‘Til Death Do We Pollute, and Beyond:

The Potential Pollution of Cemeteries and Crematoriums

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Executive Summary

Disposal of cadavers is a mandatory process that has the potential to negatively affect human and environmental health. Cremation and burial represent two methods of disposal that are widely used and contain or create harmful substances. Historical examples include spread of contaminants from cemeteries causing pollution of water and illness in the public. The importance of cremation and burial was explored and their potential for contamination, as well as the governmental, financial and social barriers. A series of recommendations have been provided for consideration by involved stakeholders. Disposal of corpses represents an increasingly recognized source of pollution that needs to be accepted and addressed.

Cremation can be traced back to ancient times; however it has recently gained popularity in its modern form due to the cessation of negative religious connotations. It has been recognized that cremation releases large quantities of atmospheric mercury from dental amalgams that can cause negative health effects such as neurological, immunological, heart and reproductive disorders. The spreading of ashes introduces nutrients to the environment which may cause a variety of negative effects such as eutrophication and acidification, among others. Cremation utilises large quantities of fossil fuels contributing to global carbon emissions. Overall, cremation poses potential risks that could be reduced through improvements to current practices.

Burial is a long-standing method of disposal with many associated pollutants. Historical examples of burial extend as far back as 44 000 years and is important for many cultures, such as the Catholic and Muslim religions. Decomposition releases large quantities of nutrients, such as nitrogen, and chemicals, like mercury, that can negatively affect the environment and cause human health problems, such as cancer, if contaminants reach drinking water sources. Microorganisms associated with bodies and decomposition are also found in high concentrations near cemeteries and can cause a variety of health effects like gastrointestinal, liver, neurological, lymphatic and endocrinological diseases. A variety of substances buried with bodies such as the components of coffins and embalming fluid, which contains formaldehyde, are released during decomposition posing potential risks, though future research is required for improved understanding. There are also additional risks associated with the fertilizers and pesticides used in cemeteries. The cumulative risks of burial and cremation require serious alterations to the current practices to reduce the potential impacts, however, there are barriers related to this.

Governmental, financial and social barriers exist that create resistance to changes in burial practices. Currently, there is a lack of federal legislation pertaining to the disposal of corpses and the Provincial acts and regulations provide few restrictions or protection mechanisms for the environment and human health. Financial barriers exist as the funeral industry is highly profitable, a major employer and is primarily made of large, nonlocal corporations, all factors that will result in resistance to change. Lack of space in urban communities coupled with a growing population, personal opinions and beliefs and local resistance to placement of these disposal grounds represent social barriers that will impact movements for change. With these barriers present, recommended solutions will require dedicated actions from stakeholders, particularly the federal government and increased public education.

Recommendations vary from alterations in legislation, shifts in perspective, movement toward chemical-free methods and incorporation of vegetation in cemeteries, as well as improved research. Recommendations include:

1. Creation of legislation and siting methodology – Establishment of federal guidelines prohibiting the location of cemeteries based on fundamental site characteristics to reduce contamination risk.
2. Improved filtration in crematoriums – Stricter legislation dictating air quality standards in crematoriums will reduce emissions of harmful substances.
3. Reduction in chemicals – Movement toward use of natural preservatives for embalmment as well as methods to eliminate embalming, such as rapid burial and green cemeteries.
4. Promotion of green burials – Benefits involve rapid decomposition, lack of chemicals such as embalming fluid, reduction in use of coffins and enhancing vegetation in cemeteries.
5. Promotion of planting of trees and shrubs – Enhancement of vegetation in cemeteries to provide a natural filtration system and uptake of pollutants.
6. Promotion of alternative methods of disposal – Promation and alkaline hydrolysis allow avoidance of the atmospheric pollutants of cremation and improved burial methods.
7. Future research – These suggestions will incorporate gaps in knowledge that were discovered throughout the research to better understand the risks and possible solutions.

By applying the aforementioned solutions in their entirety or in part, the current human and environmental health issues can be addressed and the disposal of cadavers will become increasingly recognized as an important contamination source by the widespread public. With this acknowledgement on the negative health effects, the movement toward a pollution-free and health conscious death care industry will emerge.

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Introduction:

As human populations and their subsequent anthropogenic effects increase, there are limitless adverse environmental and health impacts. One rarely addressed source of contamination that poses risks is the disposal of corpses. This is a long recognized problem with evidence of negative effects dating back to the 1800s (Bachelor 2004). There are five ways to dispose of a cadaver: burial in the ground, burial at sea, entombment, cremation and exposure to the elements without burial (Dent 2002). The focus of this report is on cremation and burial in cemeteries. Cremation poses risks through the release of contaminants into the atmosphere and the spreading of ashes on the earth. Burial introduces chemical and biological pollutants into the surrounding earth, water and air, through the decomposition of cadavers and funeral artefacts. Both methods pose environmental and human health risks that need to be addressed by all stakeholders: the government, funeral industry and the public. Through the actions and opinions of stakeholders, desired changes to the current practices are influenced and restricted through the lack of federal government authority, the economic success of the industry and social preferences. There are a variety of recommended solutions that can dramatically reduce the pollution associated with disposal such as green burial and filtering at crematoriums. Despite the aforementioned barriers, this is an issue that requires the recognition and cooperation of all people due to the widespread and ongoing affects of the current practices of cadaver disposal.

Historical Cases of Pollution:

Disposal of human remains is an issue that societies have struggled with throughout history. Examples of historical cases of pollution demonstrate this past struggle and illustrate the potential current contamination risks of cadaver disposal. Historic examples regarding crematoriums are absent, but there are various incidences of pollution from cemeteries.

Historic concerns and cases of pollution from cemeteries have occurred worldwide over many centuries. In ancient times, Romans and Jews believed cemeteries to be unsanitary and hazardous, consequently they sited them outside cities (Engelbrecht 1998). Later, Christians used catacombs and cemeteries within settlements, creating health and hygiene problems with the increasing population and lack of sanitary laws on Church land (Engelbrecht 1998). More recently, cemeteries were related to groundwater contamination and human health problems. Groundwater pollution from graveyards and sewers were found to be the primary cause of the first major London epidemic of cholera in the early 1800s; the English General Board of Health listed cemeteries as one of the causes of cholera in their 1850 report (Bachelor 2004). Gases hovering over cemeteries were suspected of causing anything from tarnishing silver to deadly diseases like cholera and typhus (Bachelor 2004). In the mid-1800s in Berlin, there were more cases of typhoid fever in people living near cemeteries than other locations (reviewed in Engelbrecht 1998; reviewed in Spongberg & Becks 2000). In warm summer periods in Paris, groundwater near cemeteries had a sweet taste and smelled infected (reviewed in Engelbrecht 1998). There is also evidence of arsenic still being found in the groundwater near old cemeteries as arsenic was the primary embalming agent until the twentieth century (Smith 2000). These examples illustrate historic cases of cemetery pollution and possible effects, which illustrate potential current risks for populations around cemeteries.

Cremation:

What it is

Cremation is an ancient method of cadaver disposal that has only recently begun to gain popularity. According to the Cremation Association of North America, cremation rates have

risen from 3.56% in 1960 to 36.86% in 2009. By 2025, 43.6% of human remains are projected to be cremated (Cremation Association of North America 2003; Bassett 2010; Table 1). Cremation rates are significantly higher in other countries. In Japan, over 99% of bodies are cremated, due to their high population density compared to relatively low land mass (Bassett 2010). The cremation process reduces the body to bone, ashes and fragments using intense heat (Auger 2000). The water content of the body is evaporated and carbon is incinerated leaving five to seven pounds of inorganic bone ash and fragments (Auger 2000). Contamination from cremation results from two main sources: the burning process releasing atmospheric pollutants and disposal of ashes. These will be examined to understand the risks for environmental and human health, as well as the cultural importance of cremation.

Table 1: Percent of people cremated in North America since 1960 (Bassett 2010).

Year	Percentage of Cremated Deaths
1960	3.56
1965	3.87
1970	4.59
1975	6.55
1980	9.72
1985	13.86
1990	17.13
1995	21.14
2000	26.19
2005	32.28
2008	35.79
2009	36.86

History and Culture of Cremation

Cremation has a long history of use in cadaver disposal. There is archaeological evidence of cremated remains in China 8000 years ago and Britain 6000 years ago (Davies 2009). By examining the historical examples of cremation and its modern revival, we can better understand the importance of cremation and potential barriers to change.

There are two main occurrences of cremation, ancient and modern. In addition to China and Britain, the Greeks used cremation believing it set the soul free (Auger 2000). Around 5000 BC, burial took preference in many cultures, because of the negative religious connotations of cremation and the sanctity of the body (Davies 2009; Kearle 2004). The body was considered the dwelling place of the Holy Spirit and a living temple of the divine, thus cremation was viewed to hinder the body’s resurrection and represent a lack of care (Kearle 2004). Recently there has been a resurgence of cremation. In the late 1800s, the “modern” cremation movement started in England due to concerns for human health from cemetery pollutants, lack of land in cities and the deplorable conditions in cemeteries (Irion 1968). The first official cremation in the United Kingdom took place in 1885 and now accounts for 70.7% of funeral arrangements (McLellan 2007). The first contemporary cremation in Canada took place in 1902 at Mount Royal Cemetery in Quebec for Senator Alexander Walker (Smith 2007). Ontario’s first crematorium was built in 1933 and Canadian cremations took off in 1963 (Smith 2007). This recent increase is due to monetary savings of cremations, reduced land utilization in areas with limited space and because

the body is no longer viewed as sacred in many cultures (Kearle 2004; Wirthlin 2000). It is also worth noting that religion still affects cremation rates in countries like Italy and Ireland that are of Catholic majority, discussed below, having lower rates at 6.6 and 5.4% respectively (McLellan 2007). Cremation is becoming a primary method of cadaver disposal since its recent comeback, which may pose barriers to changes in current practices despite the potential risks to human and environmental health.

Air Pollution

Release of contaminants into the atmosphere is the main health concern of cremation, as well as the energy requirements. The greatest contaminant, mercury, will be examined first followed by the fossil fuel requirements. By better understanding these pollutants, the overall environmental and health risk can be well comprehended.

Mercury is an element with large sources in cremation and detrimental health effects. Mercury is highly volatile and is emitted into the atmosphere naturally and by anthropogenic sources. It can enter water bodies through the atmosphere and from deposits in the surrounding basin with some of the aquatic inorganic mercury being converted into organic mercury which is toxic and bioaccumulates (Takaoka et al. 2010). In humans, low levels of mercury exposure can cause nervous system dysfunction, decreased motor skill and memory function and reduced attention span; it is associated with a wide variety of ailments like neurological, immunological, heart and reproductive disorders (ENDSreport 2008; Zahir et al. 2005). With regards to cremation, mercury tends to be present in bodies as dental amalgams used widely since the 7th century (Dent 2002). While mercury is a toxic substance, the amounts released into the bodies of patients with dental amalgams are considered small enough that the Health Protection Branch of Health Canada has placed no restrictions on it and it is still widely used (Canadian Dental Association 2005). This can result in large amounts of mercury being released upon cremation.

Crematoriums represent a significant source of mercury in countries worldwide. A report by the Arctic Monitoring and Assessment Programme and the United Nations Environment Programme Chemicals (2008) lists crematories as a significant source of mercury emissions. Cremation is expected to be the single greatest source of airborne mercury in Britain by 2020 (Everts 2010). It is currently estimated to account for 16% of total atmospheric mercury emissions in the UK with total emissions estimated at 0.4 to 1.34 tonnes annually (McLellan 2007). Takaoka et al. (2010) estimated that the average mercury concentration emitted per cremation was 31.7mg. These concentrations are considered lower than would be seen in North America, potentially due to less mercury per filling (Takaoka et al. 2010). Mercury from cremations is expected to continue to rise. According to the Department for Environment Food and Rural Affairs (DEFRA) (2004) mercury emissions in 2020 will be 1.67 times those in 1995 contributing 11-35% of the total mercury emissions in the UK and will peak in 2035. Another study estimates that mercury emissions from crematories are expected to increase by 2.6 fold between 2007 and 2037 (Takaoka et al. 2010). The increasing popularity of cremation poses a severe risk to health.

In addition to public health, crematoriums pose a risk to their employees. Maloney et al. (1998) suggests that one crematorium emits 5.453 kg/year of mercury, posing a health risk not only to the general public, but also to those working in the crematoriums. Hair analysis, which tracks exposure over time and correlates with concentrations in the liver and kidney, found that of 36 sites tested, 66% had mean hair concentrations higher than controls (Maloney et al. 1998). The average mercury concentration in hair of employees working at crematoriums carrying out more than 1600 cremations per year was significantly higher than in lower output crematoria, though

this correlation did not exist at lower levels (Maloney et al. 1998). Maloney et al. (1998) found 3% of the 97 workers had mercury concentrations in their hair higher than the tolerable limit of 6ppm. These health concerns, for both the public and employees, are greater in areas of higher population densities and significant cremation percentages like the United Kingdom and Japan due to the greater atmospheric mercury releases. The issue of mercury and additional emissions from cremation is an interesting phenomenon as there is a lack of scientific study examining the release of contaminants, the likelihood of exposure and the actual risks to health, thus additional research is required.

A second atmospheric pollutant source from cremation is the release of greenhouse gases (GHG). Natural gas is the main fuel used in the cremation process (McLellan 2007). The burning of each body requires 20L of natural gas (Smith 2007). This emission of GHGs can have many negative effects, primarily contributing to the widely known issue of climate change. GHGs in the atmosphere trap infrared radiation at the earth’s surface, resulting in changes in climate (Schneider 1989). Climate change has countless effects, such as warming temperatures, extreme weather conditions, species distribution and phenology changes, even extinctions, as well as human health effects (McMichael et al. 2003; Parmesan 2006). Due to the dramatic effects of climate change, the major challenge currently facing societies is reducing GHG emissions (McMichael et al. 2003), thus it is important to note cremation as a source and potential avenue for reduction. Another issue with the use of natural gas is the rising cost associated with it (McLellan 2007). Both the risks of climate change from GHG emissions and the release of atmospheric mercury represent significant negative effects that need to be recognized and addressed to improve environmental and human health.

Disposal of ashes

The spreading of cremated ashes also presents an important source of pollution. Ashes contain large amounts of nutrients, like phosphates, which can act as fertilizers (Smith 2007). Nutrient enrichment can have many negative effects on both aquatic and terrestrial ecosystems. Potential effects of nutrient enrichment of water bodies include eutrophication, increased occurrence of toxic algal blooms and fish kills, amphibian declines, acidification, nitrate toxicity in drinking water, economic costs of increased water treatment and loss of aesthetics and recreational opportunities (Chambers et al. 2001). Nitrogen enrichment in terrestrial ecosystems can cause shifts in species composition, loss of diversity and alterations to soil chemistry (Smith et al. 1999). In the Scottish mountains, frequent scattering of ashes around mountain summits has caused enrichment of the acidic, impoverished soils resulting in changes to the native plant community (McLellan 2007). While this source is not likely to represent as great a risk as the air pollution associated with cremation, it does represent an important nutrient source that can have environmental, social, economic and human health effects. The atmospheric and nutrient contaminants need to be addressed and further studied to reduce their negative effects.

Burial:

What is it

Burial is another method of disposal where bodies are placed in the earth. Cadavers may be buried directly in the ground, wrapped or placed in a coffin with artefacts and clothing and may also be embalmed (Dent 2002). Embalming is the art of preserving a body after death, which requires the use of toxic chemicals (Spongberg et al. 1998). Before 1905, poisonous substances such as arsenic and mercury were used for the embalmment of cadavers (Spongberg et al. 1998). Eventually the high environmental and human health risks of these substances were

realized resulting in the current use of formaldehyde (Spongberg et al. 1998). Contamination results from the decomposition of corpses and the substances used in the burial, such as embalming fluid, coffins and clothing, and poses a particular risk to groundwater. Groundwater is an important source of water for human use (i.e. drinking, agriculture, etc.) and many other organisms and processes, but its’ quality and quantity are vulnerable to anthropogenic activities (Danielpol et al. 2003). It is important to note that cemetery groundwater reflects all aspects of potential contamination sources from the body, the substances used, memorial pieces, maintenance of the graves, lawns and gardens, road creation and uptake, visitors and their cars and potentially onsite sewage disposal, making it difficult to isolate each pollution source (Dent 2002). To better understand the effects of these two sources, decomposition of the body and funeral artefacts, each is examined in turn beginning with the historical background and cultural basis of burial practices and ending with additional pollution sources from cemeteries.

History and Culture of Burials

Burials have long been a preferred method of disposal of human remains. There is evidence of burials in Australia 7000 years ago (Bachelor 2004). Prior to that, there is archaeological evidence of Neanderthal (44 000 years ago) and Cro-Magnon (35 000-10 000 years ago) burials (Turner 1976). By examining the history and culture of burial, its importance can be understood.

Many cultures and religions embrace burial as the desired method for disposal. Ancient Egyptians embalmed the bodies before burial or placement in tombs; they believed that after death, the soul returned to inhabit the body, thus they used embalming to delay decay for life after death (Auger 2000). Romans used burial with the bodies cared for by *libitinarius*, professional undertakers, who did embalming and assisted with funeral activities, representing an early funeral industry (Auger 2000). Early Hebrews believed cremation was a disgrace to the body which is a creation of God and used burial; Jewish people still carry such beliefs (Auger 2000). Early Christians mirrored these beliefs, especially Catholics, due to the sanctity of the body and resurrection after death (Newton 2005). The idea of returning bodies to the earth, recycling them to the biota that supports life is the basis for burial in many cultures and religions (Stowe et al. 2001). These beliefs show the importance of burial historically across cultures.

Many of these historical ideas remain in religions and culture today, though few examples are covered here as beliefs and practices are highly variable making it unfeasible to examine all. The Islamic religion promotes protection of vegetation in cemeteries, burial without a casket and no use of pesticides on or around the grave (Uslu et al. 2009). In the Muslim faith, cremation is prohibited because it destroys the body, thus burial is used; autopsies and embalming are also prohibited (Auger 2000; Northcott & Wilson 2008). The Christian religion is highly variable accepting burial, with or without a coffin, and cremation (Uslu et al. 2009). Under Catholicism, burial is still preferred though cremation is no longer forbidden (Bachelor 2004; Newton 2005). These examples illustrate the continued importance of burial in many religions today.

Cemeteries and burial practices can play an important role in the grieving process. They represent a place of meeting with the dead and remembrance for loved ones (Auger 2000; Folgi 2004). Different features in cemeteries play important roles. For example, to secure our immortality, humans construct symbols to represent the connection between the living and dead and tools of remembrance and comfort for the living, such as coffins and tombstones (Auger 2000). In nineteenth century Europe, it was believed that gravestones within cemeteries could sustain the memory of the dead (Auger 2000). In many cultures, such as Hutterite, Mennonite and in Africa and South America, coffin building is an essential part of the funeral process

(Auger 2000). Cemeteries are more than a disposal site for the dead, they represent something important to the people visiting them and the instruments involved, such as coffins and gravestones, play a role in helping the living grieve and remember.

Embalming has a rich history as well, as illustrated by its use in Ancient Egypt and Rome. Its importance lies in the ability to allow family and friends to view the dead at peace and aid in the acceptance of their loss (Auger 2000). Despite its history across the ocean, embalming did not arrive to North America until the 1800s (Auger 2000). The Civil War led to an increase in interest for methods of preserving bodies resulting in embalming becoming more common (Auger 2000; Smith 2007; Stowe et al. 2001). In 1999, most of the 2.3 million dead Americans were embalmed (Stowe et al. 2001). Overall, it can be seen that both burial and embalming have a rich history and play essential roles in the funeral practices of many cultures and religions.

Pollution caused by bodies

To understand the potential pollution of cadavers, it is essential to understand the process of decomposition. Decomposition begins shortly after death and occurs through a series of microbial and chemical reactions within the body (Dent 2002). Microorganisms in the body move to the tissue, quickly using up the oxygen which leads to anaerobic decomposition (Dent 2002). Overall, aerobic conditions result in faster decomposition and removal of products (Dent 2002; Üçisik & Rushbrook 1998). Figure 1 illustrates the series of decompositional steps for a human body. It will take approximately 10-12 years to decompose a corpse depending on the conditions, with the amounts of substances leaching into the soil and groundwater declining each year (Environment Agency 2004; Young et al. 2002). This brief description illustrates the continued release of products into the surrounding burial environment.

Various parts of the body decompose into different substances and potential pollutants. The body is made up of 64% water, 20% protein, 10% fat, 5% mineral and 1% carbohydrate (Dent 2002; Environment Agency 2004). Focussing on the decomposition of proteins, fats and carbohydrates individually allows better understanding of the different products. Protein decomposition releases gases, like purscine and cadaverine, both of which are toxic with a foul smell, and hydrogen sulphide and methane (Dent 2002). Ammonia, nitrate,sulphide (transformed to sulphurous acid) and organic acids, are also produced, accumulating in the soil or potentially the groundwater (Dent 2002). Fat decomposition results in the production of adipocere, composed of saturated fatty acids, which slowly decomposes under anaerobic conditions with the assistance of bacteria (Dent 2002). Carbohydrate decomposition creates sugars, further decomposing through bacterial and fungal actions to gases and organic acids (Dent 2002). The resulting decomposition products from the body are now able to enter the surrounding environment. Table 2 illustrates potential volumes of effluent produced in small and large cemeteries. Contaminants can enter the soil surrounding it, travel to the unsaturated zone of the aquifer below it or into the groundwater (Environment Agency 2004). They can also be released atmospherically. However, as there is a lack of measurements regarding atmospheric contamination (Young et al. 2002), it will not be examined here.

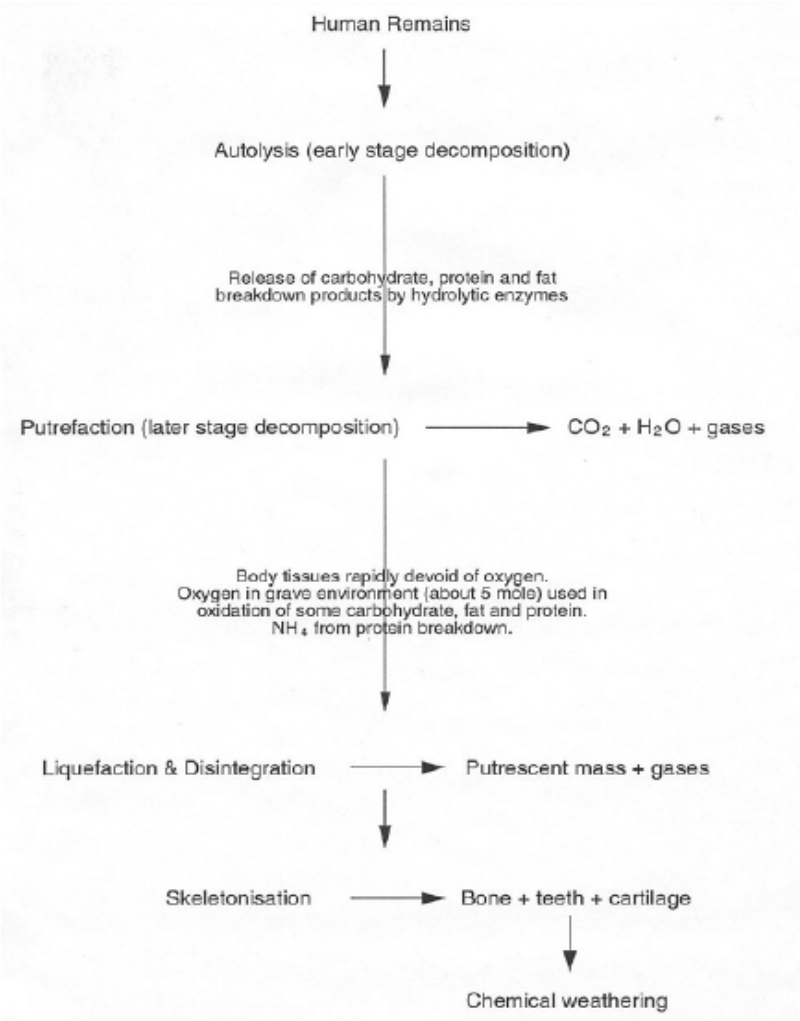

Figure 1: Process of decomposition of the human body (copied from Dent 2002).

Table 2: Estimates of liquid effluent produced in a small and large municipal cemetery in England (copied from Rodrigues & Pacheco 2003).

Year	Cumulative area of burials (m^2)		Annual effluent production (litres)	
	Small	**Large**	**Small**	**Large**
1	125	4375	25 000	918 750
2	250	8750	50 000	1 837 500
3	375	13 125	75 000	2 756 250
4	500	17 500	100 000	3 675 000
5	625	21 875	125 000	4 593 750
6	750	26 250	150 000	5 512 500
7	875	30 625	175 000	6 431 250
8	1000	35 000	200 000	7 350 000
9	1125	39 375	225 000	8 268 750
10	1250	43 750	250 000	9 187 500

Inorganic chemicals and bacteria and/or viruses are the two main pollution sources from decomposition of cadavers. Organic compounds can also be associated with cemeteries and may be represented by indexes such as biological oxygen demand or total organic carbon (Young et al. 2002). However, they appear to be less researched and will only be mentioned briefly as dissolved organic carbon (DOC). DOC concentrations are increased in water samples from cemeteries compared to regional concentrations (Engelbrecht 1998; Table 3). While not directly harmful, it can cause ill health effects when chlorinated, as well as interfering with water purification and reducing aesthetic appeal of water through taste, smell and colour changes (Government of Saskatchewan 2009). With regards to inorganic chemicals, previous studies and the potentially negative environmental and human health effects will be examined. The first substance examined is mercury. As mentioned, mercury is found in the dental amalgams of corpses. Once dead, these buried amalgams become weathered releasing the mercury into the soil and groundwater (Dent 2002). Dent (2002) found relatively low mercury levels in the groundwater below cemeteries, though some exceeded the limit of 1ug/L. This is still an important contaminant source as there is some evidence of accumulation in groundwater and because of its toxicity and health effects as described with cremation. The wide variety of negative effects illustrates the importance of understanding even small exposure doses, like those potentially from cemeteries. There are a wide variety of nutrients released as well. Dent (2002) found that the chemical composition of groundwater in cemeteries was dominated by three groups of substances: inorganic forms of nitrogen, forms of phosphorus and major anions and cations. Engelbrecht (1998) also found increases in the nutrient (or chemical) variables measured within a cemetery compared to regional conditions (Table 3). Nitrogen, especially ammoniacal nitrogen and nitrate, is one of the main pollutants from decomposing corpses, which can have negative effects on humans and the environment (Environment Agency 2004; Kim et al. 2008; Soo Chan et al. 1992; Sililo et al. 2001; Table 4). Nitrate can cause cancer, reproductive problems and methemoglobinemia, which is especially deadly in babies (Gaffield et al. 2003; Sililo et al. 2001; Townsend et al. 2003). The Drinking Water Standard for Ontario and the World Health Organization for nitrate is 10.0mg/L, though some effects, especially increased cancer risk, have been seen below this (Soo Chan et al. 1992; Townsend et al. 2003). A study of six cemeteries in Ontario found nitrate concentrations from 0.005 to 14.3mg/L, with one site having concentrations over the standard (Soo Chan et al. 1992). Nitrogen (as nitrate and other forms) can also negatively affect the environment by causing eutrophication, decreasing species diversity and potentially reducing crop and other plant growth (Townsend et al. 2003). Ammoniacal nitrogen has been found to negatively affect plants and be toxic to algae and other organisms like fish (Alexander & Fairbridge 1999). Overall, many inorganic decomposition products can have potentially negative effects on human and environmental health and may increase in or near cemeteries.

Table 3: Minimum and maximum concentrations (and pH units) for chemical parameters measured at a local municipal cemetery in the Western Cape, South Africa. The cemetery is 53 200m^2 and is located on loose sand, with burials beginning between 1840 and 1890 and continuing forward. Comparison between typical local conditions based on samples taken from a municipal borehole, 500m away from the cemetery and groundwater samples taken in 21 sites within the cemetery. Adapted from Engelbrecht (1998).

Chemical Parameter	Concentration of Local Groundwater	Concentration inside Cemetery Groundwater
Potassium	2.1-2.5mg/L	0.3-37mg/L
Ammonia-N	<0.1-2.0mg/L	<0.1-88.9mg/L
Nitrate and Nitrite-N	<0.1mg/L	<0.1-55.4mg/L
Dissolved Organic Carbon	0.1-10mg/L	1.8-218.4mg/L
Electrical Conductivity	75-134mg/L	14-1360mg/L
Phosphate	<0.1mg/L	<0.1-0.99mg/L
pH	6.5-6.9	6.5-7.9

Table 4: Potential modelled ammonical nitrogen concentrations, volumes and loads leaching from three types and sizes of cemeteries at the first year of burial and ten years after burial began at each site. A small churchyard was modelled to have 10 burials/year, a large municipal cemetery has 350 burials/year and a green burial site has 30 burials/year. Copied from Young et al. (2002).

Cemetery	NH4 mg/l		Volume m^3/yr		Load kg/yr	
	1 year	10 years	1 year	10 years	1 year	10 years
Small churchyard	348	69	23	250	8.7	17.25
Municipal cemetery	331	66	920	9190	304.5	696.5
Green burial	305	61	86	855	26.2	52.2

Inorganic chemicals can also play a role in microbiological pollution in cemeteries. Decomposition products can provide food for microorganisms enabling their maintenance and growth (Engelbrecht 1998). There are many bacteria and viruses that are associated with the human body and its decomposition. For example, *Bacteriodes spp*., *Escherichia coli.*, *Salmonella spp*., *Clostridium spp*., *Enterobacteria* and *Streptococcu spp*. can exist within the body during life and remain post-mortem, thus are associated with cemeteries (Dent 2002; Üçisik & Rushbrook 1998). Many are able to survive within the soil and groundwater without a host for an extended time, allowing them to spread (Dent 2002). A variety of these bacteria and viruses are known to cause disease in humans; even those present naturally in the body can be pathogenic in other individuals and at different concentrations (Dent 2002). Dent (2002) detected several disease causing bacteria in the groundwater of cemeteries, such as *Enterococcus faecailis* and *Pseudomonas aeruginosa*, as well as faecal indicators like *E. coli*. Rodrigues & Pacheco (2003) also found higher bacteria concentrations from water samples within cemeteries compared to those hundreds of metres away. Engelbrecht (1998) found an increase in the number of bacteria colony forming units in groundwater within and surrounding a cemetery compared to the overall regional conditions, to such a level that it was considered extremely polluted microbiologically (Figure 2). These studies illustrate that groundwater within and surrounding cemeteries can be highly polluted by bacteria and viruses. However, a variety of factors influence their effects on the human population. The dose plays a major role, as the ability to cause disease is highly

variable with viruses being infectious at low doses, but bacteria often requiring higher doses, as does the susceptibility of the population and the microorganisms’ ability to survive and reach groundwater and humans without being attenuated (Dent 2002; Engelbrecht 1998; Young et al. 2002; Rose et al. 2001; Üçisik & Rushbrook 1998). There are also regulations regarding the treatment of drinking water to remove microorganisms; however, not all people are protected as standards are violated, certain organisms are not removed and some homes, especially in the country, use untreated well water (Rose et al. 2001). Despite the potential for attenuation and removal from treatment, this is a potential health hazard. Water-bourne pathogens are associated with many ailments such as gastrointestinal, neurological, liver, lymphatic and endocrinological diseases, in addition to increasing cancer risk (Rose et al. 2001). Approximately 10-15% of yearly infectious outbreaks are caused due to drinking water contamination in the USA (Rose et al. 2001). *E.coli* can cause diarrhea, stomach flu and even kidney failure and death, faecal coliform is linked to Giardiasis and faecal *Streptococci* to diarrhea; for all of these, the World Health Organization standards are 100% absence (Erah et al. 2002; Fong et al. 2007; Gundry et al. 2004; Rose et al. 2001; Yassin et al. 2006). Another example is *Salmonella spp*. which can cause typhoid fever, gastrointestinal problems, diarrhea and arthritis (Pell 1997). Many diseases such as typhoid fever, cholera, polio and hepatitis can be spread by biological contamination of water (Sililo et al. 2001). With these risks, it is important to understand and account for the potential microbial contamination from cemeteries.

Pollution of chemicals and funeral artefacts

Beyond the potential chemical and biological contamination caused by the decomposition of corpses, there is risk of pollution from the items and chemicals buried with the body, including caskets, their chemical leachate and embalming fluid. An estimated 30 million hardwood caskets, 104 272 ton vaults for caskets and graves, 2700 tons of copper and bronze and 872 060 gallons of embalming fluid are placed in the ground each year in the USA for the burial of 2.5 million people (Uslu et al. 2009). Caskets may contain harmful chemicals based on their materials. Metal caskets are prone to cause contamination in acidic soils and leach metals such as iron, copper, lead and zinc (Spongberg, 1998). Wood caskets pose a threat if wood preservatives are present, which can contain arsenic (Spongberg et al. 1998). To reduce to possibility of contamination, caskets may be placed in a concrete, metal or fiberglass vault that prevents subsidence of the earth above and may preserve the buried contents, though this remains unverified (Spongberg et al. 1998). This entombment also slows natural decomposition and could extend the period of contamination. Both caskets and vaults could pollute the surrounding soil and water sources by leaching varnishes, preservatives, sealants and metals (Stowe et al. 2001). These leached substances could present additional environmental and health issues to nearby residents and the surrounding environment.

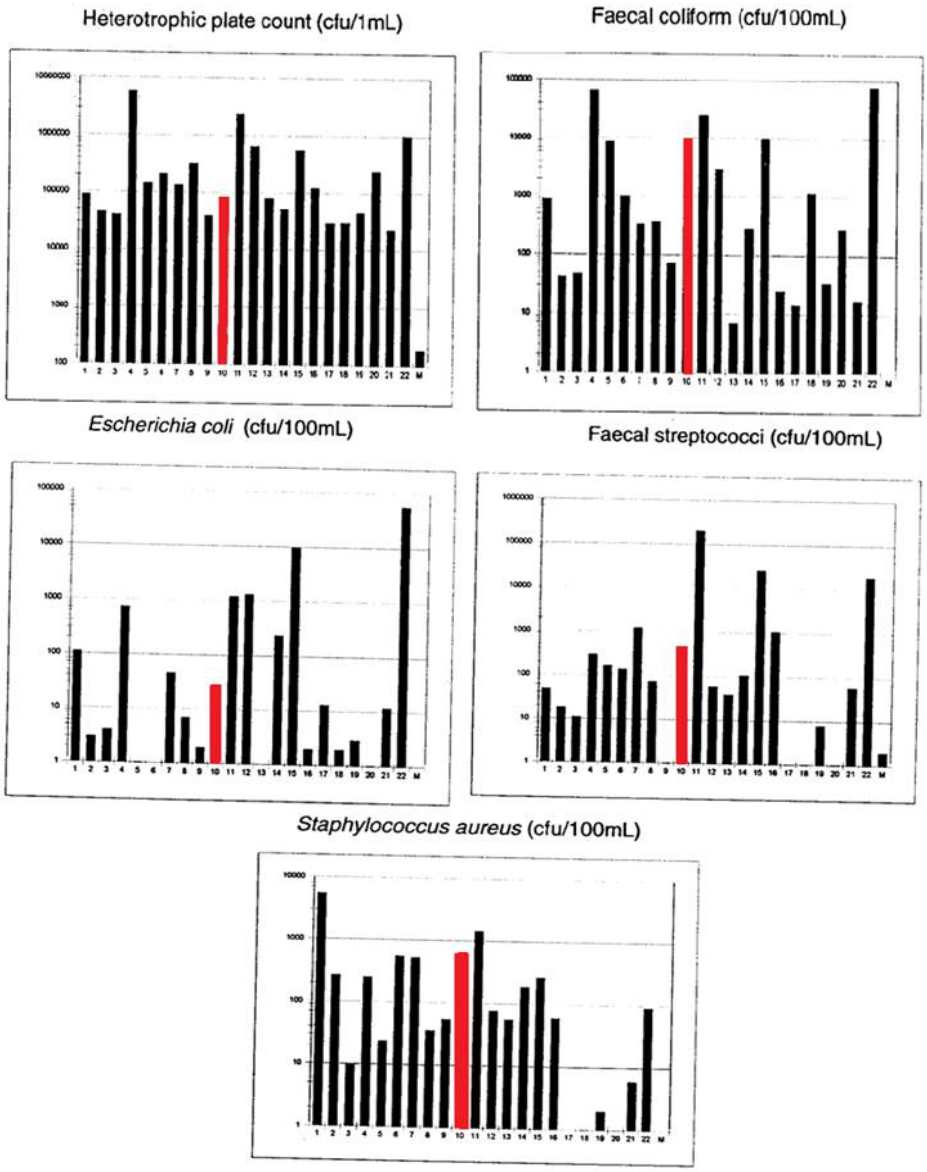

Figure 2: 95 percentile values for number of colony forming units (CFU) per 100ml samples for each bacterial parameter at a local municipal cemetery in the Western Cape, South Africa. The cemetery is 53 200m^2 and is located on loose sand, with burials beginning between 1840 and 1890 and continuing. Sites 1-9 and 11-22 represent groundwater samples taken throughout the cemetery. The red site (Site 10) represents groundwater samples taken at a site 50m outside the cemetery and the final site (Site M) represents the desirable groundwater conditions, based on the local municipal samples taken 500m from the cemetery. Figure adapted from Engelbrecht (1998).

Embalming fluid represents a potential pollutant from cemeteries. The Environmental Protection Agency (EPA) is concerned about the of leaching toxins in embalming fluid, such as arsenic (now outlawed), formaldehyde and gluteraldehyde, into groundwater from cemeteries (Stowe et al. 2001). Formaldehyde is a volatile organic compound, a potential carcinogen and is known to cause comas, internal bleeding and death (Uslu et al. 2009). It is listed for future banning by the European Union and has been proven to be a risk for those working with the

substance. It is also on the US Hazardous Substance List and has regulated standards for usage and exposure by both the Occupational Safety and Health Administration and the EPA (Mao et al. 1994). In environments where formaldehyde is manufactured, death rates from nasopharyngeal cancer are significantly increased and a relationship between the disease and the substance has been confirmed (Cogliano et al. 2005). Those working in embalming practices, in funeral parlours and pathologists or anatomists have been found to have an increased risk of developing leukemia from formaldehyde exposure (Cogliano et al. 2005). Also, when used for embalmment, the chemical is oxidized, converting it to formic acid, an irritant of the eyes, skin and respiratory system, which is released into the atmosphere (United States Department of Labor 2011; Uslu et al. 2009). Kerfoot and Mooney (1975) collected air samples from six funeral homes and found the average formaldehyde concentration in the air in embalming rooms was 0.74 ppm with a peak of 5.26 ppm, which caused eye and upper respiratory tract irritation in some employees (Mao et al. 1994). Observations of 36 embalmings in Manitoba revealed that 83% of cases had atmospheric formaldehyde levels above standards (reviewed in Smith 2007). These risks to workers can be extrapolated to indicate risks for the public should formaldehyde reach groundwater sources or through atmospheric exposure, though further research is needed. With the high embalming rates since the Civil War and the use of caskets, the burial of these substances poses a risk to human and environmental health that needs to be minimized.

Other sources of pollution

In addition to these sources of pollution from cemeteries, there are also minor sources, such as pesticides, fertilizers and potential fossil fuel use and exotic species. These uses are often related to the maintenance of the site and may be required. For example, in Ontario, cemeteries must have a Care and Maintenance Fund which is used for the upkeep of the site (Canadian Legal Information Institute [CanLII] 2011b). Many of United States cemeteries use biocides to keep the sites lush and green (Uslu et al. 2009; reviewed in Stowe et al. 2001). Despite federal regulations on pesticides in Canada, the bans for cosmetic use only exist at the municipal and provincial level (Christie 2010; Health Canada [HC] 2011b). Over 170 municipalities have by-laws restricting lawn pesticide use and some provinces have strict regulations, even bans for pesticides (Gouvernement du Québec 2006; Government of New Brunswick 2009; Government of Prince Edward Island 2010b; Ministry of the Environment 2009; Office of the Legislative Counsel, Nova Scotia House of Assembly 2010). However, in Ontario, for example, even with the recent ban on pesticides, certain kinds are still permitted for use in cemeteries such as those for removal of harmful species (mosquitoes, wasps, poison ivy) and Class 11 pesticides (including biopesticides and lower risk types) (Ministry of the Environment 2009). Pesticides can enter the groundwater through the same processes as decomposition products and can be potentially harmful (Sililo et al. 2001). Potential risks of chronic low dose exposure in humans include cancer, neurotoxicity and reproductive and developmental effects; there are also poisoning effects with acute exposure (Hodgson & Levi 1996; Sililo et al. 2001). Environmental effects include pesticide toxicity in bees, water contamination, death of sensitive species and decreased reproduction and growth, even death (Pimentel 2005). With these potential effects, further research is needed to determine how many cemeteries use pesticides, what kind, as well as the possible risks from loss.

Fertilizers can also play a role as they may be used to maintain a desired appearance. Fertilizers contain large amounts of nutrients that can runoff areas in aquatic or terrestrial ecosystems leading to many negative human and environmental health effects (Chambers et al. 2001; Smith et al. 1999), as seen in the spreading of ashes. As with pesticides, research is

required to determine how many cemeteries use fertilizers and the levels lost to surrounding ecosystems. Additional minor pollutants include fossil fuels used in machines to dig graves and from vehicles for visitor travel and exotic species being planted (Stowe et al. 2001; Uslu et al. 2009). These additional pollution sources represent areas of future research relating to the overall negative effects of cemeteries on the environment and human health.

Legislation:

In Canada

Contrary to the severity of the potential adverse environmental and human health effects related to the disposal of cadavers, Canada has minimal legislation to monitor and address the issue. Those few related acts and regulations are highly variable. In Canada, the industry is regulated at the provincial level, with no direct legislation at the federal level (Smith 2007). Table 5 lists the acts and their regulations related to the funeral industry. As illustrated, there is little consistency as some acts relate to cemeteries, others to funeral homes and embalming and others to religious aspects. Even within similar acts, the requirements differ. For example, embalming is required in Manitoba, if the body will be transported across the province and not reach the destination in 72 hours whereas in Quebec, it is required if the body is exposed for 24 hours or if there is an 18 hour period before visitation and in Alberta, if the body is shipped out of province (Smith 2007). The responsible department also varies across provinces from consumer protection to health to culture to justice (Table 5). Overall, the funeral industry has very few consistent regulations except for requiring funeral directors be licensed (Smith 2007). This inconsistency results in different levels of protection afforded to human health and the environment across Canada and represents a barrier to change.

Table 5: Legislation and regulations relating to the funeral industry for each province.

Province	Relevant Department	Legislation (and Regulations)	Reference
British Columbia	Business Practices and Consumer Protection Authority	Cremation, Internment and Funeral Services Act (Cremation, Interment and Funeral Services Regulation, Funeral Services Licensing And Business Practices Regulation)	Queen's Printer 2011
Alberta	Service Alberta	Cemeteries Act (Commercial Cemeteries Regulation, Crematories Designation Regulation, Crematory Regulation, Cemeteries Exemption Regulation, General Regulation) Cemetery Companies Act (Cemetery Companies Regulation) Funeral Services Act (Exemption Regulation, General Regulation)	Government of Alberta 2011
Saskatchewan	Consumer Protection Branch of the Ministry of Justice and Attorney General	The Cemeteries Act (Cemeteries Regulations) The Funeral and Cremation Services Act (Funeral and Cremation Services Regulations)	Government of Saskatchewan 2007
Manitoba	The Public Utilities Board	The Cemeteries Act (Cemeteries, Crematories and Perpetual Care Funds Regulation) The Funeral Directors and Embalmers Act	Province of Manitoba 2010

	Member of the Executive Council charged by the Lieutenant Governor in Council Manitoba Health	Embalmers and Funeral Directors Board Allowances Regulation, Funeral Directors and Embalmers Regulation) The Prearranged Funeral Services Act (Funeral Directors Regulation) The Religious Societies' Lands Act The Public Health Act (Dead Bodies Regulation)	
Ontario	Ministry of Consumer Services (Board of Funeral Services) Ministry of Consumer Services (Cemeteries Regulation Unit)	Funeral Directors and Establishments Act (Board-Compensation and Remuneration, Compensation Fund, Equipment and Premises and Licensing and Business Practices) Cemeteries Act (Revised) (Burial Sites, Establishing, Operating and Closing Cemeteries and Crematoria, Licences, Trust Funds)	Board of Funeral Services 2010; CanLII 2011a Ministry of Consumer Services 2009; CanLII 2011b
Quebec	The Minister of Economic Development, Innovation and Export Trade and Minister of Revenue Ministry of Health and Social services Ministry of Justice	Cemetery Companies Act (Tariff of fees payable under the Cemetery Companies Act) An Act Respecting Roman Catholic Cemetery Corporations Non-Catholic Cemeteries Act Burial Act An Act Respecting Pre-arranged Funeral Services and Sepultures (Regulation respecting the application of the Act respecting prearranged funeral services and sepultures)	CanLII 2011c,d Gouvernement du Québec 2011 CanLII 2011e
Newfoundland and Labrador	Member of the Executive Council charged by the Lieutenant Governor in Council	Prepaid Funeral Services Act (Prepaid Funeral Services Regulations)	CanLII 2011f
Nova Scotia	Minister of Education and Culture Minister of Consumer Affairs Governor in Council	Cemeteries Protection Act Cemetery and Funeral Services Act Cemetery Companies Act	Office of the Legislative Counsel, Nova Scotia House of Assembly 2011

New Brunswick	Minister of Health Minister of Justice and Consumer Affairs	Cemetery Companies Act **(**Cemetery Companies Act, N.B. Reg) Pre-arranged Funeral Services Act (Compensation Fund Regulation, General Regulation)	CanLII 2011g CanLII 2011h
Prince Edward Island	Minister of Justice and Public Safety and Attorney General	Cemeteries Act Prearranged Funeral Services Act Coroners Act (Coroners Act Regulations)	Government of Prince Edward Island 2010a
Nunavut	Consumer Affairs (Community and Government Services)	n/a	Smith 2007
Northwest Territories	Ministry of Justice	Coroners Act (Coroners Forms Regulations, Coroners Remuneration, Expenses and Fees Regulations)	Government of the Northwest Territories 2009
Yukon	Department of Health and Social Services	Public Health and Safety Act (Embalmers and Embalming Regulations, General Regulations, perhaps additional regulations)	Government of Yukon 2011

At the federal level, there appears to be no acts or regulations directly relating to the funeral industry, though some are indirectly related through the effects on human health and the environment. Health Canada and Environment Canada are two of the federal ministries that may indirectly play a role. Health Canada aims at improving and maintaining the health of Canadians (HC 2011a). It has responsibilities with regards to air and water quality and environmental contaminants (HC 2009a). For example, Health Canada, in conjunction with the provinces and territories, creates guidelines for drinking water quality; these guidelines include contaminants introduced in the disposal of cadavers such as bacterial (*E. coli*) or chemical (mercury) pollutants (HC 2009c, 2010). Another example, is the control of toxic substances like mercury through the Canadian Environmental Protection Act (CEPA), administered with Environment Canada (HC 2009b, Government of Canada 2010). Environment Canada aims at protecting the environment by restoring past damages and preventing future ones (Environment Canada [EC] 2011a). As with Health Canada, it has responsibilities regarding air and water, as well as pollution and wastes (EC 2011c). With water, the responsibilities are shared between federal, provincial and municipal governments; the federal level is responsible for fisheries (the Fisheries Act), health and release of toxic pollutants (CEPA) (EC 2010a,b). CEPA also plays a role in the release of pollutants into other parts of the environment, like air (EC 2011b). Returning to the pollution potential of corpse disposal, it appears that the federal government's role is indirectly through the creation of guidelines, the CEPA and Fisheries Act and working with stakeholders, including the other levels of government. However, as mentioned, the lack of direct involvement at the federal level results in various levels of protection at the provincial level and thus potential for pollution.

<u>In Ontario</u>

To examine the legislation at a more local level, the acts and regulations for Ontario were studied. The new Funeral, Burial and Cremation Services Act was also read which will replace the Cemeteries Act Revised and Funeral Directors and Establishments Act when implemented

(Smith 2007). Under these three pieces of legislation, there is very little mention of guidelines or tools to prevent or minimize pollution and risks of cemeteries and crematoriums. The focus is on licensing, issues of misconduct, consumer protection, business practices, but not on potential pollution (CanLII 2011a,b; Ministry of Government Services [MGS] 2009). When creating a cemetery, the only requirement is an application describing the layout and placement of different features including roads, waterways and fences with a single location limitation in the regulations requiring a medical officer of health to state the locations is appropriate (CanLII 2011b; MGS 2009). Beyond this, there is no description of the standards used to determine if a site is appropriate. Other statements that could relate to pollution control are the required depth of burial and implementing sewers and drains to keep cemeteries drained and dry (CanLII 2011b; MGS 2009). There did not appear to be any regulations relating to pollution caused by cremating bodies or scattering ashes, as they can be scattered wherever permission is obtained (CanLII 2011b; MGS 2009). The only additional concern for human health is that the licence to own a cemetery or crematorium can be revoked or refused if it poses risks to human health (CanLII 2011b; MGS 2009). Based on the examination of this legislation, there appears to be minimal control of the potential contamination sources of cemeteries and crematoriums, such as location, scattering of ashes and cremation emissions.

Economics:

One barrier that will be faced in changing current practices is the funeral industry. Due to its profitability, job provision and increases in corporations, there will be resistance to changes that restrict or limit practices. The funeral industry is a highly profitable business. In North America, approximately $9-10 billion a year was grossed by death-related businesses in the 1990s (Northcott & Wilson 2008). Its profits are due in part to the necessity of the business, effective marketing, high prices such as a 100-400% mark-up on caskets and urns and lack of customer knowledge as there is often little chance to compare prices and services after a loved one’s death (Northcott & Wilson 2008). Examples of marketing strategies include restricting use of self provided caskets and the third unit rule, where a customer is shown a cheap, average and expensive casket, so they usually choose a moderately priced one (Smith 2007). These strategies seem to be aimed at making money rather than serving the public. One quote “...if I can take the casket away from you [the funeral industry], you are dead in the water. You will die financially” (Smith 2007 p.39), illustrates the dependence of the business on caskets and other products rather than the body. In Canada, funerals cost $5000-10 000 on average, with each service equating more money; a cremation is approximately half the cost (Northcott & Wilson 2008). These costs have increased dramatically over the last half century from $1000US in 1963 to $6000US in 1999 (Smith 2007). The industry is also a large employer, providing both direct and indirect jobs, such as construction of caskets and urns, building funeral homes, embalmers, maintenance, supplying flowers, printing obituaries and providing travel methods, among others (Northcott & Wilson 2008). These financial aspects may negatively impact any movement for change that may reduce the benefits. For example, the current concern is the shift from the traditional funeral with caskets and embalming to cremation (Smith 2007). Cremation does not necessarily exclude the traditional funeral as before cremation, bodies may be viewed requiring a casket and potentially embalming (Smith 2007). Future changes may result in a loss or reduction of these products and services so may be resisted.

In addition to the financial benefits, there has been a shift from the family run funeral home to large corporations which may impact the ability to make changes. Since the 1980s and 1990s, this shift has resulted in a few companies monopolizing the business (Northcott & Wilson

2008). For example, in twenty years, the number of independent funeral homes in Montreal declined from 28 to 6 (Smith 2007). In Canada, two companies dominate the funeral industry, Service Corporation International, owning over 2000 North American funeral homes and crematoriums in 2006, and Arbor Memorial Services (Northcott & Wilson 2008; Smith 2007). Even the casket industry is dominated by corporations, like Batesville Casket and Matthews International, decreasing the number of companies from over 700 in 1950 to 177 in 1997 (Smith 2007). This shift to the business of death may influence the ability to create change as corporations do not live in the areas that they are potentially polluting or see the environmental or health effects. Therefore with no governmental action influencing them, they may have little reason to alter their behaviour though they may possess greater financial resources to cause change. Overall, the high profitability and job provision of the funeral industry and the increase in corporations may present barriers to alternative methods of disposal and funeral practices and must be kept in mind when trying to create change.

Social:

In addition to governmental and economic barriers, current and future disposal practices may face social resistance resulting from cultural and religious beliefs, the growing population and public resistance. As Canada is a culturally and religiously diverse country, there are a wide range of rituals associated with death (Northcott & Wilson 2008), as addressed above. With this variety, it may be difficult to enforce certain changes to the funeral industry as they may go against particular religions and cultures. For example, promoting cremation would likely result in resistance from Catholic and Muslim religions. These beliefs must be considered when recommending changes as they represent important barriers. The amount of space required for corpse disposal, especially burials, is another barrier as with the rising population, the land required for cemeteries will increase at a similar rate. In the future, it may be difficult to find land within cities to place cemeteries (Üçisik & Rushbrook 1998). This is especially a problem as public opinion may also play a role in placement based on the idea of “not in my backyard”. These factors could result in the placement of cemeteries in inappropriate locations that have high pollution potential. Some communities have recognized the potential adverse environmental impacts of crematoria and have been resistant to new crematoria developments. The citizens of Isla Verde, Puerto Rico protested the construction of a new funeral parlour and crematorium, concerned that the crematorium could contaminate the area (Pacheco 2006). Their resistance is indicative of social concern for pollution associated with corpse disposal. These social barriers are important to consider when instituting changes to practices in the funeral industry. Additional social barriers will be addressed below in connection with green burials.

Recommended Solutions:

Based on the examination of the issues and potential barriers, a series of potential solutions have been determined that can reduce the contamination and negative environmental and human health effects associated with the disposal of cadavers in cemeteries and through cremation. The following recommendations are listed in order of perceived importance. Solutions vary from alterations of current practices, increased governmental influence and reduced pollutants. Public opinion plays a major role in all of these recommendations due to their ability to influence and motivate change in the government and funeral industry. Education and awareness of the issue and possible solutions may influence public actions and result in the necessary changes required to reduce pollution, as illustrated in green burials below. The implementation of one or all of these recommendations, in conjunction with increased public

awareness, will dramatically reduce the polluting effects of corpse disposal and improve environmental and human health.

Alteration of Legislation and Siting Methodology

As mentioned, there is a lack of federal legislation directly related to the funeral industry and based on Ontario's acts and regulations, little control of the pollution potential of the industry. With regards to legislation, we have two recommendations: creation of federal regulations and guidelines for siting cemeteries. With the first, as seen in Table 5, legislation related to the funeral industry varied across provinces. This inconsistency leads to different levels of protection for human and environmental health throughout Canada. We recommend that either Health or Environment Canada, preferably both, establish legislation regulating the amount of pollution released from the funeral industry to create consistency across Canada, as well as guidelines for siting cemeteries and filtering in crematoriums, described below. In addition, we suggest that they promote or require practitioners to incorporate the additional recommendations in their practices and increase public education with regards to the pollution potential and alternative methods of disposal.

Vulnerability to pollution is highly dependent on the conditions within the cemetery, such as soil type, precipitation and aquifer characteristics. We recommend that the federal government create guidelines describing the type of sites acceptable for cemeteries and require the utilization of risk analysis in siting decisions. Sites to be avoided for cemetery placement include those in areas with large amounts of precipitation as it can result in greater movement of contaminants and high water tables allowing direct contamination through contact with the bottom of coffins (Dent 2002; Environment Agency 2004; Üçisik & Rushbrook 1998). A small unsaturated zone above groundwater also provides poor protection and is vulnerable to contamination, as are sites with highly permeable conditions like sand, gravel or fractured rock (Engelbrecht 1998; Environment Agency 2004; Rodrigues & Pacheco 2003; Sililo et al. 2001). Cemeteries close to drinking water supplies like springs are also at increased risk, thus should be placed a minimum distance from potable groundwater and watercourses or springs (250m and 30m respectively) (Environment Agency 2004; Uslu et al. 2009). Sites that are very sloped or flat should be avoided, as they can create drainage issues (Uslu et al. 2009). There are certain conditions that are well suited for cemeteries as they can attenuate the pollutants. Moving through the soil and unsaturated zone, contaminants can be attenuated through reactions with the soil, filtration and adsorption to particles (Environment Agency 2004; Kim et al. 2008). A thick unsaturated zone is one of the greatest defence mechanisms as it filters and adsorbs contaminants (Üçisik & Rushbrook 1998). Clay soils are also good barriers as they limit the percolation of water and decomposition productions through the soil to the groundwater (Folgi 2004; Rodrigues & Pacheco 2003; Sililo et al. 2001; Spongberg & Becks 2000). A contaminant reaching the groundwater may also be diluted by the volume and movement of water (Environment Agency 2004; Young et al. 2002). Distance is a major attenuating factor as concentrations of pollutants decrease with increasing distance from cemeteries (Rodrigues & Pacheco 2003). Based on these factors of sensitivity and attenuation, guidelines can be created to assist in the locating of new cemeteries. Risk analysis should be employed for each newly proposed cemetery to reduce risks of poorly sited locations. The UK Environment Agency (2004) has a three tier system of assessing risks with each level indicating greater risk or uncertainty, with associated recommendations (Figure 3). A similar system could be developed and utilized in Canada. Overall, improved siting will reduce the pollution potential of cemeteries and subsequent health and environmental risks. This is also beneficial as it would face little resistance because it would

result in no changes for the public and simply more care and analysis of sites when proposing and creating new cemeteries. Federal legislation and creation of siting guidelines would create consistency across Canada and provide protection of human and environmental health through utilization of natural attenuating factors and avoidance of sensitive sites.

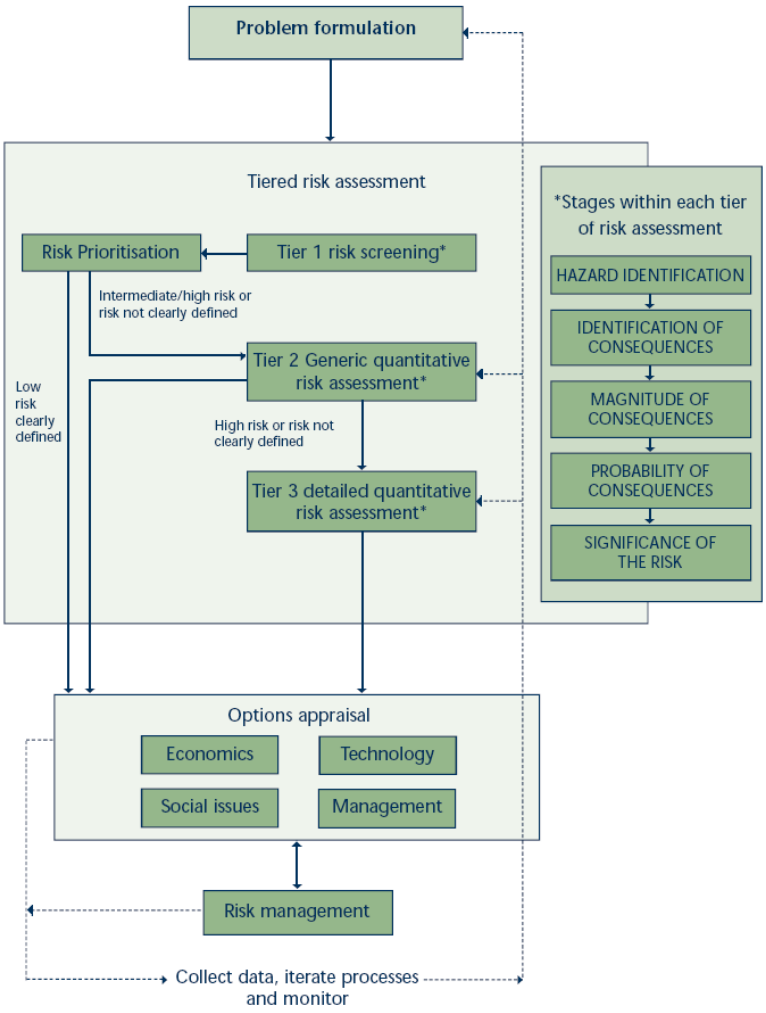

Figure 3: Framework for assessing risks using a three tiered approach developed by the Environment Agency with increasing levels of detail and effort at each subsequent tier (Environment Agency 2004).

Creation of Crematorium Legislation

In Canada, there is no overriding Federal legislation that addresses quality standards in crematoria. Ontario’s Environmental Protection Act addresses standards for industrial emissions, but is not specific to crematoria (Environmental Protection Act 1990). The United Kingdom has taken the lead on reducing crematoria emissions just as they took the lead in popularizing the practice (DEFRA 2004). In England, permits for crematoria are required to add a condition to fit mercury emission abatement strategies or join a burden sharing scheme under the Environmental Permitting Regulations (ENDSreport 2008). Burden sharing schemes are used to reduce mercury emissions while preventing high costs to the operators due to installation of expensive equipment (ENDSreport 2008). DEFRA is requiring a 50% reduction in mercury emissions from crematoria

by 2012 (Environmental Protection (England)(Crematoria Mercury Emissions) Direction 2008). Another proposal in the UK is the creation of an environmental levy of 27.50£ per cremation to recompense abatement costs (DEFRA 2004). In Sweden, installations of selenium filters in crematoria that remove 80-85% of mercury from emissions are underway (Maloney et al. 1998). Despite the increasing regulations in Europe, there are few restrictions on emissions in Canada or the USA as it is seen as a low risk source of pollution (Smith 2007). As seen above, potential risks indicate that it would be valuable for Canada to adopt the same standards as the UK to reduce pollution caused by crematoria emissions.

Reductions in Chemicals

The best method to reduce the possibility of chemicals leaching into the environment is to limit the amount of harmful chemicals used in the burial process. The claim that embalming protects public health is false as the body is no danger to the public until it begins decomposing and this can be slowed by cold temperatures (Smith 2007). Embalming is only required if the body has not been buried, cremated, refrigerated or placed in a casket within 24 hours of death (Stowe et al. 2001). There also exist more natural methods of preservation as seen in historical natural, chemical-free embalming methods. Before 3200 BC, Egyptians wrapped cadavers in natural materials like straw mats or cloths and placed them in a shallow grave where the body was covered with sand, preserving the body by drying (Mao et al. 1994). Another ancient method removed the major organs, filled the body with herbs, honey, wax and spices and then used natron, a combination of sodium chloride, sodium sulfate, sodium carbonate, potassium sulfate and potassium nitrate, to dehydrate the body before wrapping it in layers of cloths (Mao et al. 1994). Injection of cedar oil through the rectum and coverage of the body in natron is another method to treat the body through the dehydration (Mao et al. 1994). The most effective method based on cost and time consisted of cleaning the body, drying with natron and wrapping in cloths (Mao et al. 1994). During the Middle Ages, bodies were immersed in wine and preservation herbs were inserted into the flesh through incisions, followed by wrapping the body in sheets of wax or tar (Mao et al. 1994). In the late seventeenth century, a new method of injection of and immersion in a mixture of one pound of cream of tartar and half-a-pound of “sal ammoniac” with six pounds of water for six weeks was used to embalm corpses and then laid out in the sun to dry (Mao et al. 1994). These examples illustrate the potential for the use of natural ingredients in the preservation of bodies rather than harmful chemicals.

In order to reduce the amount of chemicals used in embalming, a shift needs to be made in legislation, as well as the human view on funeral services. There may be resistance from the funeral industry if changes result in a loss of profit and opposition from the population to modifications in traditional practices. A necessary shift in funeral practices would be burial within two days of death, thus embalming would not be necessary and would reduce the formaldehyde in the funeral industry (Mao et al. 1994). Cremation or green burials are also alternatives that do not require the body to be embalmed. Formaldehyde could also be substituted with non-toxic chemicals such as ethyl alcohol or polyethylene glycol (Mao et al. 1994). Use of these substitutions or any of the methods described above, all of which are feasible today, could dramatically reduce the quantities of chemicals entering the environment from cemeteries and lessen the potential human and environmental health risks.

Promotion of Green Burials

Green burial is a potential method to reduce pollution created by conventional burial and cremation. The aim of green burials is to reduce the amount of wood, metal and chemicals used

in burial, diminish pollution and protect native species (Uslu et al. 2009). Burial occurs at a shallower depth compared to conventional practices in a degradable coffin or wrapped in a cloth; embalming is discouraged (Environment Agency 2004; Young et al. 2002). These features allow greater oxygen presence which results in faster, aerobic decomposition; the resultant decompositional products are less polluting than those created under anaerobic decomposition (Environment Agency 2004; Young et al. 2002). Shallow burial also creates a thicker layer for attenuation between degrading bodies and groundwater (Kim et al. 2008). Green cemeteries can be located in forested areas, nature reserves and gardens, having natural appearances and tend to be smaller and less dense than traditional sites (Environment Agency 2004; Kim et al. 2008). They rarely have permanent markers, with a tree or shrub often planted to mark a grave (Young et al. 2002; Kim et al. 2008; Uslu et al. 2009). Trees and shrubs have benefits beyond marking sites as they increase evapotranspiration, reducing water infiltration and movement of pollutants and can uptake decompositional products, as discussed below (Environment Agency 2004; Üçisik & Rushbrook 1998). An additional benefit is cost. Green burials are often cheaper than traditional burials and part of the cost may be used for maintenance and ecological restoration (Stowe et al. 2001). This idea is beginning to spread as there are currently, there are hundreds of green cemeteries in the UK, six across the USA and many planned in other countries, like Canada (Smith 2007; Uslu et al. 2009). Future research is required to examine potential pollution from green burials compared to conventional practices, but this preliminary information suggests that they may represent a method for reducing pollution.

While green burials may reduce pollution, there are potential issues related to social concerns, economics and space. Cemetery appearance, viewing practices and people’s desires represent social issues. Most visitors want cemeteries to be neat and nicely gardened (Smith 2007). This desire is also expressed in the requirement for a Care and Maintenance Fund in Ontario’s legislation. With green burials, cemeteries are more natural, with native plants and can exist in natural ecosystems, thus will not appear like traditional cemeteries. This may present an area of contention, as may the lack of embalming. Embalming allows for delay of burial and permits viewings of bodies for people to say good-bye; without embalming, the body must be buried quickly before decomposition begins, though refrigeration may slow this (Northcott & Wilson 2008; Smith 2007). However, a refrigerated corpse does not resemble an embalmed one (Smith 2007). The main argument for embalming is the ability to say farewell and see the dead at peace, but a hundred years ago, few individuals were embalmed and people could still deal with death and loss (Smith 2007). Depending on the importance of viewing the body and delaying burials, these could represent barriers to green burial. Public opinion also plays a role. As the green burial movement is still new, people are not educated on the potential effects of body disposal. Without this education, people may be less likely to participate. There also exists the opinion that green burials are less satisfactory compared to traditional ones. For example, in the Lazy Environmentalist, a customer said “...this [a biodegradable casket] is Prius, I drive a Cadillac and Mercedes” (Green Burial Council 2011). Opinions like this represent another barrier. However, education and further support of the green movement may reduce these barriers. There may also be resistance from the funeral industry due to financial loss. Green burials are often cheaper than traditional which may result in losses of profit; it is a similar concern with cremation. However, green burials can still be marketed, with shrouds and biodegradable caskets (Smith 2007) and do offer opportunities for financial gain. The final aspect is the lack of space. As human populations are growing, it may become increasingly difficult to find space for cemeteries within cities (Üçisik & Rushbrook 1998), which is one of the arguments for cremation. As seen, green burials are not without their own problems, however

they represent a possible solution, or partial solution, to the pollution related to traditional burial and cremation. Further education and public support will likely increase its utilization in Canada.

Promotion of Planting of Trees and Shrubs

One method that could be easily applied at all cemeteries to reduce contamination is the planting of trees and shrubs throughout the cemetery, especially at the edges. Vegetation can uptake decomposition products through their roots and incorporate them into their tissues preventing their exit from the site (Üçisik & Rushbrook 1998). Infectious viruses have been found within plants, implying that they are able to take up viruses and bacteria from the soil; roots can also restrict their movement (Üçisik & Rushbrook 1998). Trees can also take up large quantities of water, lowering the water table in the area and reducing the possibility of direct contact of groundwater with corpses and subsequent contamination (Üçisik & Rushbrook 1998). In addition, there is potentially reduced water infiltration due to increased evapotranspiration from the trees and shrubs planted (Environment Agency 2004). Greater water volume and movement reduces the attenuation of contaminants and increases contamination, thus this is beneficial (Üçisik & Rushbrook 1998; Yassin et al. 2006). While this solution does not deal with the cause of the pollution, it does provide an initial, cost-effective way to reduce contamination that can be employed at all cemeteries immediately.

Alternative Methods of Disposal

Scientists are currently developing alternative methods of corpse disposal. Promation transforms human remains into organic waste through deep-freezing (Borzykowski 2009). After freezing, small vibrations are used to shatter the body into five millimetre pieces and water is subsequently removed as it promotes tissue decay (Borzykowski 2009). The dry powdered remains can be then placed in a biodegradable coffin and buried approximately 20cm in the earth (Borzykowski 2009). Moisture can then seep into the coffin and the nutrients are available to support plant and insect populations (Borzykowski 2009). Another alternative is the dissolving of corpses in chemicals. Through a procedure called alkaline hydrolysis, corpses are placed in a stainless steel container, submerged in lye and exposed to 300°F and 60 psi of pressure until the soft tissues break down, causing bones to soften (Hutchinson 2008). The softened bones remain intact leaving burial an option (Hutchinson 2008). BioSafe Engineering in Indiana originally developed this procedure to handle biohazardous material and animal carcasses, but has begun marketing the procedure to funeral homes (Hutchinson 2008). This method avoids the carbon dioxide and mercury emissions produced by traditional cremation. Both alternative disposal methods, while potentially valuable for environmental concerns, may be viewed as unsavoury and be resisted.

Future Research

As mentioned throughout this report, little research has fully examined the intricacies of pollution related to cemeteries and crematoriums. Additional research adhering to the scientific method is required for all aspects studied in this report to better create effective legislation and pollution reduction strategies. However, focus should be on examining the actual risks to people and the environment from both the emissions and spreading of ashes from crematoriums and the chemical and biological contaminants from cemeteries rather than the known pollution.

Conclusion:

This report has complied and examined years of scientific research illustrating the polluting effects of cadaver disposal and their potential impacts on human and environmental health. Crematoriums introduce atmospheric mercury, require fossil fuels and pollute through the dispersion of ashes. Cemeteries leach chemical and biological contaminants into the environment from the decomposition of corpses and funeral artefacts. The long-standing cultural and historic importance of these methods of disposal, the lack of governmental influence, the financial prosperity of the industry and social preferences pose barriers to mitigating these pollutants. However, change is essential with these illustrated negative effects and a series of recommendations have been provided that can play an important role in reducing these impacts. Death is natural, however, our current methods of disposal introduce pollutants into the environment at rates unseen in the past due to the rising population. This issue needs to be recognized and addressed by all people to assuage these negative effects.

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