Making a difference...together

REPORT TO ENVIRONMENTAL SUSTAINABILITY COMMITTEE
MEETING OF WEDNESDAY 27 APRIL 2011

SUBJECT **LAND APPLICATION OF CLASS A BIOSOLIDS – LITERATURE REVIEW**

ISSUE

Land application of biosolids has several benefits, but there are potential risks to human health and the environment. Both the Saanich Peninsula Wastewater Commission and the Environmental Sustainability Committee have directed staff to provide additional information regarding these potential concerns in order to support decisions and policies for biosolids management.

BACKGROUND

Biosolids are generated through wastewater treatment processes. One of the potential uses of this product is its application to land, with a primary benefit of providing nutrients to agricultural, landscaped or reclaimed land, displacing the need for synthetic or non-sustainably sourced fertilizers.

In Canada, approximately 660,000 tons of biosolids are produced annually with approximately 43% applied to agricultural land, 4% to landfill and 47% to various types of land applications. The United States generates more than 7 million tons of biosolids per year, with approximately 51% going onto agricultural land, 38% to landfill and 11% to incineration. Countries in the European Union generate more than 6 million tons of biosolids per year. The percentage of biosolids being applied on land in Europe varies from country to country, e.g., Germany 25%, Netherlands 44%.

As with any product, there are potential risks associated with its use. Human health and environmental concerns about biosolids land application arise because of the potential for direct or indirect exposure to pathogens or contaminants contained in the land applied biosolids. Risk assessment evaluates the source, pathways and receptors that can lead to contaminant exposure. To provide a full and timely response to the committees' requests, the Capital Regional District (CRD) retained the services of Stantec Consulting Ltd. to undertake a literature review on the risks of the land application of biosolids. Stantec's report is attached as Appendix A, and a brief summary is provided below.

Potential contaminant exposure risks are primarily associated with metals and, as such, the various international regulations include the metal concentration limits. These limits have been set conservatively to reduce the risks for direct and indirect toxicity to human health and the environment. Many of the supporting risk assessments have also investigated the potential for adverse effects of micro-constituent contaminants, such as industrial organic chemicals (e.g., fertilizers and pesticides, flame retardants, etc.) pharmaceuticals and personal care products, and other emerging substances of concern. These peer-reviewed scientific risk assessments have determined that many of the industrial organic chemicals are indeed present in the biosolids, but that concentrations are well below those demonstrated to have human health or ecological effects. With respect to pharmaceuticals, personal care products and other substances of concern, the ability to analyze and detect these compounds currently supersedes the ability to fully interpret any potential effects. However, the detection of these chemicals does not imply unacceptable risks or potential effects. Current research about their potential environmental effects is limited; however, preliminary and ongoing research indicates that the risk of adverse effects is low. As a result, regulatory agencies are not developing revisions to the current frameworks that permit land application of biosolids.

The general consensus of scientific studies and risk assessments have also concluded that potential pathogen exposure risks, such as those that have been publicized in the media, are primarily associated with the land application of sewage sludges (i.e., untreated wastewater residuals with no pathogen reduction) or the application of Class A or Class B biosolids in ways that are not in accordance with the regulations.

Given the scientific research conducted to date, regulatory bodies have developed risk management approaches that allow for the land application of biosolids, which includes legislation, guidance documents, policies and procedures and administrative requirements. For example, in BC, biosolids land application is regulated through the BC Organic Mater Recycling Regulation (OMRR). This regulation sets:

- allowable limits for pathogens and contaminants (specifically metals) in the biosolids;
- allowable limits for these same parameters in the agricultural soils post-land application; and
- direction for site specific conditions that must be considered prior to, and during land application.

The OMRR, consistent with other regulatory frameworks in Canada, the US and Europe, is based on peer-reviewed, scientific risk assessments that have involved investigating all potential sources, pathways (as outlined in Table 1 of the Stantec report), receptors and effects associated with the land application of biosolids, and then undertaking an overall risk/benefit analysis.

In conclusion, the BC provincial government, along with other jurisdictions with statutory responsibility for protecting human health and the environment, have considered the risks of biosolids application to land, and provided enabling legislation and technical and administrative guidance to ensure that the proper application of biosolids poses acceptable risk to human health and the environment.

Monitoring of the Saanich Peninsula treatment plant's PenGrow biosolids product confirms that it meets all Class A pathogen and metal limit criteria required by OMRR and, as such, the product can be applied to land with approved land application plans that result in acceptable risk levels for human health and the environment.

ALTERNATIVES

That the Environmental Sustainability Committee:

1. receive this report for information; or

2. not receive this report for information and direct staff to provide additional information.

CONCLUSION

The production of biosolids from the Saanich Peninsula wastewater treatment plant meets Class A standards under the OMRR. The proper application of these biosolids to land would result in acceptable risk to human health and the environment as defined by the protections standards set by the BC Ministry of Environment, which are consistent with other national and international regulatory bodies. These conclusions allow for a range of risk management options to the CRD besides land application, and include landfilling, incineration, and a feedstock for other industrial processes.

RECOMMENDATION

That the Environmental Sustainability Committee receive this report for information.

Glenn Harris, PhD, RPBio
Senior Manager, Environmental Protection

Larisa Hutcheson, PEng
General Manager, Environmental Sustainability
Concurrence

CL:km
Attachment: 1

Land Application of Wastewater Bio-solids

Concise Literature Review of Issues for CRD

Prepared by:

Dr. Robert Dawson
Stantec Consulting Ltd.
Suite 400, 655 Tyee Road
Victoria, BC V9A 6X5
P. (250) 388-9161
F. (250) 382-0514

April 12, 2011

Table of Contents

1.0 Introduction

The Capital Regional District (CRD) retained Stantec Consulting Ltd. to provide a report that summarizes a literature review of the scientific research regarding the land application of bio-solids.

1.1 DEFINITION OF SLUDGE AND BIO-SOLIDS:

Sludge is the term applied to the solids which are separated from the wastewater at treatment facilities from the bottom of primary settling tanks, or as the waste activated sludge solids separated from the liquid stream in final settling tanks. Sludge contains inert solids, heavy organic material and light flocculant biological organisms driving the biological treatment process. The sludge also contains 80 to 90 % of the heavy metals originally contained in the raw wastewater, as well as high concentrations of bacteria some of which can be the residual pathogenic organisms surviving the liquid stream treatment processes. As well, the secondary biological sludge usually contains organic compounds adsorbed on the biological sludge which can be industrial in nature such as phenols or PAH's and in very small concentrations trace organics referred to as pharmaceuticals and personal care products (PPCP's).

Usually the primary and secondary sludges are mixed together and receive further stabilization in anaerobic or aerobic digesters to kill off pathogenic bacteria and significantly reduce the soluble organics and organic solids. Following sludge stabilization, say by anaerobic digestion at temperatures of 35 deg C, most of the bacteria are killed (reduced by several orders of magnitude) or attenuated, and organic material is degraded by about 60 to 70% producing a usable bio-gas product. The residual digested sludge solids from such an operation are readily dewatered and are classed as Class B bio-solids. The above stabilization processes easily achieve a pathogenic bacteria and virus kill of about 99%. As discussed below, the Class B bio-solids can be applied to agricultural land as a liquid or as dewatered bio-solids (15 to 40% solids). The bio-solids are valued by the agricultural community throughout Canada the USA and Europe as a source of nutrients (nitrogen and phosphorus) which are beneficial to crop production. The application of Class B bio-solids is governed by a number of site use restrictions with respect to public and farm animal access and types of crops that can be produced etc.

The bio-solids can be further upgraded to Class A bio-solids which can be applied to agricultural lands with very few site restrictions because stabilization processes essentially kill all of the pathogenic bacteria and viruses. The more intensive stabilization processes which achieve Class A bio-solid classification are: anaerobic digestion (thermophilic) which occurs at a temperature of 55°C (as proposed for the Core Area generated bio-solids) and alkaline stabilization at high temperature as currently carried out by use of the RDP process for the Peninsula plant bio-solids. Class A bio-solids are also significantly lower than Class B bio-solids in terms of metal, and trace organic material concentration because of additives, sand, lime or organic material such as wood chips added in stabilization and composting processes used to produce soil amendment products. Because of the accumulation of residual pollutants in the bio-solids which occurs the following concerns were and still are the subject of research for the development of land application regulations:

- Heavy metal accumulation and toxicity
  - Soil organisms toxicity from specific metals
  - Uptake of metals by plants subsequent-toxicity to grazing animals
  - Plant toxicity
  - Mobility to groundwater – water quality problems
  - Health Impacts on Humans – plant ingestion, water
- Pathogen Survival-public health problems

- Disease transmission to grazing animals
- Disease transmission to humans via animal products
- Public health concerns of aerosol spread of pathogens
- Disease transmission directly to humans
- Disease transmission to humans through consumption of crops
- Mobility of pathogens to water resources- animal and human health impacts

- Organic Micro—constituent
  - Toxicity to plants, animals and humans-trace organics such as PAH's, Phthaltes
  - Endocrine Disruptor Compounds (EDC's) - effects on soil and aquatic ecology and reproduction caused by pharmaceuticals, personal care products and other EDC's.

Basic research on these issues combined with risk assessment and clear land application regulations and guidelines have eliminated most of these concerns-particularly for Class A bio-solids and bio-solid products. A large number of universities and government research agencies in the USA, Europe, and Canada – essentially worldwide-contributed to developing regulations for environmentally acceptable and safe land application practices.

1.2 WORLDWIDE AND NORTH AMERICAN APPROACH TO BIO-SOLIDS MANAGEMENT:

On a worldwide basis land application of bio-solids is common practice and encouraged by environmental control agencies such as the USA Environmental Protection Agency (EPA). In USA, over the last 75 years there has been a great deal of research into the optimum rates of application of bio-solids to cropland to maximize their fertilization benefits and minimize any potential environmental or health impacts. In the USA for example over 7 million tons/ of bio-solids are produced each year of which 60% are applied to agricultural land or composted to produce soil amendment products. (1) In Europe bio-solids application to land is also common practice with the percentage of bio-solids being applied varying from country to country e.g. (Germany 25%, Netherlands 44%). In Canada land application of stabilized bio-solids to agricultural land as either Class B or Class A bio-solids is commonplace throughout Western Canada as well as Ontario and Quebec and accounts for about 60% of the bio-solids management. In BC, data from 2000 indicates that approximately 60% of the 100,000 tonnes per year of bio-solids generated from WWTP's are applied to land.

The production of soil amendment and fertilizer products from Class A biosolids is becoming more and more common throughout North America e.g. Vancouver, BC, Tacoma Washington, Boston Massachusetts are typical examples. Tacoma produces 3 commercially competitive products through TAGRO – a soil amendment (consisting of 2 parts Class A biosolids, 2 parts sawdust and 1 part sand) as well as mulch and a topsoil. Currently 3600 tonnes a year of dry biosolids are reused in this manner at Tacoma generating a revenue stream of about $400,000 annually at this City with a population of 200,000 persons. (2)

1.3 REGULATORY APPROACH TO LAND APPLICATION OF BIO-SOLIDS

The US Environmental Protection Agency (USEPA) initiated a comprehensive research and risk assessment process to establish reliable management practices for bio-solids application to land starting in 1980's which is well described in a series of EPA publications.(3,4,5)

The EPA adopted a risk assessment approach which established allowable concentrations of pollutants in bio-solids – a range of heavy metals, toxic organics and indicator bacteria for application to land. This risk based approach is well described in “A Guide to Bio-solid Risk Assessments for the EPA 40 CFR Paint 503 Rule.(6)

Representative pathways by which humans, animals and plants could be exposed to pollutants that may be present in bio-solids were selected. These 14 pathways are shown in Table 1. Exposures were determined for each pathway and were confirmed with data on allowable doses extracted from medical, veterinary medicine and agricultural plant research to develop a limit for each pollutant that would be an acceptable risk. These limits were evaluated for “the most exposed individual” (MEI) for each pollutant and pathway. For humans, this MEI was the most sensitive individual being exposed for a 70 year life time to a pollutant at its maximum concentration in a given pathway. For plant and animals the MEI was the most exposed or most sensitive species exposed over its critical life period to the maximum pollutant solubility, bioavailability and/or concentration.

The risk assessment methodology has a large number of safety factors built into the selection of dosages etc. to calculate the risk. The risk levels selected for each compound of concern are also low – for example for those components known to be involved in increasing the likelihood of cancer the increased risk was selected as 1 in 10,000.

Table 1 – Exposure pathways used in the risk assessment process for land application of bio-solids (USEPA, 1995h).

Pathway	**Description of the highly exposed individual**
1. Bio-solids → Soil → Plant → Human	Human (except home gardener) lifetime ingestion of plants grown in bio-solids-amended soil
2. Bio-solids → Soil → Plant → Human	Human (home gardener) lifetime ingestion of plants grown in bio-solids-amended soil
3. Bio-solids → Human	Human (child) ingesting bio-solids
4. Bio-solids → Soil → Plant → Animal → Human	Human lifetime ingestion of animal products (animals raised on forages grown on bio-solids-amended soil)
5. Bio-solids → Soil → Animal → Human	Human lifetime ingestion of animal products (animals ingest bio-solids directly)
6. Bio-solids → Soil → Plant → Animal	Animal lifetime ingestion of plants grown on bio-solids-amended soil
7. Bio-solids → Soil → Animal	Animal lifetime ingestion of bio-solids
8. Bio-solids → Soil → Plant	Plant toxicity due to taking up bio-solids pollutants when grown in bio-solids-amended soil
9. Bio-solids → Soil → Soil Biota	Soil organism ingesting bio-solids/soil mixture
10. Bio-solids → Soil → Soil Biota → Soil Biota Predator	Predator of soil organisms that have been exposed to bio-solids-amended soil
11. Bio-solids → Soil → Airbourne Dust → Human	Adult human lifetime inhalation of dust particles (e.g., tractor driving tilling a field)
12. Bio-solids → Soil → Surface Water → Human	Human lifetime drinking surface water and ingesting fish containing pollutants in bio-solids
13. Bio-solids → Soil → Air → Human	Human lifetime inhalation of pollutants in bio-solids that volatized into the air
14. Bio-solids → Soil → Ground Water → Human	Human lifetime drinking well water containing pollutants from bio-solids that leached from soil to groundwater

Based upon this work EPA rule 503 sets out:

- Ceiling concentration limits for bio-solids – above which bio-solids cannot be land applied (CCL's)
- Pollutant concentration limits (PCL's) which are the highest concentration of pollutants that bio-solids may contain without requiring tracking of cumulative pollutant addition defines bio-solids of "exceptional quality"
- Cumulative pollutant loading rate (CPLR) which is the maximum amount of pollutant that can be applied to a site in its lifetime.
- Annual pollutant loading rate (APLR) which is the maximum amount of a pollutant that can be applied to a unit area of land over a 365 day period for Class B bio-solids.

These key concentration limits and application rate limitations are shown in Table 2.

Table 2 – Pollutant limits and loading rates for land-applied bio-solids (adapted from USEPA, 1994b, and MDEQ, 1999)

Pollutant	Concentration limits[a] (mg/kg or ppm)		Loading rates[a] (kg/ha)	
	CCL	PCL (for EQ and PC bio-solids)	CPLR (for CPLR bio-solids)	APLR (for APLR bio-solids and a 365-day period)
Arsenic (As)	75	41	41	2.0
Cadmium (Cd)	85	39	39	1.9
Chromium (Cr)[b]	-	-	-	-
Copper (Cu)	4,300	1,500	1,500	75
Lead (Pb)	840	300	300	15
Mercury (Hg)	57	17	17	0.85
Molybdenum (Mo)[c]	75	-	-	-
Nickel (Ni)	420	420	420	21
Selenium (Se)[b]	100	100	100	5.0
Zinc (Zn)	7,500	2,800	2,800	140
Applies to:	All bio-solids that are land applied	Bulk bio-solids and bagged bio-solids[d]	Bulk Bio-solids	Bagged bio-solids[d]
From 40 CRF Part 503:	Table 1, Part 503.13	Table 3, Part 503.13	Table 2, Part 503.13	Table 4, Part 503.13

[a] Dry-weight basis; mg/kg = milligrams per kilogram; ppm = parts per million; kg/ha = kilograms per hectare
[b] CCL and PCL for chromium were deleted from Table 1 and 3 and PCL for selenium was increased from 36 ppm to 100 ppm by amendments to Part 503 Rule, effective October 25, 1995
[c] The PCL, CPLR and APLR for molybdenum were deleted from Part 503 Rule, effective February 19, 1994. The EPA will consider establishing these limits at a later date.
[d] Bagged bio-solids are sold or given away in a bag or other container.

Initially the EPA Rule 503 also considered 12 organic chemicals that were identified which could be present in bio-solids and could cause harm to humans, plants and the environment. All of the organics were left off the list of compounds regulated by 503 rule because (1) many had already been banned, or (2) the concentrations in bio-solids were well below the levels that would have been established by the risk analysis process. (7)

Originally 20 additional organic compounds were evaluated and proposed limits were established for aldrin/dieldrin, benzopyrene, chlordane, DDT, heptachlor, hexachlorobenzene, hexachlorobutadiene lindane, dimethylamine, toxaphene, and trichloroethylene. In all cases the amount of these compounds found in bio-solids were present at less than 1/1000th of the proposed regulatory limit so they were dropped from the regulated compounds.(8)

In British Columbia application of bio-solids to land is regulated under the Organic Matter Recycling Regulations developed in 2009. A similar slate of metals is regulated under OMRR as for the EPA Rule 503. In most cases the BC regulations are more stringent then the EPA releases particularly for the Class A levels as shown in Table 3. This table also shows the range of metals occurring in commercial chemical fertilized as regulated by Agriculture Canada. For most of these metals the typical concentrations allowed in commercial fertilizers are higher than in the bio-solids. Similar to the EPA regulations guidelines and regulation are provided in the OMRR with respect to site limitations for soil cover, appropriate soils, maximum slope, depth to water table, distance to water courses, application rates, public and grazing animal access, suitable crops, harvest regulations.

Table 3 – Comparison of OMRR & EPA requirements for bio-solids application to land

	OMRR	EPA	Saanich Peninsula	Typical Concentration Range	
Trace Elements Mg/gm	Class A Bio-solids	Exceptional Quality	Bio-solids	Soils	Fertilizer
Arsenic	75	75	<20	<5	0.3.-160
Cadmium	20	85	<2	<0.5	0.75-396
Chromium	-	3000	17.2	16.9	1.3-338
Cobalt	150	-			
Copper	-	4300	336	23	1.0-29,000
Lead	500	840	<120	2.7	4.6-10,000
Mercury	5	57	0.418	<0.05	0.01-3.36
Molybdenum	20	75	-		
Nickel	180	420	<20	15.2	1.4-890
Selenium	14	100	<8	<2	
Zinc	1850	7500	148	39.3	1.6-77,000
Fecal Coliform MPN/gm uw	<1000	<1000	<20		

Note that the Saanich Peninsula PenGrow soil amendment product has heavy metal concentrations as well as fecal coliform bacteria levels which are significantly lower than either the EPA or OMRR regulations for Class A or EQ bio-solids.

The EPA regulations provide rules for application rates to soil for Class B and Class A bio-solids. Usually these application rates are based upon:

- Providing the amount of plant N needed by the crop or vegetation – the agronomic rate
- Minimizing the amount of N that passes below the root zone to groundwater (usually 15%) desirable to prevent salt accumulation.
- Optimizing the amount of phosphate and potash to the crops.

The rules also provide restrictions for access of public, grazing animals, harvesting of various categories of food crops – particularly where Class B bio-solids are applied. These rules provide a sufficient period for die-off and attenuation of bacteria; viruses in the soil to protect human health (direct contact) see Table 4. Similar restrictions of access and crop harvesting are required by the BC Organic Matter Recycling Regulations.

Table 4 – Site restrictions associated with Class B bio-solids application (adapted from USEPA, 2994a).

Land use	**Period after bio-solids application**
Public access to the land:	
• High potential for public exposure (parks, playground, golf courses)	Restricted for 1 year
• Low potential for public exposure (farmlands, remote lands, securely fenced land)	Restricted for 30 days
Crops to be harvested or grazed:	
• Food crops, feed crops or fiber crops	Can harvest after 30 days
• Food crops with harvested parts that touch bio-solids/soil mixture and are totally above the ground surface (e.g. melon)	Can harvest after 14 months
• Food crops with harvested parts below the land surface, e.g., root crops such as carrots	
o where bio-solids remained on the land surface > 4 months prior to soil incorporation	Can harvest after 20 months
o where bio-solids remained on the land surface < 4 months prior to soil incorporation	Can harvest after 38 months
• Turf grown on land where bio-solids are applied that will be placed on land with high potential for public exposure or on a lawn	Can harvest after 1 year

1.4 LITERATURE REVIEW OF ISSUES PERTINENT TO RESOLVING THE ISSUE OF HARMONIZING BIO-SOLIDS POLICY

There have been a large number of scientific investigations and literature reviews into the sustainability of applying wastewater bio-solids to agricultural land by universities, state, provincial and national government agencies as well as professional organizations. Without exception these literature reviews have concluded that the environmental, ecological, and public health and water quality impacts of land application are insignificant if the regulations recommended by the various government agencies are followed. Typical comments from the literature have stated:

"where bio-solids have been applied in accordance with regulations problems that have occurred are rare and generally related to inadequate field conditions and application techniques or poor bio-solid quality." (9)

On two occasions the National research Council of the USA National Academy of Sciences carried out literature reviews that considered whether the practice of land application of bio-solids is safe and beneficial in 1996 and again in 2002.In reference to land application of bio-solids the reviews stated that:

"when practiced in accordance with federal guidelines and regulations, (land application of bio-solids)presents negligible risk to consumer ,to crop production, and to the environment. Current technology to remove pollutants from wastewater coupled with existing regulations and guidelines governing the use of reclaimed wastewater and sludge in crop production are adequate to protect human health and the environment " (10)

"there is no documented scientific evidence that the Part 503 rule has failed to protect public health" "A causal association between bio-solids exposures and adverse health outcomes has not been documented" there are no scientifically documented outbreaks or excess illnesses that have occurred from microorganisms in treated bio-solids" (11)

In the letter from CALWMC member, which initiated this concise literature review it was emphasized that the following topics be addressed.

1.5 PUBLIC HEALTH IMPACTS

One of the primary reasons for providing waste water treatment is to eliminate the possibility of transmitting disease or creating conditions in the environment that are toxic to humans. Protection of public health is closely linked to protecting the environmental quality. The European Parliament reported that there are no cases of human, animal or crop contamination due to use of sludge on agricultural soils following the provisions of Directive 86/278/EEC (12) This document specifies land application practices to be followed for bio-solids in European Union member states.

1.6 PATHOGEN ORGANISM CONCERNS

Residual pathogenic bacteria and viruses contained in bio-solids do not survive well when applied to land because they are inactivated, made non infectious or perish because the soil chemistry and physical conditions are not conducive to their survival. As well, they are out- competed by native soil microorganisms.(13, 14, 9)

Biosolid application to land usually enhances the growth of these beneficial micro-organisms.

The delay times established in the bio-solids application regulations, shown in Table 4, provides sufficient time for residual viruses, bacteria in the bio-solids to die-off prior to public access, access for grazing animals, or crop harvesting. (15) Pathogens are also inactivated and made non infectious by desiccation, ultra violet light and heating in the soil. (13)

1.7 DISEASE TRANSMISSION TO GRAZING ANIMALS

The die-off of residual pathogens in soil and the delay times for allowing access of grazing animals to lands where bio-solids are applied are considered in the risk analysis of this pathway of potential disease transmission.

1.8 SURVIVAL OF PRIONS AND HEPATITIS A

Prions are particles of specific proteins associated with diseased animals and humans that are implicated in the spread of Creutzfeldt Jakob disease and BSE in animals and humans. Hepatitis A is a serious viral disease which attacks the liver. The hepatitis virus, similar to other enteric viruses prefers and needs the conditions within the human body to thrive. Survival rate of enteric viruses through the treatment processes and bio-solids processing – particularly Class A bio-solids(14), conditions in the farm fields and outdoor environment leads to rapid die-off. (16) There is very little literature on the presence of prions in bio-solids. The incidence of the disease in humans and animal populations is very low and would require direct ingestion by humans and animals for which the risks are extremely low.

1.9 DISEASE TRANSMISSION BY ANIMAL PRODUCTS

This pathway of disease transmission requires direct ingestion of viruses and bacteria by grazing animals or contamination of crops subsequently consumed by animals by viruses and bacteria associated with bio-solids. Because of the die-off of pathogens in soils, as well as time delays required for grazing animal access and harvesting of forage crops, the potential risk of animal products, e.g. Milk, meat, etc being a source of disease transmission to humans is extremely low for Class B bio-solids and almost zero for Class A bio-solids.

1.10 MOBILITY OF PATHOGENS THROUGH WIND DISPERSAL ETC

Recent study of potential for disease transmission through aerosol spread of bacteria and viruses to persons living downwind on adjacent land to Class B bio-solid land application sites has been shown to pose very little risk in several recent studies.(17, 18) These investigations at 10 different sites to which bio-solids were applied by a variety of techniques and under a variety of environmental conditions showed that risk of infection from aerosolized Salmonella to persons living as close as 30 meters is extremely low. Investigations have also shown that no occurrence of Staphylococcus aureus was observed in aerosols obtained during bio-solids application for Class A or Class B even though these organisms are present in the bio-solids themselves. (19) Several important literature surveys have shown that risks of infection from indirect exposures such as aerosolized pathogens appear to be low. (20) Alternatively risks could be minimized by applying biosolids to land to which people do not normally access.

1.11 DISEASE TRANSMISSION DIRECTLY TO HUMANS

The highest potential of the 14 pathways, for disease transmission from pathogens in bio-solids is by direct ingestion of soils and bio-solid materials by children accessing the land where Class B bio-solids have been applied. Usually this risk is associated with application of bio-solids to recreational land. An effective way of eliminating this risk is by restricting access beyond the survival time of pathogens in soils and the environment. (9)

1.12 DISEASE TRANSMISSION TO HUMANS BY CONSUMPTION OF CROPS

There is not a direct uptake of pathogenic organisms by agricultural crops. Contamination can only occur through inclusion of soil particles or bio-solids into the surface of crops. Mitigation of risk for this pathway is by providing sufficient die-off time for pathogen organisms in the soil prior to sowing and harvesting crops meant for human consumption. A study of effects of bio-solids applications of bio-solids on soils, crops did not establish any adverse related effects on crops on or near the bio-solids application site. (21)

A recent Literature survey indicates that land application of Class B bio-solids is sustainable and the risk to human health is low from pathogenic microorganisms if the current EPA or OMRR regulatory application practices are followed. (20)

1.13 MOBILITY OF PATHOGENS TO WATER RESOURCES – ANIMAL AND HUMAN HEALTH INGESTS

Regulations and careful site selection of bio-solid application sites and operations are very effective in minimizing the risk of pathogen access to water resources. Restriction of bio-solids application to sites with shallow groundwater, high slope and prohibition of application of bio-solids during periods of high precipitation and runoff are very effective. (22) This literature review also reported that at a site where bio-solids had been applied according to application rules for 20 years that tests of well water quality showed negligible bacterial contamination.

1.14 HUMAN HEALTH IMPACTS THROUGH EXPOSURE TO PATHOGENS IN BIO-SOLIDS

There have been reports and claims by residents living adjacent to bio-solid application sites that their health has been significantly depleted which have been documented in the literature. (23, 24, 25, 26, 27) Claims of severe allergies, respiratory infections, gastrointestinal complaints, vomiting, dizziness have been made. All of these reported incidents have been related to the application of Class B bio-solids – not Class A. Very few of the reported events have shown a direct cause effect relationship between the application of bio-solids and the specific ailments. (28) Where there has been groundwater and drainage system contamination associated with the events, subsequent investigation has shown that either the recommended bio-solids application practices have not been followed or the regulations with respect to suitable sites have been ignored.

Several studies have confirmed that the concern for potential spread of infectious disease through bacteria and viruses contained in aerosol and wind bourne particles from fields to which bio-solids have been applied is really a perception rather than a fact. (17, 18)

1.15 HEAVY METAL CONCERNS

Heavy metals occur in municipal wastewater through the discharge of metals contained in household chemicals, by discharge from commercial and industrial wastes, through abrasion and solution from metal pipes and fittings and from inclusion on soil particles giving access to the sanitary sewer. The CRD has a very active source control program to minimize the discharge of metals from industrial and commercial sources which is very effective. The industry contributing metal contaminants as part of their waste stream in very small in the Victoria area.

The source control program combined with the low level of metal discharge has resulted in low concentrations of metals in the raw wastewater. Secondary treatment of wastewater results in removal of about 80 to 90% of most of the heavy metals and inclusion by settling and absorption with the sludge and subsequently into the bio-solids.

In Table 3 we have seen that the metal concentrations for arsenic, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium and zinc in the CRD PenGrow bio-solids are all within the EPA concentration limits specified for EQ for exceptional quality bio-solids and they are well below the OMRR Class A limits.

Risk analysis studies have shown that if the Class A bio-solids are applied to land at the EPA and OMRR rates that long term application will not result in toxicity concerns to soil organisms, crops and that the risk of disease transmission to humans and grazing animals is minimal. (6) Research subsequent to the 503 Rule has shown that metals became attached to soil particles and tend to become less bioavailable with time.(9) Studies on the long term land application of bio-solids have shown that cumulative metal loading rate in the soil were far less than EPA limits.(29) Although crops grown in bio-solids-amended soils have higher metal concentrations than plants grown in control soils metal concentrations in all the test plants were lower than the limits specified in regulations for crop consumption.

1.16 MOBILITY OF HEAVY METALS INTO WATER RESOURCES

One of the major reasons for regulating the heavy metals so rigorously is to prevent their transport through the soil column or overland to groundwater and surface water resources. The rules for application rates and maximum loads of bio-solids and guidelines for site characteristics such as slope, depth and type of soil, depth to water table, are the first line of defense to prevent mobility to water resources. Prohibiting application of bio-solids in periods of high precipitation and runoff are also important. Most metals are absorbed in soil particles and usually are immobilized as they pass through the root zone. Long term studies (20 years) of water quality in groundwater beneath Class B bio-solids application sites have demonstrated that transport to the groundwater does not create problems with nutrient or metal levels provided that the EPA rules are followed. (25) These studies showed no adverse bio-solids related effects on soils, crops, or groundwater near the bio-solid application site.

1.17 METAL ACCUMULATION THROUGH REPEATED LAND APPLICATION

As discussed above, metal in bio-solids applied to land tend to become absorbed in soil particles and complex in the soil. The EPA Rule 503 application rates were selected such that long term application would not raise the soil concentrations to levels that could be toxic to plants or soil organisms. The number of years of tri-annual application of bio-solids with an equivalent metals concentration profile as contained in PenGrow (equivalent to the organic application rate for nitrogen) were calculated for the soil concentration to reach the OMRR levels of concern. As shown in Table 5 these periods were lengthy ranging from about 116 years for Copper up to 32000 years for Mercury.

Table 5 – Metal Levels and Site Life Expectancy for Bio-solids of Typical Agronomic Rate (2)

		As	Cd	Cr	Cu	Pb	Hg	Za
OMRR soil concentration	mg/kg	100	70	300	150	1,000	100	450
Bio-solid metal concentration	mg/kg	4.3	2.8	65	1052	67	2.5	1,095
Application rate metal	Kg/ha	0.03	0.02	0.47	7.54	0.48	0.02	7.85
Site Life Expectancy	years	18,900	20,400	3,770	116	12,200	32,600	336

Several of the metals are readily taken up by plants as essential nutrients e.g. Copper, Molybdenum and Zinc and are beneficial to the crops.

The EPA and OMRR require that locations where long term bio-solid application is practiced that the soils must be continuously monitored for buildup of metals and if the lifetime cumulative loading rate reaches the cumulative pollutant loading rate (CPLR) as specified in Table 2 then bio-solid application must stop.

If this type of bio-solid regulation is followed the California State Water Resources Central Branch concludes (30) that the risk of disease occurring from the presence of trace metals in applied bio-solids should be low and there would be no significant impact on public health.

1.18 BIOACCUMULATION AND BIO-CONCENTRATION OF HEAVY METALS

Several of the heavy metals tend to bio-concentrate as they are metabolized by soil organisms, plants and animals as they feed. Bioaccumulation refers to the phenomenon that the rate of uptake exceeds the rate of elimination from an organism. Many also bio-concentrate in certain tissues or organs of an organism. Biomagnification can also occur as plants or organisms are consumed by higher level life form – e.g. Grazing animals, human, predators, etc. All of these metal compound concerns were taken into account by the Risk assessment carried out by EPA in developing Rule 503. Based upon the findings of a panel of experts convened by the government and general assembly of the State of Virginia it was concluded (31) that as long as state and EPA land application regulations are followed “there is no scientific evidence of any toxic effects on soil organisms, plants grown in treated soils, or to humans via bio-accumulative pathways for inorganic trace elements (including heavy metals) found at current concentrations in bio-solids.”

1.19 FARM FERTILIZER (NUTRIENT) DISPERSAL THROUGH WEATHER RELATED RUNOFF

Bio-solids contain significant quantities of nitrogen (5%), phosphorus (3%), potassium (0.3%) and other essential nutrients required for crop growth. Most of the nitrogen is in the form of organic nitrogen associated with carbon compounds such as protein or amino acids and therefore it is a very good slow release fertilizer. Bio-solids are usually applied at the agronomic rate for the specific crop they are supporting so that the nutrient levels are matched to the crop application rate. A typical bio-solids application rate of 7 tonnes/ha/yr considering the soils and forage crops grown in BC which might need about 115 kg/ha/yr of nitrogen (32). Utilizing bio-solids offsets the use and expense of commercial fertilizer and increases the physical structure characteristics and water retention of the soil because of the presence of organic matter. Other essential plant nutrients beneficial to plant growth are present in bio-solids such as calcium, magnesium, sulfur, boron, copper, iron, manganese, molybdenum and zinc at concentrations which are more advantageous than concentrations in commercial fertilizer. An additional advantage of the Pengrow bio-solids is that lime stabilized soils have value for providing a buffering capacity for acid oils and are substitute for agricultural grade lime.

As with any fertilizer it is important that the timing if application be such to avoid periods of high precipitation and potential runoff and that the bio-solids not be applied to area with a high rate table. Following the fertilizer and OMRR practice rules such as not fertilizing within 10 or 20 metres of a natural water course high water level prevents nitrate contamination of ground and surface water.

1.20 ENVIRONMENTAL AND PUBLIC HEALTH IMPACTS OF EMERGING COMPOUNDS OF CONCERN ECOC’S

A variety of trace organic materials gain access to the sanitary sewage system and have been detected in trace amount in domestic wastewater. Some of these compounds are from commercial and industrial waste discharges such as petrochemical compounds eg. phenols, polyaromatic hydrocarbons (PAH’s) and phthalates, as well as pesticide and other agricultural chemicals. Usually, a large number of these micro constituents are present because of direct human use such as pharmaceuticals, personal care products, plasticizers, fire retardents and musk fragrances. The major concern with these compounds increasingly referred to as Emerging Substances of Concern (ESoC's) is not exposure to humans but the potential impacts on downstream environmental system. Many of these compounds can disrupt aquatic ecology and are known as endocrine disrupters (EDC's). They have the potential to cause long term birth defects in terrestrial and aquatic organisms. (29, 33, 38)

During wastewater treatment many of these compound are partially degraded during the biological treatment process. However, many of the ESoC's are absorbed upon the biological sludge and concentrate in the bio-solids. (39)

Only recently have analytical techniques been sensitive enough to detect their presence since most are present at very low concentrations of 10^{-9}gm/l in wastewater and 10^{-9} gm/gm in secondary bio-solids. (11) The significance of the presence of these compounds at these low concentrations is a subject of current research (by EPA and European Environmental Agencies) on exposure and hazard assessment to humans, terrestrial and aquatic organisms.

The Canadian Council of Ministries of the Environment are also currently implementing a major study in association with a group of Canadian universities.(11, 40) These studies are currently targeting:

- Neutral pharmaceuticals-carbamazepine, trimethoprim, caffeine, catinine
- Acid pharmeceuticals – acetaminophen, ibuprophen, gemfibozil, naproxen
- Antibacterials – tricloson, triclocarbon
- Phenols nonylpheneud octylphenol bisulphenol A
- Synthetic musk fragrances AHTN, HHCB, musk xylene musk keytone
- Sulfa antibiotics sulfamethoxazole sulfapyridine

A major research project into the removal of a similar range of ECoC's by wastewater treatment processes and subsequently in the soil environment was carried out from 2001 to 2004. This POSEIDON project (33) showed that up to 80% of the pharmaceuticals and personal care products (PPCP's) are degraded and or removed in wastewater treatment processes. A significant portion of these compounds are concentrated into the bio-solids. However, the study also showed that "During irrigation of wastewater and subsequent soil passage most of the PPCP's (>80%) are sorbed or degraded." (in the insaturated zone of the soil column). It further showed that "during subsurface flow in the saturated zone the PPCP's monitored showed similar behavior with regard to removal from the aqueous phase (during water treatment) e.g. Acidic compounds such as diclofenic, bezafibrate, ibuprophen that are removed easier during wastewater treatment are subject to additional removal during post treatment steps". Several recent publications by Water Environment Federation, Ontario Ministry of Environment and National Association of Clean Water Agencies (34, 35, 36) have indicated that they are currently carefully monitoring the research into the presence, fate and impact of ECoC's on the environment. **They conclude that although present in bio-solids, the current ongoing research by control agencies has not influenced them to change their policy on land application of bio-solids.**

Recent literature reviews of the impact of trace organic contaminants have indicated that the soils to which bio-solids are applied have a big capacity to buffer the toxic effects of organic contaminants. (37) If the bio-solids are applied at appropriate loads specified by environmental regulations then there is little or no risk to the environment. (21)

A WEF literature survey (38) of many of these same micro constituents in sewage confirmed that pharmaceuticals, personal care products, musk's and fragrances as well as fire retardants are present in bio-solids in very small amounts. Water Environment Federation also indicated that as analytical techniques become more sensitive scientific interest and public concern will identify the potential impact of these compounds in great detail. WEF also concluded that although present the environmental and public health risk does not currently warrant a change in bio-solids management practices.

1.21 LEGAL LIABILITY ARISING FROM LAND APPLICATION OF BIO-SOLIDS

In the USA there have been a number of legal actions against municipalities by groups of residents occupying properties adjacent to lands to which bio-solids have been applied. Many of these legal proceedings have been based upon odour problems emanating from the operations. The plaintiffs claim that the odour problems have caused significant life style infringements and have adversely impacted the health of adjacent residents. Where EPA or state regulations and management guidelines have been followed it has been very difficult to establish a direct cause effect relationship between the bio-solids application and claimed ailments. Prior to 2005 the City of Los Angeles applied bio-solids to land in Kern County California. Kern County banned the application of bio-solids within their area of jurisdiction. Los Angeles, Orange County and farmers and contractors in Kern County successfully appealed the land application ban and were successful in having the Kern County ban shut down. A major contribution to the successful removal of this ban which was overriding state and federal regulations and policies with respect to land application of bio-solids was the Water Environment Federation submission to the Kern County court proceedings “The State of the Science of Land Application of Biosolids”. (19)

2.0 Conclusions

Application of Class B bio-solids to land according to the regulations established by the BC Ministry of Environment in the OMRR and the risk assessment based EPA Rule 503 results in minimal risk to public health and environmental damage. The acceptable and low risks pertain to a wide range of organic compounds and metals occurring in municipal waste water, as well as, bacteria and viruses, and their subsequent concentration in the WWTP bio-solids.

Class A bio-solids currently generated in the CRD Saanich Peninsula plant and the proposed Core Area WWTP for CRD are significantly lower metal content and trace organics then Class B bio-solids. Pathogenic bacteria kill achieved for Class A solids is very high and the general bacteria and viruses kill for Class A bio-solid compared to Class B solids is several orders of magnitude higher. Soil amendment products such as PenGrow derived from Class A Bio-solids are very safe for application for landscaping purposes and home gardens by the general public. They present no significant public health threat to groundwater and surface water quality or disease transmission via aerosol dispersion to adjacent property.

There is considerable interest and research directed at organic materials referred to as emerging compounds of concern (ECoC’s) many of which are pharmaceuticals, personal care products and other endocrine disrupter compounds which are present in very small concentrations in bio-solids. At present most jurisdictions are not changing their policy towards land application of Class A or B bio-solids because of the lack of definitive information on the risk of these ECOC’s on the environment or ecology which is currently considered very low.

As it stands, the CRD CALWMC has decided that for the proposed core area plant all of the stabilized bio-solids will be Class A (thermopholic digestion) and used for fuel for thermal destruction processes at industrial and electrical energy facilities. Regardless, there will continue to be a variety of potential beneficial bio-solids land application options e.g. production of a soil amendment, or fertilizer or application to mined out areas for land reclamation.

This literature review shows that there is no scientific evidence indicating that the risks of environmental damage or public health concerns for either Class A or B bio-solids land application would be high. Therefore continued production and use of PenGrow, which is produced from Class A bio-solids, poses little risk to either public health or the environment.

3.0 References

1. Wikipedia

2. Stantec Consulting/Brown and Caldwell Capital Regional District Core Area Wastewater Treatment Program Bio-solids Management Plan 2009

3. USEPA 1992a “Sewage sludge use and disposal rule” (40 CFR Part 503) EPA-882-F-92-002

4. USEPA “Land Application of Sewage Sludge” 40 CFR Part 503 EPA/831-B-93-002b Office of Enforcement and Environmental Compliance Assurance.

5. USEPA 1995(a) “Process Design Manual Land Application of Sewage sludge and domestic septage”. EPA/625/R-95/001 Office of Research and Development US Environmental Practice Agency.

6. USEPA “A Guide for Bio-solids risk assessments for the EPA Part 503 Rule” EPA 832-93-005 Office of Wastewater Management.

7. Sally Brown “Risk Assessment” University of Washington (white paper)

8. Sally Brown “Organic Contaminants in Bio-solids” University of Washington (white paper)

9. Michigan State University Extension “Utilizing Bio-solids on Agricultural Land” Extension Bulletin 2781 (2001)

10. National Research Council “Use of Reclaimed Water and Sewage sludge in Food Crop Production” (1996)

11. National Research Council “Bio-solids Applied to Land: Advancing Standards and Practices” (2002)

12. SR Smith “The Implications for Human Health and the Environment of recycling Bio-solids on Agricultural Land” Centre for Environmental Control and waste management Imperial College

13. N.L. Lang et al ,”Field Investigations on the Survival of Esterichia Coli and presence of Other Enteric Micro-organisms in Bio-solids-amended Agricultural Soil 103 Journal of applied Microbiology 1868, 1878 (2007)

14. Raina M. Mainer et al “Environmental Microbiology” 512-13 (2000)

15. Kathleen J. Zaleski “Potential Regrowth and Recolonization of Salmonella and Indicators in Bio-solids and Bio-solid Amended Soil” 71 Applied Environmental Micro-Biology 3701 (2005)

16. James Sullivan, General Cousel Water Environment Federation Brief of Amicas Curraie Water Environment Federation in Support of Appellees and Affirmance USA Count of Appeals Count of Kern (1994)

17. John P Brooks et al “A National Study on Residential Impact of Biological Aerosols from the Land Application of Bio-solids” 99 J of Applied microbiology 310,318 (2005)

18. John P Brooks et al “The Estimation of Bio-aerosol Risk of Infection to Residences Adjacent to a Land Applied Bio-solids Site Using an Empirically derived Transport Model” 98 J of Applied Microbiology397 (2005)

19. Patricia Ranin et al “Evidence of the Absence of Staphylococcus aureus in Land Applied Bio-solids” 37 Environmental Science Technology 4027.4029 (2003)

20. I Pepper et al “Sustainability of Land Application of Class B Bio-solids” J of Environmental Quality (in Press)

21. Tracy J.B. Yager et al USGS “Scientific Investigation report Effects of Surface Application of Bio-solids on Soil, Crops, Groundwater and Streambed Sediment New Deer Trail Colorado” 1999-2005 (2004)

22. Kathryn J. Dreyer et al Water Environmental Research Foundation “Watershed Effect of Bio-solid Land Application” Literature Review 2-8 (1999)

23. Lewis DL et al “Interaction of Pathogens at Irritant Chemicals in Land Applied Sewage Sludge (bio-solids)” BMC Public Health 2:11 2002

24. Harrison EZ “Investigation of Alleged Health Incidents Associated with Land Application of Sewage Sludges” New Solutions V12 387-408

25. Lewis DL et al “Pathogen Risks from Applying Sewage Sludge to Land” Environmental Science and Technology 36 286A-293A 2002

26. Harrison EZ et al “Land Application of Sewage Sludges: An Appraisal of the US Regulations” Int. T. Environmental Pollution 11:1-36 1999

27. Harrison EZ et al “Case for Caution Revisited Health and Environmental Impacts of Application of Sewage Sludge to Agricultural Land” Cornell Waste Management Institute 2009

28. Northeast Biosolids and Residuals Association “The Science of Bio-solids Recycling” http://www.nebiosolids.org 2011

29.Benoit Lebeau CCME Bio-solids Test Group An Overview Ontario Ministry of Agriculture, Food and Rural Affective OMATRA (2010)

30. California State Water Resources Control Board Statewide Program EIR Covering General Water Discharge Requirements for Bio-solid Land Application (2004)

31. Commonwealth of Virginia House Document No. 27 “Report of the Panel of Experts Convened by the Secretary of Natural Resources and Secretary of Health and Human Resources to Study the Impact of the Land Application of Bio-solids on Human Health and the Environment”

32. BC Ministry of Environment “British Columbia Organic Matter Recycling Regulation” OMRR (2009)

33. Thomas Terres POSEIDON report “Assessment of Technologies for Removal of Pharmaceuticals and Personal Care Products i.e. Sewage and Drinking Water Facilities to Improve the Indirect Potable Water Reuse” 2004

34. Water Environment Federation “Land Application and Composting of Bio-solids” fact sheet May 2010

35. Water Environment Federation National Association of Clean Water Agencies “A Guide to Understanding Bio-solid Issues”

36. Ontario Ministry of Environment “Land Application of Sewage Bio-solids Environmental Protection Science Policy and Nutrient Management Regulation” fact sheet 2009

37. Michael Ovencash et al “Beneficial Reuse and Sustainability: The Fate of Organic Compounds in Land-Applied Waste” 34 J. Environmental Quality 29.30 (2005)

38. Water Environment Federation “Micro constituents in Bio-solids Technical Archive Update” (2007)

39. Joel A. Citulski et al “Fate of Endocrine-Active Compounds during Municipal Bio-solids Treatment: A Review” Env Science and Technology 2010, 44, 8367-8376

40. Hydromantis Inc. “Emerging Substances of Concern in Bio-solids: Concentrations and Effect in Treatment Processes” CCME Project #447-2009 2010