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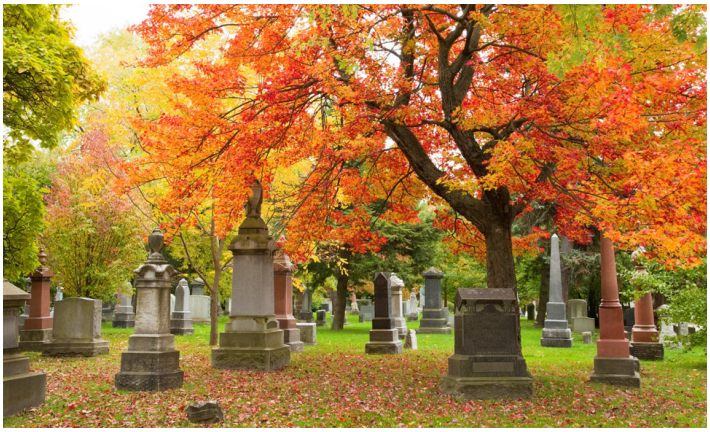
CEMETERY SETBACK DISTANCES TO PREVENT SURFACE WATER CONTAMINATION

Cemetery setback distances to prevent surface water contamination

Primary inquiry: In Canada, as in many other countries, cemeteries are required to be setback a certain distance from waterbodies to protect drinking water sources from contaminated liquids that can arise from the decomposition of bodies after burial. What is recommended as a safe setback distance? What is the rationale for the setback distances used throughout Canada?

Please note: The information provided here is for the purpose of addressing a specific inquiry and is not subjected to external review. The information offered does not supersede federal, provincial, or local guidance or regulations.



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Background

Upon death, human remains are typically cremated or inhumed (buried), with inhumation usually occurring in cemeteries. Decomposition of inhumed bodies results in leachates (liquids), typically comprised of water, protein, fat, mineral salts, and carbohydrates, plus potential microbial pathogens, i.e., bacteria and viruses,[1] and in some cases other chemical products such as heavy metals, e.g., mercury from amalgam dental fillings.[2] Leachates may include embalming fluids, materials from the coffin and from clothing, or ornaments/decorations laid with the body.[2] Over time, leachates seep into soil and can potentially contaminate ground or surface water.[3,4] The quantity of leachate seeping into soil and groundwater is directly attributable to the size of the cemetery and number of burials, how often coffins are used,[3,5] surrounding soil type,[6] site topography,[7] and siting of the cemetery in relation to ground or surface water that could transport leachates away from grave sites.

To avoid contamination of nearby water sources from leachates, cemeteries typically have setback distances, i.e., regulations or by-laws that stipulate how far from water sources, drainage, and ditches cemeteries must be situated. Because Canada spans a vast area, unique circumstances from burials may occur due to the conditions in far north communities, i.e., depth to bedrock can be very shallow and underlain by permafrost, rendering inhumation impossible for much of the year. In these communities, some burials occur above ground, with bodies covered over by rock mounds. Many of these northern communities rely on surface water for drinking water, and may thus be particularly susceptible to leachates containing microbial pathogens that could potentially impact health.

We used a three-pronged approach to seek information to help inform new or updated regulations in regards to cemetery setback distances:

1. consultation with individuals who have expertise regarding cemetery regulations;

2. a rapid academic literature search; and

3. an internet search for public health documents applying to cemetery setbacks.

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Consultation

The BC Ministry of Health was contacted to request guidance or direction to documents pertaining to cemetery setback distances, and the rationale for these requirements. The BC Public Health Act, Health Hazards regulation 216/2011, contains information that specifies that water wells must be 120 m from possible sources of contamination, including cemeteries. This provision dates back to 1917 and was more likely a "rule of thumb" approach, rather than having any scientific basis.

A cemetery manager within a large urban centre explained that shallow graves in a warmer temperature are beneficial for decomposition, and rapid decomposition is a "key outcome for modern cemeteries" *(pers. comm.)*. Concrete liners (or other suitable material) at the bottom of grave sites may help ameliorate leachate seepage, but in most cases water sources (direction, flow, topography) should have been considered before siting a cemetery. No further information on setback distances was available.

Due to similarities in the unique conditions presented in rural northern Canada and Alaska, a rural landfill specialist in the latter was contacted. He stated that he did not think there are rules/regulations regarding setback distances for cemeteries on the (US) state level *(pers. comm.)*.

Rapid Academic Literature Search

The literature scan conducted to obtain this information was limited to the last 10 years. Literature was identified through Medline, CINAHL, Biomedical Reference Collection, Web of Science, and Google Scholar. Terms used in the search included:

- (cemetar* OR cemeter* OR burial OR churchyard OR "church yard" OR grave OR graveyard OR gravesite OR inukshuk OR "stone claim" OR plot OR interment)
- (health OR design OR protocol OR guideline OR guidance OR regulation OR standard* OR legislation OR setback)
- (water OR soil OR "phreatic zone" OR ground) AND (pollut* OR contamin* OR leach* OR decompos* OR frozen)

This search turned up 30 related articles/reports, of which 15 were deemed relevant and a full article/pdf was available. Cross-referencing, i.e., looking for specific references cited in the selected literature, was conducted. None of the literature provided specific rationale for the various setback distances used either locally or internationally.

CONDITIONS AFFECTING LEACHATES

SETBACK DISTANCE FROM WATER

Water is the main transport mechanism for contaminants, bringing contaminants to deeper soil layers or to the surface.[8] In general, contaminants in groundwater attenuate with increasing distance from the source. A German study by Schraps (1972)[1,9] measured bacterial counts, ammonia, nitrate, and chemical oxygen demand in groundwater within a cemetery from 50 cm below a row of graves, at various distances down-gradient within the cemetery. High levels of each of these contaminants were found in the immediate vicinity of the cemetery, with concentrations decreasing with increasing distance from the graves (Figure 1).

PARAMETER	DISTANCE FROM GRAVES (m)					
	0.5	1.5	2.5	3.5	4.5	5.5
Bacteria Count (per ml)	6000	8000	8000	3600	1200	180
Ammonia (mg/l)	6	0.75	-	-	-	-
Nitrate (mg/l)	4.8	0.1	-	-	-	-
Chemical Oxygen Demand (mg/l)	26.7	16.4	15.4	15.4	11.4	11.4

(Source: Schraps, 1972)

Figure 1. Groundwater analyses at various distances from grave sites in a German cemetery, presented in Formanek (1997)[1] [Original source, Schraps (1972)[9]]

- In a report released in 1992 by the Ontario Ministry of Environment,[10] well water was sampled for formaldehyde (used in embalming fluids) at distances between 500 to 2000 m from cemeteries. Given the low levels found, it was concluded that formaldehyde is not a significant contamination risk at these distances in the studied cemeteries. Of concern is that there is no standard for preparing embalming fluids or for the amount to use in each corpse.[7] Of note, Health Canada has no drinking water guidelines specific to formaldehyde.[11]
- A study in South Africa examined groundwater under a cemetery by sampling water from wells within, and from outside, the cemetery (50 m and 500 m distance). Bacterial and colony forming units (E. coli, fecal coliforms, fecal streptococci) were measured. Groundwater within the cemetery was highly polluted compared to the external sample and to the city water supply.
- Zume[12] conducted a pilot study examining contamination of hand-dug wells within 25 m of traditional burial sites in Nigeria. Contaminants were found in the well water, but it could not be confirmed if these contaminants were due to leachates from body decomposition.

- Rainfall is an important factor, both in raising the water table, especially in colder months, and contributing to the rapid flushing of contaminants from the soil.[8] Plot depth above the water table should consider the maximum water table height reached during heavy rainfalls.
- Historical literature (cited in Spongberg and Becks, 2000[13]) noted cases of groundwater contamination in European cities arising from proximity to cemeteries, e.g., increases in typhoid fever in Berlin, to a "sweetish taste and infected odor in water from wells located near cemeteries in Paris." Distances of cemeteries to water sources were not given.

SOIL TYPE AND TOPOGRAPHY

Soil type is crucial for both decomposition and seepage of leachates. Fine, dense particles such as clay can prevent decomposition and seepage, whereas coarse particles such as sand can allow rapid decomposition and seepage of leachates, preventing their purification and allowing ground water contamination.[4] No information was available on the minimal top soil needed for burial.

- Multiple soil samples from within and outside of a cemetery in Northwest Ohio were analysed for adsorbed metals. Samples were collected at distances ranging from approximately 1 m to 15 m from the nearest grave at depths of up to 2.1 m, and at 5 m outside of the cemetery. Graves showing sinking of the surface area, used as a proxy for old graves where decomposition was believed to be complete, were selected. Concentrations were low at all distances both within and outside of the cemetery, with the exception of arsenic,[13] which was previously used in embalming fluids (e.g., arsenic found at 7.7 mg/kg^{-1}dry soil at 12.2 m from the nearest grave site).
- Highly permeable soils such as sand and gravel, and conversely, very fine soils that prevent aerobic conditions, should be avoided.[3]
- Highly permeable soil does not allow good purification of leachates because of speed of seepage through deeper layers and reduced contact time between soil and wastewater.[8]
- Soil type impacts survival and retention of bacteria and viruses from decomposition products. Survival of microorganisms is increased at cooler temperatures (below 5°C). Soil pH affects bacteria and virus survival, with more acidic conditions resulting in faster die-off.[4]
- Topography, i.e., gradient/slope, is important when siting a cemetery as contaminants can migrate down a slope towards water sources.[1,6]

BODY DECOMPOSITION

Decomposition products are comprised of more than the body elements of carbon, hydrogen, oxygen, etc. (Figure 2). Bacteria and/or viruses can be present, especially if the person died from a contagious illness, as can heavy metals and other organic contaminants coming from the body, the casket, and its linings, clothing on the body, or from ornaments placed with the body.

- Fiedler et al. (2012)[2] examined 40 exhumed 25-year-old graves and found a variety of materials such as cardiac pacemakers, bedding, disposable diapers, and metal from hip replacements and amalgam fillings, for example.
- The decomposition rate is controlled by temperature, soil moisture, aeration, and leaching, with an optimal temperature range between 25 and 35°C.[7]
- Üçisik and Rushbrook (1998)[4] noted "No reports have been found in the literature of epidemics or widespread disease outbreaks which were unequivocally the result of seepage from cemeteries. However, doubt and concern persist due to the paucity of sufficient and clear scientific data."

CEMETERY SOURCE	END PRODUCTS & POTENTIAL CONTAMINANTS
Body Decomposition	Bacteria (total & faecal coliform, faecal streptococci, proteolytic, lipolytic), viruses, water, carbon dioxide (carbonic acid), methane, ammonia & ammonia compounds, nitrogen (in various forms), sulphate, hydrogen sulphide, phosphate, calcium, chloride, potassium & other salts; putrescine, cadaverine; oil & grease; others
Embalming Compounds	Formaldehyde, methanol, phenol, arsenic; aluminium, mercury, lead, & other metals
Man Made Artefacts	Iron, zinc, lead, copper & other metals; phenols, tannins & lignins, water, carbon dioxide, methane, hydrogen sulphide, organic acids; protein - water, carbon dioxide, methane, ammonia, hydrogen sulphide; cellulose - acids, carbon dioxide & water; lignin - phenols & alcohols

Figure 2. End products and potential contaminants at cemeteries.[1]

COLD CLIMATES

Climate, e.g., dry or wet conditions, temperature and rainfall, is an important determinant of seepage of leachates. Permafrost forms at cold climatic conditions, high latitudes, and some high alpine areas, and renders inhumation difficult at best. Permafrost is one condition that has not been examined in relation to leachates seeping from cemeteries.

- Historically, permafrost has been considered an impermeable barrier to the movement of contaminants. When permafrost thaws, organic matter and minerals in the soil become available for remobilization and introduction into aquatic systems.[14]

- Climate change may result in the destabilization of permafrost.[15]
- Permafrost thaw, especially in light of climate change, can create new freshwater ecosystems, potentially modifying lakes, streams, and rivers[14] that could transport leachates and associated contaminants to drinking water.
- Survival of pathogens is increased at low temperatures.[4]
- In cold/dry, or cold/wet conditions, full body decomposition can take between 50 to 500 years to achieve,[1] indicating only small volumes of leachate would be available for seepage at any one time under northern latitude conditions (Figure 3).

CLIMATE TYPE IN ACIDIC SOIL	DURATION (years)
Hot - wet	25 - 100
Hot - dry	100 - 500
Cold - wet	50 - 200
Cold - dry	200 - 500

(Source: Krogman & Iscan, 1986)

Figure 3. Human body decay times, presented in Formanek (1997)[1].

Public Health Documents and Grey Literature

An internet search was conducted using the same search terms as the academic literature search, in order to identify documents from public health agencies and other organizations that indicate cemetery setback distances from water sources. Many local or municipal Canadian cemetery bylaws/regulations did not mention setback limits. However, setback distances were found in documents from some provinces and local areas, from other countries, and from the World Health Organization (WHO) (Table 1).

Outside of Canada, the Scottish Environmental Protection Agency recommends setbacks of 250 metres from a potable water source and 50 metres away from other water courses (Table 1).[5] In the situation of remote communities in areas with thin soil, the land should be raised to increase soil thickness by no more than 2 m (not a burial mound), and groundwater monitoring for contaminants should be undertaken.

KNOWLEDGE GAPS

Minimal research has been conducted into the migration of leachates from cemeteries, and scarce information exists on the potential for contamination of surface water from leachates seeping from cemeteries. Instead, the scientific research focussed on contamination of soil and/or groundwater from cemetery leachate, but not on contamination of surface water. No rationale was given as to the basis for recommended setbacks of cemeteries from potable water or other water courses, and there is little consistency, between countries and within Canada, in the distances of recommended setbacks.

We found no literature specific to how conditions encountered in far northern Canadian communities, i.e., permafrost, shallow soil, or above-ground burials in cold, dry climates, or impacts of climate change on these conditions, affects decomposition of bodies. Furthermore, there is a lack of information about the amount of formaldehyde used in embalming fluids. Consideration should be given to individual assessment of hydrography, typography, and soil conditions when siting or extending a cemetery site. There is a need for further research to address these gaps, in particular in light of how climate change may impact burial conditions and potentially affect surface water contamination.

Summary

In Canada and abroad, according to regulations and bylaws, cemetery setback distances vary and range from 250 m (e.g., WHO, UK Government, Scottish EPA) to 100 m in Saskatchewan and 120 m in BC. An anomaly is a recommendation of 30 m from the Ministry of Environment and Energy, Canada.[1,10] None of these sources of information provided a rationale for the distances given.

Some of the literature did consider the decomposition process of human bodies, including bacteria, viruses, and other pathogens that may be contained within a body and how long they can survive under various conditions. Hydrology and topography were often mentioned as having an impact on decomposition. Cemetery size and number of burials impacted leachate quantity. Such factors would determine the adequacy of specific setbacks.

Importantly, microorganism die-off rates increase with increasing temperature.[4] In the context of Canadian communities located in the far north, which, for many months of the year remain very cold and dry, buried human remains are unlikely to pose much of a public health risk via surface water contamination. However, these same frozen conditions may allow for extended survival of microbial pathogens. Permafrost will act as a barrier to seepage to groundwater, the water table, and surrounding soils.

In light of the above-ground burials that sometimes occur in small communities, risk to drinking water derived from surface water could be evident in warmer months when thawing allows decomposition to occur. It would be prudent to examine maps of surface water courses, and consider impacts of climate change on permafrost thaw on these water courses when planning cemetery extensions or new cemeteries.

To conclude, no rationale was found to explain the chosen setback distances from cemeteries to prevent contamination of water sources from leachates. No two cemetery sites are the same in regards to topography, climate, hydrology, etc., and as such, each individual site should be investigated to ensure setback distances are adequate.

Table 1. Different setback distances from various sources. A dash (-) indicates no information was found.

Potable water source, e.g., well, borehole, spring	Other springs or watercourses, field/land drains	Plot depth above a water table	Country
250 m distance; greater if cemetery site is steep, or high velocity of groundwater flow	10 m	1 m above water table	World Health Organization, Regional Office for Europe[4]
250 m distance	30 m from water not used for human consumption or food preparation; 10 m from field drains	1 m above water table	United Kingdom[16,17]
250 m distance	50 m from other water or water courses; 10 m from field drains	1 m above water table	Scotland[5]
-	-	0.7 m above water table	Germany Schraps (1972)[9] in Formanek (1997)
15 – 90 m depending on water use	-	-	USA[13]
(for private property) 61 m from potable water. No regulations for public cemeteries in Alaska.	-	-	Alaska, USA[18]
30 m distance from a well or any surface water	-	0.5 m above water table	Canada (recommendation only)[1,10]
-	-	-	City of Whitehorse, Yukon Territory, Canada[19]
-	-	-	City of Yellowknife, Northwest Territories, Canada[20]
100 m from a watercourse or well	-	-	Saskatchewan, Canada[21]
120 m from a well	-	-	British Columbia, Canada[22]
120 m from a well	-	-	Municipality of Whistler, British Columbia, Canada[23]
122 m from a well	-	-	Vancouver Island[24]

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References

1. Formanek P. An assessment of groundwater contamination at cemetery sites. Kingston, ON: Queens' University; 1997. Available from: http://www.collectionscanada.gc.ca/obj/s4/f2/dsk2/tape17/PQDD_0007/MQ28197.pdf.

2. Fiedler S, Breuer J, Pusch CM, Holley S, Wahl J, Ingwersen J, et al. Graveyards - special landfills. Sci Total Environ. 2012 Mar 01;419:90-7. Available from: https://www.ncbi.nlm.nih.gov/pubmed/22285086.

3. Engelbrecht J. Groundwater pollution from cemeteries [biennial conference], May 4–7. Cape Town, SA: Water Institute of South Africa; 1998. p. 1-8.

4. Üçisik AS, Rushbrook P. The impact of cemeteries on the environment and public health: an introductory briefing. Copenhagen, Denmark: World Health Organization, Regional Office for Europe; 1998. Available from: http://apps.who.int/iris/bitstream/10665/108132/1/EUR_ICP_EHNA_01_04_01(A).pdf.

5. Scottish Environment Protection Agency. Guidance on Assessing the Impacts of Cemeteries on Groundwater. Scotland: EPA; 2015. Available from: https://www.sepa.org.uk/media/143364/lups-gu32-guidance-on-assessing-the-impacts-of-cemetries-on-groundwater.pdf.

6. Santarsiero A, Cutilli D, Cappiello G, Minelli L. Environmental and legislative aspects concerning existing and new cemetery planning. Microchem J. 2000 2000/12/01/;67(1):141-5. Available from: http://www.sciencedirect.com/science/article/pii/S0026265X00001107.

7. Oliveira B, Quinteiro P, Caetano C, Nadals H, Arroja L, Ferreira da Silva E, et al. Burial grounds' impact on groundwater and public health: an overview. Water Environ J. 2012;27(1):99-106. Available from: http://dx.doi.org/10.1111/j.1747-6593.2012.00330.x.

8. Santarsiero A, Minelli L, Cutilli D, Cappiello G. Hygienic aspects related to burial. Microchem J. 2000 2000/12/01/;67(1):135-9. Available from: http://www.sciencedirect.com/science/article/pii/S0026265X00001090.

9. Schraps W. Die Bedeutung der filtereigenschften des bodens fur die anlage von friedhofen. Mittcilungen Deutsche Bodenkundl; 1972.

10. Soo Chan G, Scafe M, S E. Cemeteries and groundwater: an examination of the potential contamination of groundwater by preservatives containing formaldehyde. Toronto, ON: Ontario Ministry of the Environment, Branch WR;1992. Available from: https://archive.org/details/cemeteriesground00chanuoft.

11. Health Canada. Guidelines for Canadian drinking water quality. Ottawa, ON: Health Canada; 2017. Available from: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/water-quality/guidelines-canadian-drinking-water-quality-summary-table-health-canada-2012.html.

12. Zume JT. Assessing the potential risks of burial practices on groundwater quality in rural north-central Nigeria. J Water Health. 2011:609-16. Available from: http://jwh.iwaponline.com/content/ppiwajwh/9/3/609.full.pdf.

13. Spongberg AL, Becks PM. Inorganic soil contamination from cemetery leachate. Water Air Soil Pollut. 2000;117(1):313-27. Available from: http://dx.doi.org/10.1023/A:1005186919370.

14. Vonk J, Tank S, Bowden W, Laurion I, Vincent W, Alekseychik P, et al. Reviews and synthesis: effects of permafrost thaw on Arctic aquatic ecosystems. Biogeosciences. 2015;12:7129-67. Available from: https://www.biogeosciences.net/12/7129/2015/.

15. Grosse G, Goetz S, McGuire A, Romanovsky V, Schuur E. Changing permfrost in a warming world and feedbacks to the earth system. Environ Res Lett. 2016;11:040201. Available from: http://iopscience.iop.org/article/10.1088/1748-9326/11/4/040201.

16. UK Environment Agency. The Environment Agency's approach to groundwater protection. Bristol, UK: Environment Agency; 2017. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/620438/LIT_7660.pdf.

17. Cemetary Development Services. Greywater management. Bedfordshire, UK: Cemetary Development Services; 2015. Available from: http://www.cemeterydevelopmentservices.co.uk/greywater-management/.

18. Alaska Division of Environmental Health. Disposal guidance. Juneau, AK: Government of Alaska; 2017 [cited 2017 Jun 8]; Available from: http://dec.alaska.gov/eh/sw/guidance.html.

19. City of Whitehorse. Cemetaries bylaw 2003-09. (2003). Available from: http://www.whitehorse.ca/home/showdocument?id=104.

20. City of Yellowknife. Consolidation of cemetery by-law no. 3965. (1997). Available from: https://www.yellowknife.ca/bylaws/Bylaw/Details/b86242e0-2b4f-4d41-a659-15a06eb46b20.

21. Government of Saskatchewan. The Cemeteries Regulations 2001, Chapter C-4.01 Reg 1 as amended by Saskatchewan Regulations 15/2011 and 37/2015. Queen's Printer.(2001). Available from: http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/C4-01r1.pdf.

22. Government of British Columbia. Public Health Act Health Hazards Regulation 216/2011. Available from: http://www.bclaws.ca/civix/document/id/complete/statreg/216_2011.

23. Municipality of Whistler. Bylaw No. 1788, 2006. Being a bylaw to operate, regulate and maintain the Whistler cemetery. Available from: https://www.whistler.ca/sites/default/files/related/residents/bylaws/1788_-_cemetary_regulations.pdf.

24. Vancouver Island Health Authority. Guidelines for the approval of water supply systems. Victoria, BC: VIHA; 2006. Available from: http://www.viha.ca/NR/rdonlyres/71A5047A-4E40-43A3-A6ED-32C60041FCCC/0/GUIDELINESFORTHEAPPROVALOFWATERWORKS.pdf.

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