BC WATER & WASTE ASSOCIATION

ISSUE ANALYSIS PAPER AND POSITION STATEMENT

Land Application of Biosolids

Adopted by the BCWWA Board of Directors

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Section 1: Introduction

Biosolids are produced following the wastewater treatment process. They consist of a nutrient rich solid that has been stabilized to reduce or eliminate pathogens and manage volatile organic solids. Over the past year, there has been increased public attention to the practice of applying biosolids to land. The BC Water & Waste Association (BCWWA) has developed this issue analysis paper to address the question:

Under what conditions can biosolids be safely applied to land?

Treated biosolids are a plentiful, renewable resource that offer a variety of benefits through their use as a soil amendment. When applied to land, biosolids can improve crop yields through fertilization, increase soil water storage, improve soil quality, avert greenhouse gas emissions, and accelerate carbon sequestration (by improving the capacity of the soil to store carbon) *(Brown & Trlica, 2013)*. However, the benefits of recycling residuals from wastewater are not always obvious and can be accompanied by considerable concern and controversy; recycling nutrients and organic matter through the land application of biosolids represents such a case.

Biosolids represent only a small fraction of the total annual production of organic residuals and are the most processed and regulated, yet they are the most controversial with respect to beneficial use *(International Water Management Institute, 2010)*. The BCWWA recognizes that public uncertainty around the land application of biosolids can arise, driven by concerns focused on the potential impacts to human health and the receiving environment (including soil, surface water, groundwater and air) from the following constituents and traits potentially found in biosolids:

- Pathogens potentially present in biosolids and aerosols potentially generated through biosolids management;
- Trace element content in biosolids; and,
- Emerging substances of concern (ESOCs), such as pharmaceuticals, personal care products, and other materials which may be found in biosolids.

Provincial regulation and national policy recognize that the benefits of biosolids as a soil amendment are well known, and that potential risks arising from their management as a soil amendment are effectively managed to the degree that the risks are understood. This is the basis for existing regulation.

This paper outlines the BCWWA's analysis of the conditions under which biosolids can be safely applied to land.

The issue analysis paper concludes with a "position statement" that is intended to guide our members' actions around biosolids production and land application, as well as our members' engagement with First Nations, stakeholders, and the public. The position encompasses best management practices, recent science, and an ongoing commitment to continuous improvement and sustainability.

Section 2: Context & Background

The following subsections provide an understanding of the types of biosolids typically produced in North America, basic information about their physical characteristics and a background to how they are managed, monitored and regulated in British Columbia and Canada.

2.1 What are biosolids?

Biosolids originate as sludge, a liquid by-product of municipal wastewater or septage treatment processes. The sludge is processed using elevated temperature and biological processes (aerobic or anaerobic) over an extended period of time to stabilize the organic matter and reduce pathogen content and vector (i.e., disease-spreading insect or parasite) attraction. It is only when the sludge meets defined quality standards for trace elements, pathogen reduction, and vector attraction reduction that it can be considered “biosolids”. Sludge processing is accomplished by a variety of methods, with aerobic and anaerobic digestion being the most common. Anaerobic digestion generates methane gas which, if captured, can be employed in heating or energy production at the wastewater treatment plant, generating an additional beneficial use from this material.

The biosolids may be dewatered to various degrees to achieve the following types, which are categorized based on the amount of water which remains in the product and the product’s subsequent properties:

Biosolids Type	Solids Content	Characteristics
Thickened	12%	Viscous liquid
Dewatered	18 to 30%	Solid (wet soil)
Dried	50 to 90% or higher	Very dry (granular)

Processed sludge that does not meet regulatory quality requirements is not considered to be biosolids; it is understood to be treated sewage sludge. Under BC regulation, treated sewage sludge does not meet the standards required for land application under the BC Organic Matter Recycling Regulation (OMRR) (see Section 2.1.2); therefore, it is not considered for the purposes of this issue analysis paper.

2.1.1 Land application

The beneficial use of human wastes through land application has been practiced for millennia, as has the use of animal and vegetable wastes. Human wastes or “night soil” have been utilized as fertilizer in China since at least 1,000 BC, and in the United States for more than 150 years. It has been estimated that about 200 million farmers worldwide grow crops in fields fertilized with variants of human waste including biosolids *(American Society for Microbiology, 2011)*.

In context, however, biosolids and human excrement represent less than 1% of all fertilizing agents used throughout North America, with chemical fertilizers and animal manures being the most prevalent forms of fertilizers and soil amendments. By comparison, however, biosolids are a highly monitored and regulated product.

Biosolids can be applied to land in one of the following ways:

- With conventional agricultural equipment or specialized application systems to the soil surface;
- With conventional construction equipment (usually in the case of mine reclamation);
- Injection (usually in liquid form) just below the soil surface; and,
- With a side-slinger application system (usually to treed or forested environments).

During land application, biosolids may or may not be incorporated into the soil, depending on the biosolids type as well as the agricultural, forestry, or reclamation management strategy and other key environmental factors.

Biosolids are applied to land for the following purposes:

- Soil amendment and aiding plant growth on agricultural lands;
- Enhanced tree growth and increased yield in forestry and silviculture;
- Land reclamation and remediation (e.g. disturbed land/mine site and landfill closure);
- Wetland restoration;
- Erosion control and slope stabilization; and
- Roadside aesthetic improvement.

Biosolids can also be used as an ingredient in creating value-added products such as compost, soil amendment mixes, and landscaping soils. These products are used in a variety of applications, including urban landscaping, park and greenway projects, community gardens, and roadside aesthetic restoration.

2.1.2 Provincial regulation of the land application of biosolids

In BC, land application of municipal biosolids is regulated by the Ministry of Environment (MoE) through the *Organic Matter Recycling Regulation* (OMRR). The OMRR was enacted in 2002 to replace a system of permits and authorizations, and falls under the authority of the *Environmental Management Act* and the *Public Health Act*, with minor amendments carried out in 2007 by the MoE. Biosolids used within the Agricultural Land Reserve must also be considered through the *Agricultural Land Commission Act.*

The OMRR was created to provide clarity on how biosolids can be produced, how to effectively use biosolids while protecting soil quality and water resources, and who is qualified to ensure biosolids are applied according to best management practices. The regulation was promulgated following a six-year development process, involving a peer evaluation group of experts selected for their knowledge from throughout North America. The regulation used a significant amount of knowledge and risk assessment information developed from other jurisdictions, including the use of the rigorous US EPA biosolids risk assessment, which was finalized in the mid 1990's. The regulation outlines two classes of biosolids—Class A and B—and sets maximum quality criteria for pathogens and trace elements, as well as storage requirements and management requirements for land application. The OMRR does not currently regulate emerging substances of concern (ESOCs) that may be present in both classes.

Under OMRR, the Ministry of Environment (MoE) requires the production of a site assessment and suitability document known as a Land Application Plan (LAP). This plan must describe the land application site, the quality of biosolids and receiving soils, the rate of biosolids application, and site features requiring buffering (i.e., setback distances to applied biosolids). LAPs must also contain information on site signage, biosolids stockpiling, the requirement for environmental monitoring, and predicted post-application soil concentrations of regulated trace elements. Post-biosolids application soil quality standards contained in the OMRR are based on the identified land use (e.g., agricultural land, urban park land, residential land, commercial land, and industrial land), soil pH, and site-specific factors unique to the land application site (e.g., groundwater flow to aquatic life, soil ingestion by grazing animals, toxicity to soil invertebrates, etc.). In addition to the preparation of the LAP, at least 30 days before the land application of biosolids, notification must be given to the: Waste Manager in the regional MoE office; Medical Health Officer for land application to agricultural land or in a watershed; Land Reserve Commission for land application to agricultural land reserve or forest reserve land.

The regulation follows the 'professional reliance' model. This type of regulation requires a Qualified Professional (QP) with specific fields of expertise to produce and validate the LAP. The QP accepts responsibility for the quality of the LAP and the information contained therein. The intent of the regulatory process is that planning for any application requires a person qualified through education and experience, validated by a regulated profession.

To help ensure compliance with OMRR, the Ministry of Environment has produced two associated guidance documents: the *Compost Facility Requirements Guideline* (2004) and the *Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice: Best Management Practices* (2008). The latter contains guidance on sampling and analysis as well as guidance on interpreting receiving environment conditions (such as proximity of ground and surface waters, suitable site selection, climate considerations, etc.) which aid in ensuring adherence to the regulation. It also provides best management practices for a LAP and specific details related to biosolids use in agriculture, silviculture, and reclamation.

2.1.3 National Policy – Canadian Council of Ministers of Environment

The Canadian Council of Ministers of the Environment (CCME) is comprised of 14 environment ministers from the federal, provincial and territorial governments. The CCME provides national guidelines for the beneficial use of biosolids through the *Canada-wide Approach for the Management of Wastewater Biosolids* (the Approach). The **best management principles** outlined in the Approach are:

- Municipal biosolids, municipal sludge, and treated septage contain valuable nutrients and organic matter that can be recycled or recovered as energy.
- Adequate source reduction and treatment of municipal sludge and septage should effectively reduce pathogens, trace metals, vector attraction, odours, and other substances of concern.
- The beneficial use of municipal biosolids, municipal sludge, and treated septage should minimize net greenhouse gas (GHG) emissions.
- Beneficial uses and sound management practices of municipal biosolids, municipal sludge, and treated septage must adhere to all applicable safety, quality, and management standards, requirements, and guidelines.

Further, the CCME recommends that following factors be considered:

- Characteristics of the material (e.g., water content, nutrients, organic matter, trace metals and pathogens);
- Utility and value of the residual (e.g., nutrient availability, soil amendment potential, and energy value);
- Air quality management (e.g., stack emissions from thermal treatment, odor generated during handling);
- Suitability of the application site (e.g., soil quality prior to municipal biosolids application and proximity to sensitive water resources, local air shed issues);
- Transportation to the application site (e.g., number of transport vehicles required, availability of access roads);
- Application site environmental setbacks (e.g., distance of the proposed beneficial use site from features such as residences, water resources, roads); and,
- Social considerations (e.g., community perception and level of acceptance of the beneficial use option, marketability of municipal biosolids or treated septage products).

The Approach also supports continuous improvement, such as the ongoing research related to ESOCs.

Section 3: Analysis of the Issue

Determining the BCWWA position on the land application of biosolids requires careful consideration to weigh the benefits and implications for sustainability against potential risks. It is important that environmental benefit and potential risk be clearly understood through evidence-based science, so that both may be clearly demonstrated and communicated to all stakeholders in the biosolids process. Further, understanding the research and rigor behind existing provincial regulation and national management guidelines will help ensure compliance and protect public health and the environment.

3.1 Benefits of land application

The benefits of biosolids use are understood with a high degree of certainty and scientific evidence. The land application of biosolids is supported by BC's provincial regulation, recommended by the Canadian Council of Ministers of Environment (CCME), and promoted by BCWWA-affiliated associations such as the Canadian Water Network (CWN) and the Canadian Water and Wastewater Association (CWWA).

Biosolids are primarily comprised of organic matter, a material naturally present in the soil that affects structure and functionality. Soil organic matter can be lost as a result of intensive agriculture, grazing, forestry, and mining activities; the land application of biosolids provides a way to replace this lost organic matter. The organic matter contained in biosolids improves overall soil quality, including:

- Soil tilth (i.e., ease of cultivation and overall physical condition of soil to support plant growth);
- Water-holding capacity;
- Nutrient retention;
- Soil carbon; and,
- Habitat for soil biota (microbiology and invertebrates).

In addition to improving soil quality through increased organic matter, biosolids contribute a full suite of micro and macro plant nutrients. This reduces or replaces the need for commercial or chemical fertilizers. Biosolids are primarily a residual derived from foods (containing micro and macro plant nutrients) and as the foods we eat are grown to ensure their nutritional value, many of these nutrients are transferred to the biosolids. These micro and macro nutrients are renewable, as opposed to their mineral and chemical fertilizer counterparts, which may be mined, derived from oil and gas, or be energy intensive in their production.

Biosolids use in agriculture, forestry, and mining provides other tangible benefits to land managers such as improved forage quality, increased yield/biomass, drought protection and vegetation establishment on otherwise degraded sites. These benefits and others represent the reason why land managers use biosolids. Additional benefits, however, exist even beyond the borders of an individual land application site.

By applying biosolids to land, a flow of nutrients and organic matter is established, providing closed-loop recycling of nutrients and carbon. Cereals from the prairies, beef from BC's grasslands, and fruit from the Okanagan all represent nutrient and organic matter flows from the rural environment to urban centres. The ideal recycling process returns those materials back to their sources in the rural agricultural landscape. While economics likely precludes the ability to return nutrients proportionally to their soils of origin, beneficial use of biosolids through their application to agricultural soils, or in other soil-building systems, represents an important mechanism for maximizing the use of our available renewable nutrient pools. The return of carbon from biosolids to the soil also represents a mechanism of soil carbon sequestration, which aids in greenhouse gas (GHG) mitigation by offsetting increased carbon in the atmosphere, positively impacting climate change. Field investigations of the impact of biosolids land application have demonstrated the high potential of soil carbon (C) sequestration, with soil C significantly correlated with the biosolids application rate. In fields where biosolids applications ceased for many years, soil organic C was still much higher than initial levels in the soils and were higher as compared to the fertilizer controls (Tian, et al., 2009).

3.2 Biosolids constituents

In addition to water, biosolids are composed of several important chemical constituents that fall into the following general categories and content ranges:

- Organic matter, similar in structure and function to soil humus (between 60 and 80% of total dry mass);
- Inorganic matter which may include inert sand, silt and clay particles (between 5 and 30% of total dry mass);
- Nutrients and trace elements (8-15% of total dry mass) including:
    - Plant macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium, sodium, sulphur)
    - Plant micronutrients (iron, cobalt, copper, iodine, manganese, molybdenum, zinc,
    - Non-essential trace elements (aluminum, lead, mercury, nickel, silver, gold, vanadium, beryllium)
- ESOCs, also known as microconstituents (less than one per cent of total dry mass).

In contrast to the established benefits of some biosolids constituents as detailed in Section 3.1, there are also potential risks arising from other constituents. Although many risks are well understood and carefully managed, there are some risks (such as ESOCs) which are not as well understood. The following sections identify these potential risks, review the current understanding of the constituents, and mechanisms for management of potential risks.

3.2.1 Biology and Pathogens

Biosolids, as it is derived largely from human fecal matter, contains a diversity of micro-organisms. The micro-organisms have their origin in the human digestive system, and this ecosystem contributes to the ecosystem at work in the Wastewater Treatment Plant (WWTP) which breaks down wastewater solids during the process of wastewater treatment. Although the vast majority of biosolids biology is benign or environmentally beneficial, there is a small but important subset of the biological organism contribution to the wastewater treatment system which can cause disease in humans: these are known as the pathogens. Potential pathogens include specific strains of bacteria, viruses, fungi, parasites, or proteinaceous infective particles (prions, discussed in the next section).

This diversity of micro-organisms (both beneficial and pathogenic) is significantly reduced during the treatment of wastewater sludge to produce biosolids. The OMRR requires that biosolids be treated to reduce pathogens to levels specified for Class A and B designations. While the OMRR does not specifically regulate any specific pathogen, the quality criteria for pathogen reduction are based on levels of fecal coliform bacteria, which are not themselves pathogenic, but which are well established as an indicator of pathogen concentrations. For example, OMRR Class A biosolids are subject to the most stringent quality and treatment process criteria: fecal coliforms must be reduced to less than 1,000 “most probable number per gram” (MPN/g), a level at which pathogens are considered to be almost undetectable (Yanko, 1988). As a result, Class A biosolids are subject to less stringent land application criteria due to their lower risk. On the other hand, OMRR Class B biosolids, which must attain a fecal coliform density of less than 2,000,000 MPN/g (a level at which some pathogens are expected to persist), must be managed during land application in such a way as to limit human exposure to pathogens by delaying harvesting post-application and minimizing public encroachment on lands with applied biosolids. Best management practices for both classes, such as effective site management (fencing) and signage informing the public of the project also assist in reducing the opportunity for exposure to potential pathogen risk.

The levels of concern over biosolids may be disproportionate when biosolids are compared to other managed fertilizers and soil amendments. Few other residuals are treated to reduce pathogens and the volume of land application of other residuals, including industrial and agricultural sources, far exceeds that of biosolids. As a comparative example, regulations also govern the land application of animal manure, and it is noteworthy that there are currently no requirements for treatment or stabilization of animal manures to reduce pathogen levels. Although information on agricultural and industrial residuals is limited, a US study noted levels of indicator bacteria in untreated manures are significantly higher than in biosolids, with fecal coliforms in manure ranging from five million to 30 million MPG/g (*Water, Env. & Tech., 2002*).

Microflora naturally present in soil can also help reduce the risk of pathogens from the land application of biosolids. A gram of soil typically contains many billions of organisms. Although a minute fraction of these organisms can cause harm in humans, animals and plants, the majority are overwhelmingly beneficial. These beneficial microorganisms, as well as other soil conditions, outcompete and inactivate fecal pathogens that might be introduced via land application of biosolids *(American Society for Microbiology, 2011)*.

Recent risk assessment measures the potential for illness from Class B biosolids land application to be less than one in one million, and in some cases less than one in one billion, per exposure. Typically, an appropriate baseline used for risk assessment purposes is one in ten thousand and biosolids fall far below this, suggesting that that risk of biological harm, while possible, is extremely low being between one hundred and ten thousand times lower than what is considered 'acceptable risk' *(American Society for Microbiology, 2011)*.

3.2.2 Prions

Despite strong regulation and safeguards in place to reduce the risk of pathogens to human health and the environment, there remains public concern in respect to the potential risk to public health from biological agents, and in particular, prions.

Prions are a particular type of infectious misfolded protein particle. Different particle types or strains are capable of replication in animal tissue and have an associated pathogenicity. While proteins are an important particle in all facets of animal and plant biology, prions are abnormal, infectious and transmissible in their misfolded pathogenic forms. They are understood to be the pathogenic cause for spongiform encephalopathies which include "mad cow disease" in cattle, chronic wasting disease (CWD) in deer and elk, and Creutzfeldt-Jakob (CJD) in humans. Prions as a concept underlying cause are also being explored in the understanding of Alzheimer's and Parkinson's diseases. To date, this exploration of prions does not include a consideration or transmissibility, and the model has not yet gained broad acceptance (*Goedert, 2015*).

The cases of known transmissible prion disease in North America are very low (1 in 300,000) *(Hinckley, et al., 2008)*. The risk of prions (infectious or not) entering the wastewater system through animal tissue is lower still, as abattoir waste (i.e. meat waste, including brain and spinal cord) is considered a specified risk material and is not discharged to the sewer in BC. To date, it does not appear that researchers have been able to isolate prions from wastewater biosolids, presumably due to the lack of presence or the exceptionally high dilution in the wastewater stream.

Significant advances in our knowledge of prions and their associated public health risks have been made in the past 10 years and continue to evolve in the context of biosolids. Recent methodological improvements have only very recently been able to isolate prions from human urine at exceptionally low concentrations. These concentrations appear to be several orders of magnitude lower than the infectious dose (IU_{50}) for known prion diseases, which are then further diluted by other waters entering the wastewater system and the contributions from the non-infected population, which is conservatively estimated as an additional dilution of 6 orders of magnitude within the sewer system *(Hinckley, et al., 2008)*.

The desire to understand more about prions, combined with the inability to isolate prions from biosolids or wastewater, has meant that researchers have required the use of wastewaters spiked with recoverable quantities of traceable prions, in order to understand the potential fate and mobility of prions in the treatment system and the environment. Earlier spiked trials indicated that infectious prions may be resistant to many forms of conventional wastewater and sludge treatment *(Epstein & Beecher, 2005)*, however, recent work by Miles *et al.* suggests otherwise. Their research documented significant reductions in prion infectivity when prions from spiked wastewater were recovered from biosolids at the temperatures associated with wastewater treatment digestion processes *(Miles, Takizawa, Gerba, & Pepper, 2011)*.

The potential for prions to be transmitted via aerosolization has been explored by Stitz and Aguzzi, again using spiked materials to explore the possibility. They reference studies in which prions were experimentally transferred via aerosol between mice and theorize about the potential for infection of swine abattoir workers, but also concede that "it is understood that the airborne transmission of prions has thus far only been observed under extreme conditions" *(Stitz & Aguzzi, 2011)*. Given the expectation of very low prion concentrations in wastewater and biosolids, the potential for aerosolized transmission from prions both at the wastewater treatment and in biosolids land application situations is likely very low.

The potential to consume the volume of materials required for prion infection is extremely small once applied to land. Current calculations assume a daily ingestion rate of soil from biosolids amended fields for 70 years, and even at this rate, the quantity of prion potentially available to be ingested remains below the infective dose (IU_{50}) *(Hinckley, et al., 2008)*.

Based on the current information, the threat of infectious prion transmission to humans or grazing animals via the land application of biosolids appears to be negligible. Source control is recommended as the most effective method for managing infectious prions, in particular, by enforcing existing guidelines for non-domestic facilities that may handle contaminated tissue, such as abattoirs, laboratories, hospitals, and mortuaries.

3.2.3 Trace elements

Similar to manure and commercial fertilizers, biosolids contain variable concentrations of trace elements (sometimes referred to as trace metals or heavy metals). These trace elements enter the waste water stream from multiple sources (both domestic and industrial) and are present in measurable concentrations in biosolids. The OMRR currently regulates 11 trace elements that, at certain concentrations, are considered to be detrimental, can bio-accumulate in the food chain thereby posing a risk to human and animal health, and are persistent in soils. These regulated elements are: arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn).

A large body of knowledge has been developed about the behaviour and fate of trace elements in biosolids and biosolids-amended soils both in the US and Canada. In the US, the Environmental Protection Agency (EPA) conducted a comprehensive review of the fate and effects of trace elements in biosolids using a risk assessment approach that began in 1984 with the identification of approximately 200 'pollutants of concern', which was then further assessed by expert panels, from which approximately 50 of the 200 pollutants were recommended for further study. The EPA examined multiple exposure pathways and analyzed risks to humans, animals, plants, and soil microorganisms based on hundreds of peer-reviewed research articles on toxicity, ecotoxicity, and environmental fate and transport. The risk assessments were in turn reviewed by dozens of scientists in the fields of toxicology, soil science, and agriculture. Based on this review, limits for ten trace elements (cobalt was not identified by the EPA, but was subsequently regulated in BC) were recommended, developed, and following three subsequent rounds of review, the EPA concluded that the concentration limits specified for these ten trace elements are highly conservative, very protective, and that the risk posed by trace elements in biosolids adhering to these limits is minimal.

The quality criteria for trace elements in Class A biosolids in the OMRR directly references the Canadian Food Inspection Agency (CFIA) metal standards for fertilizers, while quality criteria for trace elements in Class B biosolids are also partially derived from the US EPA standards, which conform to the *BC Contaminated Site Regulation* (CSR). In general, the OMRR trace element standards are more stringent than the limits set by the US EPA. The CFIA metal standards are based on maximum acceptable cumulative metal addition to soils. These acceptable levels are calculated using the standard maximum addition to soil over a period of 45 years (which are fixed per metal) and the annual application rate of the product. The CFIA's standards (except copper and chromium standards) have also been incorporated into the CCME's *Guidelines for Compost Quality*. Some OMRR biosolids trace element criteria are higher than risk-based limits determined by the EPA, but OMRR is considered a more conservative regulation as it also regulates the quality of the soil environment receiving biosolids applications.

	BC OMRR		USEPA 503	
	Class A Biosolids	Class B Biosolids	Class B Biosolids	Exceptional Quality (EQ) * Biosolids
Trace elements (mg/kg)				
Arsenic	75	75	75	41
Cadmium	20	20	85	39
Chromium	-	1,060	3,000	2,000
Cobalt	150	150	-	-
Copper	-	2,200	4,300	1,500
Lead	500	500	840	300
Mercury	5	15	57	17
Molybdenum	20	20	75	-
Nickel	180	180	420	420
Selenium	14	14	100	36
Zinc	1,850	1,850	7,500	2,800

****USEPA EQ Biosolids can be freely distributed in bulk, or sold or given away to the public (i.e. no permit or Land Application Plan required)***

OMRR soil trace element concentration criteria are harmonized with the BC *Contaminated Sites Regulation* (CSR) soil standards. The CSR soil quality standards are also based on a risk assessment approach that calculated soil standards based on defined exposure scenarios for specific land uses (e.g. agricultural, residential, parkland, industrial, commercial) and toxicity information. Soils where biosolids have been land applied, meet the specified land use scenario of the CSR soil quality standards for the OMRR regulated trace elements following the biosolids application.

There are several trace elements which are not regulated by the OMRR, and it should be acknowledged that there is a general lack of data on concentrations of non-regulated trace elements in biosolids across Canada (e.g., antimony, beryllium, thallium, titanium, and vanadium). The consensus amongst regulators and experts is that non-regulated trace elements do not pose a significant risk to humans or the environment because of their low concentrations (based on limited data) compared to other trace elements, and because the characteristics of biosolids reduce their availability. However, both the CCME and the EPA acknowledge that further research is required due to a lack of source data. As part of their *Targeted National Sewage Sludge Survey*, the EPA has gathered sufficient biosolids source data to evaluate five trace elements (barium, beryllium, manganese, molybdenum[1], and silver) to determine if they should be regulated. The evaluation has not been released to date, but was expected by late 2015 (United States Environmental Protection Agency, 2009).

3.2.4 Emerging substances of concern

In following similar recommendations from the US EPA, the BC Ministry of Environment expert panel for the development of OMRR found that potential risks from organic contaminants were generally low, their occurrence was not frequent, and that in many cases, the potential pollutants were 'legacy compounds' no longer produced or used, meaning that the concentrations were anticipated to slowly decrease over time in line with degradation. Emerging substances of concern (ESOC) in wastewater residuals have more recently become a focus of related research in Canada and internationally. There is no consensus definition of ESOCs, but the term refers to a broad range of substances that households and industry may send down the drain to the wastewater treatment facility and potentially may be present in biosolids:

- Pharmaceuticals (e.g. Non-steroidal anti-inflammatory medication [e.g. Ibuprofen], antibiotics [e.g. Ciprofloxacin], steroids, narcotics, etc.)
- Personal Care Products (e.g. toothpaste, deodorant)
- Perfluorinated compounds (e.g., perfluorooctanoic acid [PFOA], Teflon, non-stick coating on cookware, fluorotelomers)
- Plasticizers (e.g. reusable food and drink containers)
- Quaternary Ammonium Compounds (commercial disinfectant, e.g. Quat)
- Polychlorinated alkanes and napthalenes
- Surfactants (e.g. dish detergent, alkyl phenol ethyloxylate [APE])
- Polybrominated Diphenyl Ethers (Flame retardants, commonly used on textiles, furnishings, children's sleepwear)
- Steroidal compounds, hormones and their mimics (e.g. nonylphenol, testosterone, estrogen)
- Dioxins and furans (e.g. created during production of pesticides, dyes, disinfectants; produced in combustion processes such as forest fires, or in vehicle exhaust)
- Nanoparticles (e.g. nanosilver used in athletic clothing)

Some of these compounds may occur naturally in the environment; however, the majority are from human sources (Canadian Council of Ministers of the Environment, 2012).

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[1] Molybdenum is being re-evaluated using updated information to determine the need for a revised numerical standard in land-applied biosolids.

Research has shown that some ESOCs degrade rapidly in soils, or simply dissolve in water and do not end up in the biosolids product or receiving soils (Canadian Council of Ministers of the Environment, 2012). Those ESOCs found in wastewater residuals are in very low concentrations, and detection does not necessarily imply a risk to human health and the environment. Detection and quantification of ESOCs in municipal biosolids simply serves as an initial step in determining the risks that these compounds might pose.

Many ESOCs have been assessed and their impacts have been calculated, tested, or inferred. Through the 1990s and the first decade of the millennium, science focused on a quantitative understanding of a handful of the ESOCs considered to have the greatest potential for environmental impact. The *Canadian Environmental Quality Guidelines* recommended guidelines for several hundred substances which rely on quantitative calculation to provide concentrations for no predicted effects or no observable effects. However, a recent review of the risks associated with land application of biosolids (Ryerson University, 2015) has identified successes and limitations of this approach.

Limitations to the single-substance approach include difficulty in apprehending the sheer number of substances that are potentially found in biosolids, the significant amount of time and resources required to assess each, and an inability to detect potential combinations of substances. An alternative is a holistic assessment of biosolids using live organisms to measure potential toxicity. These toxicological assessments use organisms found within the ecosystem to which biosolids are applied and measure their performance and any lifecycle impacts. This approach is unable to provide specific numerical standards for individual substances, but may produce results that can indicate overall environmental suitability of biosolids. The review by Ryerson University (2015) has identified the likelihood that a mixed science approach, combining holistic and single-substance approaches, is currently the best method to assess the impact of ESOCs.

The Ryerson University review indicated that ESOCs had little to no negative impact on test plants, insects, bacteria and fungi present in agricultural land.

- Plant studies show the positive effects of fertilization after the land application of biosolids with low or no adverse impacts on growth, germination, or seed yield.
- Laboratory studies of hexapods (Springtail *Collembola*) demonstrate very few to no adverse effects from exposure to biosolids. While some assessments using higher than agronomic rates of biosolids application began to show negative impacts to reproductive capability, field studies showed no changes in total abundance or diversity, and certain species experienced population increases.
- Studies assessing earthworm growth in agricultural soils amended with biosolids have shown no or some positive growth with amendment. Studies examining higher rates of biosolids application, or rates in reclaimed soils with higher metals content, demonstrated mixed results and some declines in earthworm productivity, which have been related to salinity, pH, and trace elements found in the native soils to be reclaimed. It is challenging to interpret these results, as many of these studies have been undertaken on a species of worm (*Eisinia fetida*) which is not native to agricultural soils; other studies using agriculturally relevant worms (*Lumbricus terrestris*) tend to be less sensitive. Land application bioassays using relevant worm species and relevant amendment rates appear to demonstrate benefit to the worms.
- Nematodes (microscopic worm-like soil fauna) demonstrated no significant trends or decreases in population density through several biosolids field trials.
- Soil bacteria populations increased in response to biosolids application, resulting in positive changes to soil respiration rates and enzymatic activity. In a few trials, biosolids applications showed no effect on microbial biomass or respiration.
- Trials examining the impact of biosolids on fungal communities have demonstrated positive, neutral, and decreased productivity.

In addition to the above findings, the review acknowledges the "lack of data" and that the "potential impact to public and environmental health is not well understood." (Ryerson University, 2015). More research is warranted to access the potential impacts of ESOCs on environmental and human health.

Continued research using both holistic and single-substance approaches is underway in Canada, and is expected to provide published conclusions within the next two years. Preliminary results have indicated that biosolids applied at agronomic rates do not have a deleterious effect on ecologically relevant plants nor soil biota studied to date, and demonstrate significant benefits despite the presence of ESOCs (Ryerson University, 2015).

3.3 Regulatory conditions

Municipal, provincial, and national policy is key to minimizing potential risks to human health and the environment and maximizing the benefits of the land application of biosolids.

3.3.1 Source control

Before municipal wastewater is recycled to produce biosolids, steps can be taken to minimize potential environmental and health risks by monitoring and enforcing what enters into the sewage system. According to the *National Guide to Sustainable Municipal Infrastructure* (InfraGuide, 2003), the elements of **best practices for a source control program** are:

- Enactment of a bylaw;
- Monitoring and enforcement;
- Education and awareness;
- Codes of practice;
- Wastewater rates; and,
- Pollution prevention programs.

The CCME suggests that all wastewater facility owners with appropriate legislative authority give serious consideration to establishing a sewer-use bylaw to control what is discharged to their systems by non-domestic (industrial/commercial) wastewater generators (Canadian Council of Ministers of the Environment, 2009). By implementing source control initiatives for non-domestic wastewater producers, municipalities have observed a reduction of trace element concentrations in biosolids quality data (Canadian Council of Ministers of the Environment, 2012). For example, some municipalities have observed a more than 50 per cent decrease in mercury concentration within one to two years of implementing treatment requirements for dental operations (SYLVIS, 2007).

Source control programs are not universally applied, but are generally used in the restriction of key wastes containing pathogens, trace elements, and ESOCs through the prohibition of specific wastes or wastes from specific industries from entering the sewers, such as:

- Metalworks and electroplating facilities;
- Specified risk materials (including wastes from slaughterhouses, abattoirs, mortuaries, and hospitals);
- Heavy industry (ports, industrial terminals, coal terminals, oil and gas facilities); and,
- Wastewater with high organic matter or oxygen demand (brewing waste, dairy waste).

The effectiveness of source control initiatives can vary. The following table summarizes mercury concentration trends in jurisdictions that have implemented dental amalgam (i.e., a method of removing mercury from removal of fillings in dentist office wastewater) program initiatives and bylaws.

Mercury Concentration Trends in Biosolids (reported in mg/kg dry weight)

Jurisdiction (Location)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Trend
Metro Vancouver (Lions Gate)							**5.7**	4.6	2.9	2.7	2.1	2.1	2.0	1.9	Decreasing
Metro Vancouver (Annacis)							**2.8**	2.5	2.6	2.0	1.7	1.8	1.9	1.6	Stable
Metro Vancouver (Lulu)							**3.1**	3.3	2.9	1.9	1.8	1.6	1.2	1.4	Stable
City of Abbotsford (JAMES)									**3.7**	2.6	2	2	2	1.8	Decreasing
King Country (West Point)	**2.35**	2.1	2.1	1.3	1.5	1.3	1.5	1.2	1.0	.9	1.1	.75	1.0	.75	Stable

Notes:

- **Metro Vancouver, King County and City of Abbotsford concentrations extrapolated from available charted data**
- **Data in bold font indicates enactment of source control program initiatives for dental operations**

Furthermore, education and awareness initiatives can be used to target domestic sources of wastewater and help reduce the amount of trace elements and ESOCs entering the wastewater system. Examples of outreach campaigns are:

- The *I Don't Flush* campaign in Ontario encourages the proper disposal of pharmaceuticals, personal hygiene products and household hazardous wastes to reduce wastewater contamination (Ontario Clean Water Agency and the Clean Water Foundation, 2015).
- The *Flushing Awesome – Protecting Water Quality Starts with Each of Us* campaign in King County, Washington, offered in five languages, uses a humorous approach to promoting the protection of the environment and sewer infrastructure.
- *Adult Toilet Training* is Metro Vancouver's campaign to encourages proper disposal of wipes; additional information on how to properly dispose of pharmaceuticals and other household wastes are also provided at *Prevent Problems in the Pipes*
- As part of the City's Source Control program, Abbotsford has developed Sewer Savvy, an educational campaign targeted at domestic sources. The campaign materials are in development and set to be released soon.

3.3.2 Regulatory rigor

As discussed in Section 2.1.2, BC's OMRR (2002) was intended to enable biosolids beneficial use, while protecting human health and the environment. The OMRR outlines treatment and management requirements for pathogen reduction processes, vector attraction reduction, pathogen attraction limits, quality criteria, sampling and analysis (protocols and frequency) as well as record-keeping for each class of biosolids. The OMRR also specifies the maximum allowable trace element concentrations for each biosolids class, as well as in the soil following land application of the biosolids. Treatment and management requirements are based on a large body of scientific information and effectively reduce risk. Examples of some of these requirements include:

- Setbacks from surface water and domestic water sources;
- Storage restrictions (i.e., limits on the length of time that biosolids can be stored);
- Sampling of biosolids and receiving soils to estimate trace element loading rates to ensure compliance with regulated site-specific soil standards;
- Restricting harvesting of plant material from land application sites for specified periods following Class B biosolids land applications;
- Restricting livestock grazing immediately after land application to minimize any potential pathogen exposure; and
- Signage where Class B biosolids have been applied to inform the public of biosolids applications.

Other guidelines such as the Ministry of Environment's guidance document *Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice* (BC MoE, 2008) describe other safeguards which add additional assurance of environmental protection:

- Maximum recommended number of applications (e.g., maximum of one application every five years on pastures in Southern BC);
- Fertility analysis, prior to biosolids application soil samples are collected from the proposed land application area to assess crop nutrient requirements in order to determine agronomic rates thereby reducing the risk of nutrient loading and surface run-off;
- Incorporating biosolids into soils to reduce exposure to humans, wildlife, and livestock, and to reduce the potential to enter into the air through vaporization; and,
- Public notification and consultation to inform the community of activities (i.e., hauling and shared roadways, odours, etc.).

A key component of the OMRR is the reliance on qualified professionals (QPs). A QP is a registered member of a professional organization such as the BC Institute of Agrologists, the College of Applied Biology, the Association of BC Forest Professionals, and others. The QP bears responsibility for environmental protection during biosolids beneficial use projects. The LAP – the document which lays out the rationale for an individual project – must be authored by the QP and contains information that ensures the QP is familiar with the site and its environment. Following land application of biosolids, the discharger must obtain written confirmation from a QP that the land application was done in accordance with the LAP. QPs are beholden to the professional and ethical standards of their organizations and are subject to disciplinary action by those organizations if required.

As previously mentioned in Section 3.2.3, the development of the OMRR took into consideration, and has much in common with, the EPA's regulation for biosolids, the US Federal Part 503 Rule (Environmental Protection Agency, 2014). The US National Academy of Sciences has twice evaluated the EPA Part 503 rules and biosolids quality standards and found no documented scientific evidence that the EPA Part 503 Rule has failed to protect public health. In addition, the Academy found no documentation of causal associations between biosolids exposures and adverse health outcomes, and no scientifically documented outbreaks or illnesses that have occurred from microorganisms in treated biosolids (National Research Council, 2002). However, it is recognized that the public has a more precautionary view and does not want to wait for negative effects to occur.

The CCME's *Canada Wide Approach* (2012), discussed in Section 2.1.3, is a set of guidelines predicated on the recognized benefit of biosolids to the environment for soil development and soil quality improvements as well as vegetation production. In developing the *Canada-Wide Approach*, the CCME Biosolids Task Group undertook the following research and reviews:

- *Emerging Substances of Concern in Biosolids: Concentrations and Effects of Treatment Processes* (2009) and *Emerging Substances of Concern in Biosolids: Concentrations and Effects of Treatment Processes – Field Sampling Program* (2010) – A literature review and field survey of ESOCs in Canadian municipal biosolids including their concentrations and the effects of treatment processes. The project was designed to: review the state of the knowledge with respect to municipal biosolids science and research; identify, inventory, and quantify ESOCs that may be present in Canadian municipal biosolids through collection of municipal biosolids samples across Canada; determine the effects of wastewater residuals treatment on degrading ESOCs; identify those ESOCs that may pose a risk to the environment if land-applied; and, recommend best management practices and future research for ESOCs.
- *A Review of the Current Canadian Legislative Framework for Wastewater Biosolids* (2010) – The review outlined the regulatory framework for biosolids, summarizing and documenting the current status of wastewater biosolids regulation across Canada at the federal, provincial and territorial levels.

British Columbia's current estimated biosolids annual production is 37,700 Tonnes dry solids (Tds), and is predicted to reach 52,700 Tds by 2020, and 71,500 Tds by 2040, as municipalities implement secondary wastewater treatment to meet the federal *Wastewater Systems Effluent Regulations*. In addition to the research behind the development of the CCME Approach and the OMRR, the strength of existing regulation is supported by demonstrated success in the field. After more than 20 years of land application of biosolids in BC, there is no documented scientific evidence that the OMRR has failed to protect public health or had negative impacts on the environment. Municipalities and regional districts that have recycled organic matter and biosolids under the OMRR include: Prince George, Whistler, Squamish, Saanich, Salmon Arm, Abbotsford/Mission, Kelowna, Chilliwack, Fort St. John, Sechelt, Gibson's, Powell River, District of Kent, Regional District of Central Okanagan, Regional District of Nanaimo, City of Campbell River, Metro Vancouver, Capital Regional District, Comox-Strathcona Regional District, and many more. A range of private operators in various regions of the province also recycle biosolids or other organic matter under the regulation, creating soil amendment products that are sold under a variety of trade names at reputable home and garden centres.

In April 2016, the British Columbia Ministry of Environment announced a formal review of OMRR. It is anticipated that this review will enable the regulation to be considered in light of significant volumes of new data and information which have been produced since the previous minor review of OMRR. Within OMRR, there is a review clause that indicates that the MoE will evaluate the regulation within three years of it coming into force to determine if there are changes required.

3.3.3 Continuous improvement

Based on existing information and research, it is the view of the BCWWA that the OMRR and CCME guidelines adequately protect human health and the environment. Positions and support for the beneficial use of biosolids are based on the best available information; as information evolves, so too may the positions of regulators and professionals working with biosolids; it is incumbent upon professionals to remain current and use the best available information in their decision making processes. Both the OMRR and the CCME support continuous improvement, such as the ongoing research related to the potential impact of non-regulated trace elements and ESOCs. Several studies are currently being conducted to determine the risks related to ESOCs in biosolids and inform practices for provincial and federal regulatory end-users.

3.4 Social conditions

In addition to environmental factors, the CCME also recommends that social factors, such as community perception and level of acceptance of the beneficial use option, be considered in the development of a biosolids management program (Canadian Council of Ministers of the Environment, 2012).

First Nations, stakeholders, and the community in proximity to the application site or production facility may understandably have a number of concerns about health and environmental impacts that must be addressed to ensure the success of biosolids beneficial use projects. The CCME suggests a range of factors that should be considered, including proposed site proximity to neighboring land uses; odour issues associated with the level of use and application timing; and cultural and historical concerns.

Communications, engagement, information sharing, and dialogue about the associated benefits and risks of the land application of biosolids is also crucial to the success of the program (Canadian Council of Ministers of the Environment, 2012). Several resources have been created to help biosolids professional in this process, including *Public Perception of Biosolids Recycling: Developing Public Participation and Earning Trust* (Water Environment Research Foundation, 2004) and the *Strategic Risk Communications Process for Outreach and Dialogue on Biosolids Land Application* from the Water Environment Research Foundation (WERF 2011). Taking steps to continuously earn the trust and respect of First Nations, stakeholders and the public through ongoing, open communications is critical to any future project.

3.5 Partner organization positions

The position of the Water Environment Federation (WEF), a BCWWA-affiliated organization, on the land application of biosolids is as follows (adopted by the WEF Board of Trustees December 2, 2011).

> The WEF supports a comprehensive approach to wastewater treatment and solids management that ensures the recycling and recovery of valuable resources including water, nutrients, organic matter, and energy. In addition, WEF recognizes that biosolids, natural by-products of the wastewater treatment process, are a renewable resource that is too valuable to waste in the context of growing needs for renewable energy and sustainability. WEF supports advancing the use of biosolids as a renewable resource and supports initiatives to ensure this expanded view of wastewater and solids management. WEF actively supports the promotion and enhancement of the beneficial recycling of biosolids that are best suited to meet the management needs of local communities, whether that use is beneficial recycling through land application, composting, energy generation, product development, landfilling, incineration, or other uses. This position is consistent with decades of scientific research and years of field practice that have clearly established the value and environmental benefits of biosolids when properly treated and managed. It is also consistent with the US Environmental Protection Agency's position and those of other federal agencies, which encourage the beneficial use of biosolids through policies and regulations, including the *Clean Water Act* (Water Environment Federation, 2015).

Section 4: Recommendation

Biosolids constituents have been the subject of much research since the beginning of beneficial use programs, and research continues today in response to the identification of new issues. However, after many years of study and risk assessment in Canada, the US, and Europe, regulatory agencies (as reviewed in Ryerson University, 2015) have concluded that biosolids should be beneficially recycled to land for their fertilizer value, and that constituents present which have the potential to pose risks to human health and the environment can be managed through source control, wastewater treatment, and regulated land application. It is recognized that there are countries and situations globally where land application is not favoured for geographical or political reasons, however land application in the BC context should be evaluated based on BC geography and a rational discourse of opportunity and risk. The BCWWA believes that current regulation in BC is protective of human health and the environment; however, we believe the regulation should be periodically reviewed and updated as necessary to reflect scientific advances and to support continuous improvement in the practice of biosolids and application.

Based on the available information, the BCWWA supports the beneficial use of biosolids land application in BC, such as in agriculture, forestry, reclamation of degraded land and mines, and the creation of value-added products such as composts and soils. However, we also recognize that the use of biosolids requires appropriate consideration in order to effectively mitigate, minimize, or eliminate risk from source to field. Biosolids may contain pathogens, trace elements, and emerging substances of concern that have the potential to be harmful to public health and the environment and thus biosolids must be managed carefully to ensure no harm or adverse impact. In addition, regardless of whether environmental and economic conditions have been met, land application of biosolids is made much more difficult without First Nations, stakeholder, and public confidence in and support for the practice. Ongoing effective communications about biosolids management and knowledge is an important component in supporting positively perceived biosolids beneficial use.

Effective biosolids beneficial use includes:

- Implementing and enforcing municipal source control and sewer-use programs.
- Strictly following the BC Ministry of Environment's *Organic Matter Recycling Regulation*, following the Ministry's recommended best management practices *Land Application Guidelines for the OMRR and the Soil Amendment Code of Practice* (2008), and strongly considering the Canadian Council for Ministers of Environment's *Guidance Document for the Beneficial Use of Municipal Biosolids, Municipal Sludge, and Treated Septage* (2012).
- Continuing research and risk assessment to stay abreast of changes in wastewater and biosolids quality and monitor the long-term impacts; and this could be supported by establishing a Canadian consortium to serve as an information clearinghouse for current research, enabling effective identification of knowledge gaps that may be addressed through additional research.
- Following community engagement best practices where possible and practicable throughout all stages of biosolids use.

The BCWWA acknowledges that positions and support for beneficial use of biosolids are based on the best available information. As information evolves, so too may the positions of regulators and the industry. As such, the BCWWA position statement on the land application of biosolids will be regularly updated every three years (or in tandem with OMRR reviews) under the direction of the Wastewater and Residuals Management Technical Advisory Committee to ensure that it accurately reflects the position of its members, and the position of regulators and evidence-based science as it pertains to BC.

Position Statement

The BC Water & Waste Association supports the land application of biosolids under the following conditions:

- That municipal sewer-use bylaws are established and enforced, and public education is carried out to control the amount of potential contaminants entering the sewage system through domestic and non-domestic sources.
- That provincial requirements detailed in the *Organic Matter Recycling Regulation* of British Columbia are adhered to.
- That management principles recommended by the Canadian Council of Ministers of Environment are strongly considered.
- That professionals working with biosolids and government demonstrate continuous information gathering and improvement through ongoing research and updates to biosolids management best practices and regulation.
- That First Nations, stakeholder, and public engagement best practices are followed throughout all stages of biosolids beneficial use.

The BC Water and Waste Association (BCWWA) prepares Position Statements to guide its members and others in the water and waste community in implementing best practices to support the safeguarding of public health and the environment as related to water and waste.

Our protocol for developing position statements begins with a well-researched and balanced analysis of the topic, which is normally drafted with support of one or more BCWWA Technical Committees who are considered to be subject matter experts on the issue. This analysis is then presented to the BCWWA Board of Directors in the form of an Issue Analysis Paper.

The Association staff present a *draft* Position Statement on the topic for review and input by BCWWA Technical Committees, the BCWWA Leadership Council, the BCWWA membership and in some cases, external stakeholders before the final Position Statement is presented to the BCWWA Board of Directors and officially adopted on behalf of the Association.

A special thank you to all those who contributed to the development of this position statement.

Appendix A: References

American Society for Microbiology. (2011). *Land Application of Organic Residuals: Public Health Threat or Environmental Benefit?* American Society for Microbiology.

BC Ministry of Environment. (2002, February 5). Organic Matter Recycling Regulation. *Environmental Management Act and Public Health Act*. British Columbia. Retrieved from http://www.bclaws.ca/Recon/document/ID/freeside/18_2002

Brown, S., & Trlica, A. (2013). Greenhouse Gas Emissions and the Interrelation of Urban and ForestSectors in Reclaiming One Hectare of Land in the Pacific Northwest. *Environmental Science & Technology*, 7250–7259.

Canadian Council of Ministers of the Environment. (2009, February 17). *Canada-Wide Strategy for the Management of Municipal Wastewater Effluent.* Retrieved from Canadian Council of Ministers of the Environment web site: http://www.ccme.ca/files/Resources/municipal_wastewater_efflent/cda_wide_strategy_mwwe_final_e.pdf

Canadian Council of Ministers of the Environment. (2012). *Canada-wide Approach for the Management of Wastewater Biosolids.* Canadian Council of Ministers of the Environment.

Canadian Council of Ministers of the Environment. (2012). Guidance Document for the Beneficial Use of Municipal Biosolids, Municipal Sludge and Treated Septage. Canadian Council of Ministers of the Environment.

Eggers, S., Thorne, S., Butte, G., & Sousa, K. (2011). *A Strategic Risk Communications Process for Outreach and Dialogue on Biosolids Land Application.* Alexandria: Water Environment Research Foundation.

Environmental Protection Agency. (2014, July 14). *Sewage Sludge (Biosolids)*. Retrieved from Environmental Protection Agency: http://water.epa.gov/polwaste/wastewater/treatment/biosolids/

Epstein, E., & Beecher, N. (2005). Mad Cow Disease, Creuzfeldt-Jakob Disease, Other TSEs, and Biosolids. *Journal of Residuals Science & Technology, Vol. 2, No. 3*, 181-187.

Goedert, M. (2015) Alzheimer's and Parkinson's diseases: The prion concept in relation to assembled Aβ, tau, and α-synuclein. *Science, Vol. 349, 61-69.*

Hinckley, G. T., Johnson, C. J., Jacobson, K. H., Bartholomay, C., McMahon, K. D., McKenzie, D., . . . Pedersen, J. A. (2008). Persistence of Pathogenic Prion Protein during Simulated Wastewater Treatment Processes. *Environmental Science Technology*, 5254-5259.

InfraGuide. (2003). *National Guide to Sustainable Municipal Infrastructure.* InfraGuide.

International Water Management Institute. (2010). *Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-Income Countries.* London/Sterling.

Miles, S., Takizawa, K., Gerba, C., & Pepper, I. (2011). Survival of infectious prions in Class B biosolids. *Journal of Environmental Science and Health*, Part A 46(4): 364–370.

National Research Council. (2002). *Biosolids Applied to Land: Advancing Standards and Practices.* National Research Council.

Ontario Clean Water Agency and the Clean Water Foundation. (2015, September 15). *I Don't Flush*. Retrieved from I Don't Flush: http://idontflush.ca/

Ryerson University. (2015). *Risks Associated with Application of Municipal Biosolids to Agricultural Lands in a Canadian Context.* Canadian Water Network.

Stitz, L., & Aguzzi, A. (2011). Aerosols. *Prion*, 5(3): 138–141.

SYLVIS. (2007). *Source Management and Biosolids Quality: Initiatives and Opportunities. Final Report.* Prepared for Metro Vancouver.

BC Ministry of Environment (2008). *Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice.* Best Management Practices.

United States Environmental Protection Agency. (2009, January). *Biosolids: Targeted National Sewage Sludge Survey Report.* Retrieved from US EPA web site: http://water.epa.gov/scitech/wastetech/biosolids/tnsss-overview.cfm

Water Environment Federation. (2015, September 15). *Policy and Position Statements.* Retrieved from Water Environment Federation web site: http://www.wef.org/uploadedFiles/Government_Affairs/Policy_and_Position_Statements/Policy-Position_PDFs/WEFBiosolidsPositionStmttoBOT120211.pdf

Yanko, W. (1988). *Occurrence of pathogens in distribution and marketing municipal sludges.* Cincinnati, OH: US Environmental Protection Agency, Health Effects Research Laboratory.

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