NH_4 (mg l^{-1})
1	10	51	10000	8700	870
2	20	101	20000	13050	653
3	30	152	30000	15225	508
4	40	202	40000	16313	408
5	50	253	50000	16856	337
6	60	304	60000	17128	285
7	70	354	70000	17264	247
8	80	405	80000	17332	217
9	90	455	90000	17366	193
10	100	506	100000	17383	174

Large municipal cemetery

The predicted areas, volumes and concentrations for a municipal cemetery receiving 350 burials per year are shown in Table B5.

Table B5 Example of estimates of effluent concentrations, large municipal cemetery

Year	Cumulative burials	Cumulative burials area (m^2)	Annual effluent production (l)	Annual leached mass NH_4 (g)	Mean NH_4 concentration (mg l^{-1})
1	350	1771	393750	304500	773
2	700	3542	787500	456750	580
3	1050	5313	1181250	532875	451
4	1400	7084	1575000	570938	363
5	1750	8855	1968750	589969	300
6	2100	10626	2362500	599484	254
7	2450	12397	2756250	604242	219
8	2800	14168	3150000	606621	193
9	3150	15939	3543750	607811	172
10	3500	17710	3937500	608405	155

Green (woodland) burial ground

The predicted areas, volumes and concentrations for a green burial ground receiving 30 burials per year are shown in Table B6.

Table B6 Example of estimates of effluent concentrations, green (woodland) burial ground

Year	Cumulative burials	Cumulative burials area (m^2)	Annual effluent production (l)	Annual leached mass NH_4 (g)	Mean NH_4 concentration (mg l^{-1})
1	30	190	30300	26100	861
2	60	380	60600	39150	646
3	90	570	90900	45675	502
4	120	760	121200	48938	404
5	150	950	151500	50569	334
6	180	1139	181800	51384	283
7	210	1329	212100	51792	244
8	240	1519	242400	51996	215
9	270	1709	272700	52098	191
10	300	1899	303000	52149	172

Formaldehyde

Estimation of the possible release of formaldehyde from embalming can be made assuming:

- an average of 9 litres of 2% formalin solution is used per body (Davies, 1998)

- 50% of the formaldehyde is broken down by the putrefaction process (Soo Chan *et al*, 1992)
- all remaining formaldehyde is leached within the first year
- other conditions (e.g. water flux) are as set out above.

Leached mass of formaldehyde per body = 20g x 9 x 0.5 = 90g

Hence for the scenarios above the effluent concentrations would be:

Scenario	No of burials	Effluent volume (l)	Formaldehyde concentration (mg l^{-1})
Small church	10	10000	90
Large municipal	350	393750	80
Green	30	30300	89

If the release were to follow the pattern postulated for other potential contaminants, then for the large municipal cemetery the release pattern would be as below.

Year	Cumulative burials	Cumulative burials area (m^2)	Annual effluent production (l)	Annual leached mass CH_2O (g)	Mean CH_2O concentration (mg l-1)
1	350	1771	393750	31500	80
2	700	3542	787500	47250	60
3	1050	5313	1181250	55125	47
4	1400	7084	1575000	59062	38
5	1750	8855	1968750	61031	31
6	2100	10626	2362500	62015	26
7	2450	12397	2756250	62507	23
8	2800	14168	3150000	62753	20
9	3150	15939	3543750	62877	18
10	3500	17710	3937500	62938	16

B5 Estimation of pollutant load from mass burial of animals

The body weights of farm stock and the size of typical herds are listed in Table B7, where they are combined with relative body weight factors to estimate the total pollution load (as kg N) which could be imposed. In making the estimates it is assumed that a herd is composed of 70% adults and 30% juveniles.

Examination of the table suggests that the greatest threat may come, not from the slaughter of herds of cattle, but from the disposal of culled poultry, in particular turkeys, which by virtue of the very large size of commercial flocks may impose a high aggregate pollution load. Nevertheless, significant loadings may arise from cattle culls.

Table B7 Estimates of potential contaminant loads from mass burial of animals, based on liveweights and group sizes

Class of animal	Typical juvenile weight (kg)	Typical adult weight (kg)	Flock / herd size	Potential pollution load (kg N)
CATTLE				
Milker	35 (birth)	500 (24 months)	70	616
Beef	35 (birth)	600 (below 30 months)	70	736
Sheep	8 (6 weeks)	80	700 (but even distribution between 300 and 2000)	1 000
PIGS	25 (piglet)	90	250	430
POULTRY				
Chickens		3	50% of flocks >20 000	1 470
Turkeys		5 - 14	92% >100 000 <1% below 5000	24 400
Ducks		3	1000	73
Geese		10	1000	244