HALIFAX REGIONAL MUNICIPALITY

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Item No. 11.1.2
Halifax Regional Council
October 25, 2011

TO: Mayor Kelly and Members of Halifax Regional Council

Original Signed by

SUBMITTED BY: ____
Mike Labrecque, Acting Chief Administrative Officer

DATE: October 3, 2011

SUBJECT: **Municipal Usage of N Viro Halifax Soil Amendment**

ORIGIN

Regional Council, November 16, 2010.

RECOMMENDATION

It is recommended that Halifax Regional Council continue the use of Halifax Soil Amendment in accordance with the findings of the peer review.

BACKGROUND

On November 16, 2010, following a comprehensive report on the municipal usage of N Viro Halifax Soil Amendment (NVSA), Regional Council requested that Halifax Water contract for an independent review of the biosolids treatment process currently employed by Halifax Water, including a literature review on the subject. Following the Halifax Regional Municipality's (HRM) request, Halifax Water issued a Request for Proposals. That solicitation process resulted in an award to Hydromantis Environmental Software Solutions Inc.

DISCUSSION

Hydromantis Environmental Software Solutions Inc. prepared the review report in Attachment One.

Study Objectives:
The objectives of this study were to:

1. Produce a literature review of available information on biosolids processing including environmental benefits/impacts and health implications;
2. Review the N Viro technology and Halifax Soil Amendment product quality and compare them with other treatment options;
3. Review relevant scientific publications and annotated bibliography;
4. Prepare a compendium of Best Management Practices regarding biosolids beneficial use;
5. Review biosolids regulations from other jurisdictions as well as the "Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia";
6. Address questions from Regional Council and noted websites and reports; and
7. Provide conclusions and recommendations on use of the Halifax Soil Amendment product and/or other potential products.

Study Approach:

- The Project Team conducted an on-site inspection of the N Viro site in April 2011. This included all processing areas of the site, including the biofilter for process odour reduction;
- The Project Team compared long term analytical data;
- The Project Team completed the Regulatory Requirements Review across Canada and the various Provinces and the European Union;
- The Project Team reviewed the N Viro treatment process and alternative treatment processes;
- The Project Team reviewed the web sites and literature requested by Regional Council;
- The Project Team reviewed recent research containing concerns about the usage of Biosolids and Soil Amendment;
- The Project Team reviewed a compendium of Best Management Practices; and
- The Project Team prepared responses to Regional Council.

Study Conclusions:

1. Nova Scotia guidelines for application of Class A biosolids are as restrictive as, or more restrictive than the guidelines and regulations in other Canadian and international jurisdictions;
2. The N-Viro process for biosolids stabilization is accepted by jurisdictions in North America for production of Class A biosolids when operated according to the design intent;
3. An on-site inspection of the Halifax N-Viro technology in late April, 2011, determined that operation was occurring according to the design intent;
4. The cause of the odour incident on Dunbrack Street could not be attributed directly to application of NVSA product. There is reason to believe that the NVSA was blended with source separated organics which may not have been fully composted and cured prior to use;
5. Analytical data for the period between March 2010 and April 2011, indicate that the Halifax NVSA product does not exceed any Class A criteria for metals, pathogens or organics, with the exception of selenium (a few values of 2.5 mg/kg DS compared to the guideline value of 2.0 mg/kg DS). It is suggested that the NVSA is acceptable for use as a Class A material;
6. Based on conclusions No. 4 and 5 above, there is no regulatory basis for continuing the moratorium on application of NVSA product on HRM properties;
7. A technical review of potential alternatives to the N-Viro process currently used by Halifax Water, determined that there was no benefit at this time to replacing the N-Viro process with another, either in terms of biosolids quality, or in the logistics of transporting and treating sludge from Halifax Water's numerous small wastewater treatment facilities;
8. A review of the recent literature identified numerous observations on positive effects of biosolids on microbial activity in soils, and an absence of adverse effects on plant and animal species growing in biosolids-amended soils;
9. Questions submitted to council ranged from seeking factual information to reflecting a negative opinion of beneficial use of biosolids;
10. The NVSA product is most suitable for large, commercial agricultural operations rather than local public giveaway programs, because of the potential presence of free alkali material in the product and the potential for irritation of skin and breathing passages of the public, who might be unaware of the handling risks; and
11. Successful biosolids beneficial use programs are associated with pro-active and dedicated public outreach programs.

Study Recommendations:

1. Halifax Water should continue with the N-Viro technology, and ensure that it meets all design and operational specifications for acceptable product quality;
2. The moratorium on use of NVSA on HRM properties should be lifted based on implementation of the recommendations provided herein;

3. In conjunction with Recommendation No. 2, tests plots should be established on HRM property using NVSA to track potential odour formation or dissipation, pH neutralization rates and effects on vegetative growth, to demonstrate to the public the safety and effectiveness of the NVSA product;
4. The procedure and specifications for blending the NVSA product with other components such as compost or other organics, should be codified, strictly managed and tracked to ensure that only well stabilized materials are included in any blend;
5. Halifax Water should conduct an ongoing review of NVSA quarterly analytical data to better understand the variability of the product quality;
6. Halifax Water should initiate efforts to reduce levels of selenium in the NVSA through monitoring, an aggressive sewer use control program, and public outreach and education programs;
7. Halifax Water and N-Viro should promote Best Management Practices to minimize odour emissions from NVSA land application sites, and to demonstrate sincere and dedicated efforts to ensure public acceptability of this practice;
8. NVSA analysis should continue to include non-required regulatory parameters, such as total neutralizing value and sieve mesh size, TPHC, volatile fraction of total solids and total organic carbon, to characterize the product for potential agricultural applications; and
9. Halifax Water, HRM and N-Viro should establish a more enhanced public outreach program for the N-Viro technology and NVSA product use, including facility tours, demonstration cropping experiments, downtown exhibitions, featured expert guest speakers, and speaking engagements in classrooms and other venues, to obtain buy-in from the public concerning the safety and effectiveness of the NVSA product as a soil amendment material.

The Halifax Water Board provided this report to HRM staff on September 29, 2011. This report has been expedited to Regional Council in order to have the report in the public realm in advance of the UNSM discussion panel on Biosolids scheduled for the first week of November.

BUDGET IMPLICATIONS

The budget implications of accepting the recommendations include:

- Costs required to participate in public outreach programs as described in the reviewed recommendations. It is not yet clear of HRM’s role in this. However, it is anticipated that Halifax Water and N Viro would be seeking participation from the municipality. At this point, staff expects that the cost would not exceed $20,000 per year.
- Costs for the usage of N Viro Soil amendment inclusion in municipal projects, would not be anticipated to cost in excess of $5,000 per year and would be contained within existing Operating and Capital Budgets.

The budget implications of not accepting the recommendations could limit N Viro’s ability to market and sell the product. Should an inability to market the product expand, a change in process, potentially a new technology, and a new approval from Department of Environment would be required. That scenario poses a very large variety and range of scale of financial and legal risks to the municipality.

Any changes in operating and capital costs for Waste Water Services would be factored into future Halifax Water Rate Applications.

FINANCIAL MANAGEMENT POLICIES/BUSINESS PLAN

This report complies with the Municipality's Multi-Year Financial Strategy, the approved Operating, Project and Reserve budgets, policies and procedures regarding withdrawals from the utilization of Project and Operating reserves, as well as any relevant legislation.

COMMUNITY ENGAGEMENT

One of the key recommendations of the report is the adoption of a best practices public outreach program.

ALTERNATIVES

Council could choose to continue the self imposed municipal property moratorium. This is not recommended as there is no scientific basis to make that decision and the cost implications are in the millions of dollars.

ATTACHMENTS

Attachment One: Hydromantis Report

A copy of this report can be obtained online at http://www.halifax.ca/council/agendasc/cagenda.html then choose the appropriate meeting date, or by contacting the Office of the Municipal Clerk at 490-4210, or Fax 490-4208.

Report Prepared by: Richard MacLellan, Manager, Office of Energy and Environment, 490-6056

Financial Approval by: Original Signed
James Cooke, CGA, Director of Finance/CFO, 490-6308

Report Approved by: Phillip Townsend, Director, Planning and Infrastructure, 490-7166

Attachment

Review of Halifax Water's N-Viro Biosolids Treatment Process

Final Report

Prepared for:

Halifax Water

Prepared by:

Hydromantis Environmental Software Solutions, Inc.
Hamilton, ON

In association with:

Webber Environmental
Burlington, ON

and

Stephenson Environmental Services, Ltd.
Port Burwell, ON

August 15, 2011

Hydromantis Environmental Software Solutions, Inc.

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Table of Contents

List of Tables

List of Figures

Abbreviations

AA	Alkaline admixture
ATAD	autothermal thermophilic aerobic digestion
BNQ	Bureau de Normalisation du Québec
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
CFU	colony forming units (measurement for microorganisms)
CKD	cement kiln dust
cP	centipoise, a unit of viscosity
DS	dry solids
dw	dry weight
DEHP	diethylhexyl phthalate (a compound used to keep plastics soft and flexible)
EC	European Community
EPA	Environmental Protection Agency
EQ	exceptional quality (biosolids term)
ESOC	emerging substance of concern (also called micro-constituents, trace contaminant)
GMSC	Greater Moncton Sewerage Commission
HRM	Halifax Regional Municipality
HRT	hydraulic retention time (a measurement used in wastewater treatment)
LONO	Letter of No Objection (from CFIA)
MOE	Ministry of the Environment
MPN	most probable number (measurement for microorganisms)
NAS	National Academy of Sciences (US)
NBP	National Biosolids Partnership
NIOSH	National Institute for Occupational Safety and Health
NVSA	N-Viro soil amendment
O&M	operations and maintenance
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PAHs	Polyaromatic hydrocarbons
PBDEs	polybrominated diphenylethers (flame retardant compounds)
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzodioxins
PCDFs	polychlorinated dibenzofurans
PFRP	Process to further reduce pathogens
SOUR	specific oxygen uptake rate (a measurement used in wastewater treatment)
TNV	total neutralizing value
TEQ	2,3,7,8-tetrachlorodibenzodioxin toxic equivalents
TPAD	temperature-phased anaerobic digestion
TS	total solids
USDA	US Department of Agriculture
VS	volatile solids
WEAO	Water Environment Association of Ontario
WEF	Water Environment Federation
WWTF	wastewater treatment facility

Executive Summary

Background

Municipal wastewater residuals (i.e., sludge) produced by Halifax Water's wastewater treatment facilities are processed by the N-Viro alkaline stabilization process. According to criteria for reduction of pathogens and vector attraction specified by the U.S. Environmental Protection Agency's 40 CFR Part 503 regulations, the processed material is designated as "Class A" biosolids, a pathogen-free material that is acceptable for use in managed land amendment strategies.

An incident in which a material (N-Viro soil amendment product (NVSA) plus soil and compost of unidentified source and quality) was administered by a contractor as a topsoil along Dunbrack Street in Halifax on August 12 and 13, 2010, resulted in a number of odour complaints commencing on August 13. These complaints triggered Halifax Regional Council to place a moratorium on use of the N-Viro Soil Amendment (NVSA) product on Halifax Regional Municipality properties, and to request that Halifax Water conduct an independent third party review of the N-Viro soil amendment (NVSA) process. A number of questions from concerned citizens were to be included in this review.

Objectives

The objectives of this study were to:

- produce a literature review of available information on biosolids processing including environmental benefits/impacts and health implications;
- review the N-Viro technology and NVSA product quality and compare them with other treatment options;
- review relevant scientific publications with annotated bibliography;
- prepare a compendium of Best Management Practices regarding biosolids beneficial use;
- review biosolids regulations from other jurisdictions as well as the "Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia";
- address questions from HRM Council and noted websites and reports;
- provide conclusions and recommendations on use of the NVSA product and/or other potential products.

Review of the Halifax Water N-Viro Technology

An on-site inspection of the N-Viro site by Mr. Monteith of the Project Team was conducted in late April. The review inspection included all processing areas of the site, including the biofilter for process odour reduction. At that time, the finished product storage area had an odour identified as being mild to moderate ammonia-like. This was considered normal given the pH (12 or slightly higher) of the processed biosolids. The operation was considered normal and operating to design intent, with no issues that needed attention.

Long-term analytical data (for a three-year running period) posted on the Halifax N-Viro website are compared to the NS Guidelines for Class A biosolids and allowable soil metal concentrations in **Table ES1**.

Table ES1. Comparison of Regulatory Requirements and Halifax Water NVSA Contaminant Levels

Contaminant (dry solids basis)	Nova Scotia Guideline Category A	CFIA Maximum Concentrations for Fertilizers and Supplements[1]	Allowable Metal Concentrations in Soils		Halifax Water NVSA[2]
			Nova Scotia	CCME	
Arsenic (mg/kg)	13	75	12	15	4.0
Cadmium (mg/kg)	3	20	1.4	4	0.2
Chromium (mg/kg)	210		64	210 (interim)	15.1
Cobalt (mg/kg)	34	150	20	30	1.9
Copper (mg/kg)	400		**63**[5]	150 (interim)	121.5
Lead (mg/kg)	150	500	**60**	100	69.6
Mercury (mg/kg)	0.8	5	0.5	1	0.2
Molybdenum (mg/kg)	5	20	4	4	3.2
Nickel (mg/kg)	62	180	32	36	10.7
Selenium (mg/kg)	2	14	**1.6**	2.8	2.0
Zinc (mg/kg)	700	1850	**200**	370	266.9
Fecal coliform (MPN[3]/g) or	<1000				<10
Salmonella (MPN/g)	<3				Neg. to <3
Viable Helminth ova (# per 4 g)					<1
Total Culturable Enteric Virus (# per 4 g)					<1
PCB (mg/kg)	0.8				<0.5
Dioxin/Furan (ng TEQ[4]/kg)	17				10.5

[1] http://www.inspection.gc.ca/english/plaveg/fereng/tmemo/t-4-93e.shtml

[2] 3-year average data from: http://www.n-viro.ca/bank/pageimages/WebPage%20Test%20Results%20April%202011%20-%20Nova%20Scotia.pdf

[3] most probable number

[4] 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalence

[5] **Bold** value indicates soil limit is lower than found in NVSA

Data indicate that the NVSA exhibits lower metal concentrations than either the Canadian Food Inspection Agency (CFIA) limits for fertilizers and supplements or the more stringent Nova Scotia Guidelines for Class A biosolids (selenium is at the limit for NS Class A biosolids). All NVSA metal concentrations are lower than the CCME soil limits but several exceed the NS soil limits and land application of NVSA would involve care not to exceed those limits. Pathogen and organics concentrations in the NVSA are below the NS Guidelines for Class A biosolids Thus, Halifax NVSA qualifies as a Class A biosolids containing plant nutrients, organic matter and lime all of which contribute to its value as a soil amendment.

Review of Regulatory Requirements for Biosolids in Various Jurisdictions

Canada and Provinces

Environment Canada administers the *Canadian Environmental Protection Act*, 1999, and can establish regulatory and non-regulatory instruments to manage many of the environmental protection risks on federal and aboriginal lands. The Canadian Food Inspection Agency (CFIA) regulates the sale and import of biosolids intended for use as a fertilizer or supplement, and issues a Letter of No Objection (LONO) for sale of products that meet its standards and requirements under the *Fertilizers Act and Regulations*. The provinces manage the maintenance and operation of wastewater treatment and/or composting facilities, and also the processing, use and management of biosolids including land application, through provincial/territorial acts and regulations. There are various standards and information requirements to meet to obtain approvals or permits or licences from the provinces. In addition to the federal and provincial regulations, organizations such as the Canadian Council of Ministers of the Environment (CCME) and the Bureau Normalisation du Québec (BNQ) develop standards and guidelines that jurisdictions can reference when developing policy or reviewing requirements related to biosolids.

The parameters used to assess the quality of biosolids in federal and provincial regulations/guidelines include: metals, pathogens and pathogen indicators, and organic chemical contaminants and odour. But it is challenging to relate and compare the classes of biosolids and their qualities among the provinces, because they use different classification/categorization schemes and adopt different nomenclature for the various classes. For example, most provinces define one or two classes of biosolids; whereas, Quebec and Ontario define several classes based on combinations of metal, pathogen and odour properties. Despite some differences, the regulations/guidelines for Canadian jurisdictions have much in common.

Some jurisdictions including Nova Scotia define two classes of biosolids based on metal limits: (1) - high quality biosolids that may be land applied without metal and pathogen restrictions and (2) lower quality biosolids for metal and pathogen restricted land application. The Nova Scotia soil metal limits are consistent with other jurisdictions for which no metal contamination of soils or crops have been reported following repeated biosolids applications.

Disease transfer to humans and animals is a major concern related to land application of biosolids and Canadian jurisdictions have either defined biosolids stabilization requirements for land application (e.g., QC, ON, BC) and/or have adopted part or all of the US EPA (1993) pathogen standards for Classes A and B biosolids. Despite an occasional claim to the contrary, there are no documented cases of sickness resulting from land application of either Class A or B biosolids in Canada during the approximately 35 years that this practice has been regulated.

To date there is no compelling evidence of the need for organic contaminant limits in land applied biosolids and most Canadian jurisdictions have not defined limits. Dioxins are a particular concern because of the highly poisonous nature of some congeners (e.g., 2,3,7,8-tetrachloro dibenzo-p-dioxin); however, following detailed risk analysis the US EPA (2003) concluded that there is no need for a dioxin limit for land applied biosolids. The Nova Scotia and Quebec limits of 17 and 50 ng TEQ/kg (parts per trillion) of dioxins and furans for high and lower quality biosolids are conservative and in the light of current scientific evidence, they are not necessary.

There is growing recognition that odour is an extremely important factor related to land application of biosolids. Frequently it is the factor that attracts public attention and elicits a negative reaction to biosolids application. Most Canadian jurisdictions, including Nova Scotia have not accounted for odour in land application regulations/guidelines. However, Quebec and Ontario have defined three odour categories for biosolids and require increasing separation distances from residences, schools, etc. and/or special application requirements related to increasing odour.

European Union

The recycling of sewage sludge in agriculture in EC countries has been regulated by Directive 86/278/EEC since 1986. The Directive was set up to encourage and regulate sludge use to prevent harmful effects on soil, vegetation, animals and man. The potential for metal accumulation in soil is addressed, and limit values are set for sludge and sludge-treated soil. In addition, the Directive specifies general land use, harvesting, and grazing restrictions, to provide protection against health risks from residual pathogens. It allows untreated sludge to be used on agricultural land if it is injected or worked into the soil. Otherwise sludge needs to be treated to significantly reduce its fermentability and pathogen content prior to use in agriculture. Development of guidelines, codes of practice and statutory controls has been an ongoing process at national levels since the 1986 Directive was implemented and most countries have adopted more stringent limits and management practices than were originally specified by the Directive. In addition, standards for parameters not included in the Directive (e.g., pathogens and organics) are included in some national regulations.

Regulatory Conclusion

The detailed review herein indicates that the "Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia" (revised March 2010) are among the most conservative of the Canadian and International regulations/guidelines for land application of sewage biosolids and particularly for metals, they are much more conservative than the US EPA (1993) Part 503 regulations.

Review of Alternative Biosolids Treatment Processes

The objectives of biosolids treatment processes are stabilisation of organic matter, odour reduction, volume reduction, pathogen inactivation, and reduction in vector attraction. Processes are often referred to as Class A or Class B based on designations originally prescribed by the U.S. EPA in the U.S. Federal Register Part 503 Biosolids regulations. These designations are based primarily on reduction of pathogenic organisms during treatment of wastewater sludges to produce biosolids. Class A biosolids are those of "exceptional quality" that have been subjected to rigorous levels of treatment. Because of the high level of treatment, there are few restrictions on the use of Class A biosolids. The pathogen and metal concentration requirements for producing Class B biosolids are less stringent than those for Class A and the potential uses are more restricted.

In essence, the Class A biosolids processing technologies that have been used widely include:

- Autothermal Thermophilic Aerobic Digestion (ATAD)
- Thermal drying
- Alkaline Stabilization and Drying (includes N-Viro and other providers)
- Composting

These Class A processes are discussed in detail in the body of the report. Each process is examined separately, with discussions of the advantages and disadvantages of each, and the applicability as an alternative for treating Halifax Water's biosolids.

In addition, some other processes are identified that while not officially cast as Class A processes, might none-the-less achieve Class A quality. These include thermophilic anaerobic digestion, temperature-phased anaerobic digestion, solar drying, and the Lystek process (another form of alkaline treatment). Lastly, the plasma arc technology is assessed briefly, but there is little operating information on this process.

Review of Web Sites and Documents

Within the Terms of Reference for this study was a specific request to review certain documents and websites identified by Halifax Regional Council. While there was no direction as to what was expected of this review, the Project Team examined the requested documents and web sites and formulated responses based on their collective expertise. In total, eight websites or documents were reviewed, ranging from technology (plasma arc), to articles in the Halifax Chronicle Herald and Toronto Star, to submissions to HRM Council.

The responses are too long to include in this Executive Summary, and readers are referred to the Chapter in the main report for the full reviews.

Responses to Questions from HRM Council

Specific questions of a technical nature were documented in the Terms of Reference, and are responded to by the Project Team. The technical questions were a subset of a larger list which also included questions on HRM policy and procedures. Questions regarding policy and procedure were not addressed in this report and are to be addressed by HRM staff separately.

In general, the questions appear to fall into two classes, those for which information is being sought to fill in knowledge gaps, and those which appear to reflect a negative view of biosolids application. In total, responses were provided for 23 questions. The responses to these questions are too long to include in this Executive Summary, and readers are referred to the Chapter in the main report for the full responses.

Review of Recent Research Addressing Concerns about Biosolids and Soil Amendment

The report updates recent information on a variety of topics related to contaminants in biosolids, and biosolids management issues including:

- Metals,
- Pathogens,
- Emerging Substances of Concern (ESOC),
- Odours,
- Drivers of Biosolids Management,
- Public Perceptions and Communication,

Metal concentrations in biosolids have declined over the past two decades due to more stringent sewer use control programs and changes in manufacturing processes. While organic contaminants such as pharmaceuticals and personal care products are found at low concentrations in biosolids, recent toxicity testing suggests that they have no adverse affect on the plants and animals growing on biosolids-amended soils, compared to control (untreated) soils. Studies suggest that microbial activity in soils is enhanced by the addition of biosolids. Readers are referred to the Chapter in the main report for a more detailed review of this recent information.

Best Management Practices for Biosolids

A compendium of best management practices for biosolids was compiled from several sources. The BMPs provided in a document produced by the Federation of Canadian Municipalities served as the basis, with other contributions from U.S. states that dealt primarily with transport and odour minimization strategies.

Conclusions

1. Nova Scotia guidelines for application of Class A biosolids are as restrictive as, or more restrictive than the guidelines and regulations in other Canadian and international jurisdictions.

2. The N-Viro process for biosolids stabilization is accepted by jurisdictions in North America for production of Class A biosolids when operated according to the design intent.

3. An on-site inspection of the Halifax N-Viro technology in late April, 2011 determined that operation was occurring according to the design intent.

4. The cause of the odour incident on Dunbrack Street could not be attributed directly to application of NVSA product. There is reason to believe that the NVSA was blended with source separated organics which may not have been fully composted and cured prior to use.

5. Analytical data for the period between March 2010 and April 2011 indicate that the Halifax NVSA product does not exceed any Class A criteria for metals, pathogens or organics, with the exception of selenium (a few values of 2.5 mg/kg DS compared to the guideline value of 2.0 mg/kg DS). It is suggested that the NVSA is acceptable for use as a Class A material.

6. Based on conclusions #4 and #5 above, there is no regulatory basis for continuing the moratorium on application of NVSA product on HRM properties.

7. A technical review of potential alternatives to the N-Viro process currently used by Halifax Water determined that there was no benefit at this time to replacing the N-Viro process with another, either in terms of biosolids quality, or in the logistics of transporting and treating sludge from Halifax Water's numerous small wastewater treatment facilities.

8. A review of the recent literature identified numerous observations on positive effects of biosolids on microbial activity in soils, and an absence of adverse effects on plant and animal species growing in biosolids-amended soils.

9. Questions submitted to council ranged from seeking factual information to reflecting a negative opinion of beneficial use of biosolids.

10. The NVSA product is most suitable for large, commercial agricultural operations rather than local public give-away programs because of the potential presence of free alkali material in the product, and the potential for irritation of skin and breathing passages of the public, who might be unaware of the handling risks.

11. Successful biosolids beneficial use programs are associated with pro-active and dedicated public outreach programs.

Recommendations

Based on the foregoing conclusions, the following recommendations are proposed:

1. Halifax Water should continue with the N-Viro technology, and ensure that it meets all design and operational specifications for acceptable product quality.

2. The moratorium on use of NVSA on HRM properties should be lifted based on implementation of the recommendations provided herein.

3. In conjunction with Recommendation #2, tests plots should be established on HRM property using NVSA to track potential odour formation or dissipation, pH neutralization rates and effects on vegetative growth to demonstrate to the public the safety and effectiveness of the NVSA product.

4. The procedure and specifications for blending the NVSA product with other components such as compost or other organics should be codified, strictly managed and tracked to ensure that only well stabilized materials are included in any blend.

5. Halifax Water should conduct an ongoing review of NVSA quarterly analytical data to better understand the variability of the product quality.

6. Halifax Water should initiate efforts to reduce levels of selenium in the NVSA through monitoring, an aggressive sewer use control program, and public outreach and education programs.

7. Halifax Water and N-Viro should promote Best Management Practices to minimize odour emissions from NVSA land application sites, and to demonstrate sincere and dedicated efforts to ensure public acceptability of this practice.

8. NVSA analysis should continue to include non-required regulatory parameters, such as total neutralizing value and sieve mesh size, TPHC, volatile fraction of total solids and total organic carbon to characterize the product for potential agricultural applications.

9. Halifax Water, HRM and N-Viro should establish a more enhanced public outreach program for the N-Viro technology and NVSA product use, including facility tours, demonstration cropping experiments, downtown exhibitions, featured expert guest speakers, and speaking engagements in classrooms and other venues to obtain buy-in from the public concerning the safety and effectiveness of the NVSA product as a soil amendment material.

1. Introduction

1.1 Background

Municipal wastewater residuals (i.e., sludge) produced by Halifax Water's wastewater treatment facilities are treated by the N-Viro alkaline stabilization process. Co-mixture of the wastewater sludge with an alkaline material such as fly ash raises the mixture pH and temperature by exothermic reaction of the ash with the water contained in the sludge. These factors, in combination with a high ammonia concentration produced in the reaction, result in inactivation of pathogenic and other organisms in the mixture. According to criteria for reduction of pathogens and vector attraction specified by the U.S. Environmental Protection Agency's 40 CFR Part 503 regulations, the processed material is designated as "Class A' biosolids, a pathogen-free material that is acceptable for use in managed land amendment strategies.

An incident in which a material (N-Viro soil amendment product (NVSA) plus soil and compost of unidentified source and quality) was administered by a contractor as a topsoil along Dunbrack Street in Halifax on August 12 and 13, 2010, resulted in a number of odour complaints commencing on August 13. These complaints triggered Halifax Regional Council to place a moratorium on use of the N-Viro Soil Amendment (NVSA) product on Halifax Regional Municipality properties, and to request that Halifax Water conduct an independent third party review of the N-Viro soil amendment (NVSA) process. A number of additional questions from concerned citizens were included in this review.

1.2 Objectives

The objectives of this study were to:

- produce a literature review of available information on biosolids processing including environmental benefits/impacts and health implications;
- review the N-Viro technology and NVSA product quality and compare them with other treatment options;
- review relevant scientific publications and provide an annotated bibliography;
- prepare a compendium of Best Management Practices regarding biosolids beneficial use;
- review biosolids regulations from other jurisdictions as well as the "Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia";
- address questions from HRM Council and noted websites and reports;
- provide conclusions and recommendations on use of the NVSA product and/or other potential products.

2. Description of the N-Viro Process

2.1 Technology Background

Alkaline stabilization is a reliable and well-established method for stabilizing biosolids. In the process, an alkaline material such as lime is added to biosolids to raise the pH to greater than 12.0 standard units to destroy pathogens. Lime as either hydrated lime ($Ca(OH)_2$; known as calcium hydroxide or slaked lime) or quicklime (CaO) is the most common alkaline treatment compound. Other alkaline compounds that have been used include cement kiln dust, lime kiln dust, Portland cement or fly ash (WEF, 1995). The proper and thorough mixing of biosolids and the alkaline compound has been considered as crucial in the development of a superior biosolids product.

When lime is used, it may be added in either liquid or dry form. For dry lime alkaline stabilization, biosolids are dewatered prior to mixing with the lime. This mixture is then typically dried and cured, resulting in a product with a soil-like consistency (WEF, 1995). In liquid form, a lime slurry may be added to stabilize and thicken the biosolids prior to land application (e.g. by subsurface injection). Alternatively, lime slurry may be added to stabilize and condition the biosolids prior to dewatering, in which case, other conditioners such as aluminum or iron salts would typically be added to enhance dewatering.

When quicklime (CaO) is used, it reacts with water in an exothermic reaction that can achieve temperatures in excess of 700^{o}C. This not only pasteurizes the biosolids but can convert it into a soil-like material. Additional heat needed to dry the treated biosolids may be supplied in a vessel such as a drum or rotary dryer. Moisture reduction may be achieved by air drying in windrows. If heat drying is applied, the final product may have a solids content of 50% to 60% or greater (WEF, 1995).

Advanced alkaline stabilization methods involve the use of chemicals in addition to lime, high chemical addition rates and supplemental drying and are designed to increase the stability of the product, decrease the odour potential and further reduce pathogens. One such method involves the addition of "possolanic" materials, which are enriched in silica-based compounds (such as fly ash, cement kiln dust or pumice), which react with calcium hydroxide at normal temperatures to form compounds that have cement-like properties.

2.2 Advantages and Disadvantages of Alkaline Stabilization

The advantages and disadvantages of alkaline stabilization are presented in **Table 1**.

Table 1. Advantages and Disadvantages - Alkaline Stabilization

Advantages	Disadvantages
The process is well understood and treatment can consistently meet treatability requirements.	The metals content of biosolids may prevent the alkaline stabilization product from being classified as a fertilizer.
There is local expertise in operating alkaline stabilization facilities.	The revenue generated from the sale of a biosolids product is small relative to the cost of producing the product.
Alkaline stabilization significantly reduces or eliminates the level of pathogens.	Alkaline stabilization ties up readily available phosphorus
The product is generally most beneficial for acidic soil conditions, such as generally found in Nova Scotia	
Since the product has been treated beyond normal levels, there may be increased acceptance of land application.	

3. Review of the Halifax N-Viro Process

3.1 Sources of Sludge/Biosolids for the N-Viro Process

Several smaller wastewater treatment facilities (WWTFs) contribute to the total biosolids managed by Halifax Water, together with the larger facilities (**Table 2**).

Table 2. Wastewater Treatment Facility Sludge Contributors to the Halifax N-Viro Facility

Location and Treatment Process		
Aerobically Digested -Fall River -North Preston -Twin Oaks	**Settle & Decant** -Springfield Lake	**RBC Sludge** -Middle Musquodoboit
Primary Sludge -Uplands Park	**No Stabilization** -Frame Subdivision -Wellington (Steeves) -Belmont Subdivision -Weirfield -Harrietsfield	**Anaerobic Digestion** -Mill Cove -Timberlea - Eastern Passage
Primary Treatment & Dewatering -Dartmouth -Halifax -Herring Cove	**SBR & Dewatering** -AeroTech	

Table 2 shows that the Halifax N-Viro facility receives a mixture of unstabilized and stabilized sludges. The largest WWTFs in Dartmouth, Halifax and Herring Cove have dewatering at the plant on-site, while the balance haul, stabilized or unstabilized, liquid sludge for dewatering at AeroTech Park.

The aerobic and anaerobically stabilized sludges could be considered as "Class B" biosolids and could potentially be used without further processing in some restricted applications. However, processing is required for the unstabilized sludges, and the existing N-Viro System converts all of the sludges to Class A biosolids.

3.2 Process Operation

Mixer: The biosolids in the receiving area (**Figure 1**) are conveyed to a mixing bin (**Figure 2**) where the alkaline admixture (AA) is added. Typically, 30% - 40% AA is added on a biosolids wet weight basis. The AA consists of industrial by-products such as cement kiln dust, lime-kiln dust, and/or fly ash, held in exterior storage tanks (**Figure 3**). The amount of the AA varies according to the amount of heat needed for processing, the type of biosolids (the higher the solids content the lower the AA dosage), the characteristics of the AA, and the intended beneficial reuse market(s) or end uses. If the admixture does not contain enough free lime (CaO, $Ca(OH)_2$ or other strong alkali) to provide the necessary temperature and pH rise, CaO (quicklime) is added. The addition of alkaline materials begins the process of pathogen destruction by creating a hostile environment for living organisms.

Figure 1 Dewatered Biosolids Received at the Halifax N-Viro Site

Figure 2. Biosolids Conveyed to Admix Reactor

Dryer: The discharge from the mixer travels by conveyor directly into the mechanical rotary-drum (see **Figure** 4) where it is dried to 60% - 65% solids content (**Figure 5**). A combination of heat from the dryer and further chemical reaction between the alkaline materials and the biosolids maintains the temperature within a controlled range of $52^{o}C – 62^{o}C$, and the pH slightly greater than 12. As in the mixing stage, this combination of heat and high pH in this step is important in the destruction of harmful pathogens. The material discharged from the dryer proceeds to a "heat-pulse cell" where the material is cured for twelve hours. The heat-pulse cell contributes to stabilization of the product and pathogen kill.

Figure 3. Lime and Cement Kiln Dust Storage

Figure 4. Biosolids after Admixture to Dryer

Figure 5. Dryer for Biosolids-CKD Mixture

Storage: Once the NVSA material has cured in the heat-pulse cell, it is stable and can be stored safely. It is then transferred with a front-end loader and/or stacking conveyors to a covered facility for storage and distribution to users. As it continues to cure while in storage, odours are generated (release of nitrogen, sulfur, etc.) and subsequently treated in accordance with the certificate of approval for air issued to the N-Viro facility.

Air Treatment: The dryer and the dryer cyclone separator are completely enclosed. Air from the dryer flows through the cyclone and is conveyed to a dust removal unit called a baghouse system. The baghouse system is efficient in the removal of airborne particulates in the dryer exhaust. The dust can be recycled by conveyor back to the process to prevent waste.
Once particulates are removed from the air, further scrubbing involving reagents and biofilters is done to remove ammonia and other odours (**Figure 6**).

Figure 6. Surface of Biofilter for Process Air Treatment

3.3 Review of N-Viro Process Data

3.3.1 Long-Term NVSA Product Quality

The Province of Nova Scotia has guidelines for required quality of both Class A and Class B biosolids. Processed biosolids sold as fertilizer/soil amendment products is governed federally according to Canadian Food Inspection Agency Trade Memorandum "T-4-93 - Standards for Metals in Fertilizers and Supplements". Concentrations of metals in the NVSA product (long-term data obtained from the N-Viro website) are compared to Provincial Class A requirements and Canadian Food Inspection Agency limits for metals in fertilizers in **Table 3**. The concentration data indicate that the NVSA is lower in concentration than either the Canadian Food Inspection Agency (CFIA) limits or the more stringent Nova Scotia Guidelines for Class A biosolids (selenium is at the limit for NS Class A biosolids).

Table 3. Regulatory Requirements and Halifax Water NVSA Contaminant Levels

Contaminant (dry solids basis)	Nova Scotia Guideline Category A	CFIA Maximum Concentrations for Fertilizers and Supplements[1]	Allowable Metal Concentrations in Soils		Halifax Water NVSA[2]
			Nova Scotia	CCME	
Arsenic (mg/kg)	13	75	12	15	4.0
Cadmium (mg/kg)	3	20	1.4	4	0.2
Chromium (mg/kg)	210		64	210 (interim)	15.1
Cobalt (mg/kg)	34	150	20	30	1.9
Copper (mg/kg)	400		**63**[5]	150 (interim)	121.5
Lead (mg/kg)	150	500	**60**	100	69.6
Mercury (mg/kg)	0.8	5	0.5	1	0.2
Molybdenum (mg/kg)	5	20	4	4	3.2
Nickel (mg/kg)	62	180	32	36	10.7
Selenium (mg/kg)	2	14	**1.6**	2.8	2.0
Zinc (mg/kg)	700	1850	**200**	370	266.9
Fecal coliform (MPN[3]/g) or	<1000				<10
Salmonella (MPN/g)	<3				Neg. to <3
Viable Helminth ova (# per 4 g)					<1
Total Culturable Enteric Virus (# per 4 g)					<1
PCB (mg/kg)	0.8				<0.5
Dioxin/Furan (ng TEQ[4]/kg)	17				10.5

[1] http://www.inspection.gc.ca/english/plaveg/fereng/tmemo/t-4-93e.shtml

[2] 3-year average data from: http://www.n-viro.ca/bank/pageimages/WebPage%20Test%20Results%20April%202011%20-%20Nova%20Scotia.pdf

[3] most probable number

[4] 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalence

[5] **Bold** value indicates soil limit is lower than found in NVSA

Allowable concentrations of metals in soils from the Canadian Council of Ministers of the Environment (CCME) and the Nova Scotia Guidelines for Biosolids are summarized in **Table 3**. The NVSA concentrations are lower than the CCME soil guidelines but copper, lead, selenium and zinc are higher than the NS maximum allowable soil concentrations. Thus, potential application sites would require soil metal analysis, and soils with concentrations of these four metals exceeding the maximum allowable concentrations could not accept the NVSA.

Pathogens and organics in the NVSA are below the NS Guidelines for Class A biosolids.

3.3.2 Inspection of N-VIRO Site

An on-site inspection of the N-Viro site by Mr. Monteith of the Project Team was conducted in late April, 2011. The review inspection included all processing areas of the site, including the biofilter for process odour reduction. At that time, the finished product storage area had an odour identified as being mild to moderate ammonia-like. This was considered normal given the pH (12 or slightly higher) of the processed biosolids. The operation was considered normal, with no evident issues that needed attention.

3.3.3 Evaluation of Quarterly Analytical Data for NVSA Product

Samples of the NVSA are submitted for routine analysis with each 1000 tonnes of product (Sutherland, 2011). The submitted sample is a composite of daily grab samples extracted from the heat pulse cell of the process, collected on the day following its production. When the production quota of 1000 tonnes has been reached, the daily composites are mixed to create the composite sample which is then submitted for analyses. The sampling procedure is conducted according to the Canadian Food Inspection Agency's (CFIA) procedure P-4-114 (LeBlanc, 2011).

Summaries of analytical data for the NVSA product for the period January 2010 to April 2011 were combined into one table for comparison with NS requirements for Class A Biosolids. The data are the results of samples submitted quarterly. The sample submissions bracket the Dunbrack Street odour episode. **Table 4** provides the data summary.

With the exception of selenium, all metals fall within NS Provincial Concentration Limits for Class A biosolids. The concentration limit for selenium is 2.0, while 3 of the 6 samples showed marginal exceedances, falling in the range 2.5-2.6 µg/g dry solids (same as mg/kg DS). Selenium may originate in personal care products such as dandruff shampoos, or from industrial inputs to municipal sewers. Active source control measures such as vigilant sewer use bylaw enforcement and public education are recommended to try to reduce the concentration of selenium in the NVSA.

Pathogen (fecal coliforms and *Salmonella*) concentrations in all the NVSA samples were below the required limits for Class A biosolids. The recorded odour descriptions ranged from no odour to mild amine and mild ammonia, as would be expected from this process due to the addition of the alkaline agent.

Table 4. Analysis (dry solids basis) of Quarterly NVSA Product Samples, January, 2010 – April, 2011

Parameter	units	Jan 12, 2010	Mar 14, 2010	Jul 13, 2010	Dunbrack St Incident	Oct 14, 2010	Feb. 14, 2011	Apr 12, 2011[a]	Guideline
Aluminum	mg/kg DS	16900	17420	13000		15100	13400		
Arsenic	mg/kg DS	4.5	3.4	4		2.2	2.2	3.1	13
Boron	mg/kg DS	20.6	20.8	15.1		29.9	4.8		
Calcium	mg/kg DS	224000	195000	245000		244000	224000		
Cadmium	mg/kg DS	<1	1.25	<1		<1	<1	<1	3
Chromium	mg/kg DS	14.7	14.1	11.9		13.2	12.4	18.6	210
Cobalt	mg/kg DS	2.55	2.4	1.8		2.2	<1	1.4	34
Copper	mg/kg DS	139	121	122		89	110	130	400
Iron	mg/kg DS	8300	7490	6880		7910	4720		
Lead	mg/kg DS	95.5	65.4	112		99.6	19.1	63.7	150
Magnesium	mg/kg DS	4280	4010	4050		5050	1580		
Manganese	mg/kg DS	482	287	386		282	279		
Mercury	mg/kg DS	0.16	0.12	0.11		<0.1	0.21	0.17	0.8
Molybdenum	mg/kg DS	3.35	2.3	2.65		3.5	2.2	3.4	5
Nickel	mg/kg DS	11.8	10.5	9.05		10.4	6.85	13.7	62
Phosphorus	mg/kg DS	6730	6830	6030		4100	7550		
Potassium	mg/kg DS	9170	12900	16320		15780	2100		
Selenium	mg/kg DS	2.6	2	2.5		2.5	1	1.1	2
Sodium	mg/kg DS	1030	940	1430		1470	1220		
Sulphur	mg/kg DS	11970	12070	12640		15910	2790		
Thallium	mg/kg DS	<1	<1	<1		<1	<1	<1	
Zinc	mg/kg DS	304	230	233		231	197	257	700
Total Nitrogen	%	0.96	1.15	0.94		0.95	1.32	1.61	
Total Phosphorus (as P_2O_5)	%	1.54	1.56	1.38		0.94	1.73	1.68	
Total Potassium (as K_2O)	%	1.1	1.55	1.97		1.91	0.25	1.23	
Total Organic Carbon	%	12.8	19.3	15		13.3	21.04	no data	
pH	std units	7.37	10.2	8.69		12.3	10.5	11.05	
Total Neutralizing Value	%	48.5	42.2	65.7		54.0	55.3	no data	

Continued

Table 4. cont'd

Parameter	**units**	**Jan 12, 2010**	**Mar 14, 2010**	**Jul 13, 2010**		**Oct 14, 2010**	**Feb. 14, 2011**	**Apr 12, 2011[a]**	**Guideline**
Sieve # 10 mesh	% pass	99.5	99.9	99.7		100	91.4	no data	
Sieve #100 mesh	% pass	92.2	88.2	93.4		94.0	70.0	no data	
Total Solids	%	83.9	62.9	80.3		68.9	58.4	54.6	
Volatile fraction of TS	%	23	34.8	27		23.9	37.9	no data	
Odour		no odour	mild amine	mild		mild ammonia	mild	no data	
Fecal Coliforms	MPN/g	<3	<3	<3		<3	<3	<3	<1000
Salmonella	MPN/4g	<3	<3	<3		<3	<3	<3	<3
THPC	cfu/g	3.2 x 10^7	150000	4.2 x 10^9		450	191000	no data	

[a] The dataset from April 12 had a reduced number of parameters requested for analysis

In addition to small concentrations of micronutrients (e.g., copper, manganese, molybdenum, zinc) the NVSA contains major nutrients including calcium (>20%), magnesium (~0.5%), nitrogen (~1%), P_2O_5 (~1.5%) and K_2O (~1.5%). It also contains ~15% organic carbon (i.e., ~25% organic matter) and ~50% total neutralizing value ($CaCO_3$ equivalency) and since ~90% of it passes the #100 mesh screen, the NVSA would react quickly in contact with soil and be effective as a soil liming material. The pH of the NVSA exhibited considerable variability from 7.4 to 12.3 which may have been related to sample collection procedures, handling and preparation prior to analysis since it shows no relation to the total neutralizing value (i.e., the amount of alkali addition for processing).

As the NVSA product cools and the pH of the material declines due to carbonate formation, the NVSA product becomes more hospitable for supporting growth of microorganisms, as illustrated by the values of the total heterotrophic plate count (THPC) test. Heterotrophic microorganisms are those that require organic carbon for growth, and include bacteria, yeasts and moulds. The THPC test is a simple culture-based test intended to recover a wide range of microorganisms from water. The test itself does not specify the organisms that are detected. The actual organisms recovered in THPC testing can vary widely between locations, between seasons and between consecutive samples at a single location (WHO, NSF and IWA, 2003).

The detection of microbes by the THPC test is not indicative of the presence of pathogens, but, that NVSA is capable of supporting microbial activity. The N-Viro process operates at a lower temperature than thermal drying units, and so complete sterilization of the product does not occur (LeBlanc, 2011). In NVSA product applied to land, the heterotrophic bacteria are not problematic, but contribute to the total soil microbe population, which in a typical soil ranges from 10^4 to 10^7 CFU (colony-forming units)/gram of soil (U.S. EPA, 1994).

3.4 Summary of N-Viro Process Review

All metal concentrations are lower than the maximum allowable concentrations for NS Class A biosolids, with the exception of selenium, observed on occasion in the 2.5-2.6 mg/kg DS range, compared to the limit of 2.0 mg/kg DS. None of the pathogen concentration data (fecal coliforms and *Salmonella*) exceeded the required limit. As such the NVSA appears acceptable for use as Class A biosolids.

Based on the data reviewed, there is no apparent threat to public health from the metals, pathogens or organic contaminants contained in the NVSA. Concentrations of regulated metals and pathogens comply with Class A biosolids limits, with the exception of minor exceedances of selenium. Moreover, there is no evidence to support the contention that the offensive odour incident on Dunbrack Street was caused by the NVSA alone. As a result, there appears to be no evidence justifying a continued moratorium of the use of the NVSA on HRM properties. At the same time however, we recommend the use of test plots on HRM properties to better understand the behaviour and fate of the NVSA, including potential for odour production and decline in pH.

Halifax NVSA is a Class A biosolids with no pathogens and acceptable low concentrations of metal contaminants. It contains several plant nutrients including nitrogen, phosphorous and potassium, in addition to organic matter and considerable lime all of which contribute to its value as a high quality soil amendment material. It is recommended that Halifax Water undertake a public relations program involving stakeholder identification, information dissemination and demonstration experiments to obtain buy-in from the public concerning the safety and effectiveness of the NVSA product as a soil amendment material. However, due to the irritant nature of material with pH above 8, NVSA should be handled by professionals and should not be made available for use by the general public.

4. Review of Provincial and Other Jurisdictions regarding Land Application of Biosolids

The following reviews the "Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia" in relation to other Canadian and international regulatory instruments for sewage biosolids.

4.1 Canadian Regulations/Guidelines for Land Application of Biosolids

4.1.1 Delegation of Authority for Biosolids in Canada

A review of the federal and provincial regulatory framework for biosolids in Canada completed for the Biosolids Task Group (BTG) of the Canadian Council of Ministers of the Environment (CCME, 2010) (http://www.ccme.ca/assets/pdf/pn_1446_biosolids_leg_review_eng.pdf) summarizes the rather complex framework as follows:

The various steps in biosolids management including production, treatment, sale and end use/disposal are regulated under a multi-faceted regulatory system, involving federal and provincial/territorial legislation of Canada. At the national level, Environment Canada administers the *Canadian Environmental Protection Act*, 1999, and can establish regulatory and non-regulatory instruments to manage many, but not all, of the environmental protection risks on federal and aboriginal lands that would otherwise be addressed by provincial and territorial legislation. The Canadian Food Inspection Agency (CFIA) regulates the sale and import of biosolids intended for use as a fertilizer or supplement, and issues a Letter of No Objection (LONO) for sale of products that meet its standards and requirements under the *Fertilizers Act and Regulations*. Issuance of a LONO does not exempt a product from marketplace monitoring and compliance activities undertaken by the CFIA.

The provinces regulate the maintenance and operation of wastewater treatment and/or composting facilities, and also the processing, use and disposal of biosolids including land application, through the provincial/territorial acts and regulations. There are various standards and information requirements that are to be met for obtaining approvals or permits or licences from the provinces. Most provinces have some form of guidance document(s) which outline(s) information requirements for approval/permit/license.

In addition to the federal and provincial regulations, organizations such as the Canadian Council of Ministers of the Environment (CCME) and the Bureau Normalisation du Québec (BNQ) develop standards and guidelines that jurisdictions can reference when developing policy or reviewing requirements related to biosolids.

The multi-faceted regulatory framework for sewage biosolids management in Canada is summarized in **Table A1** of Appendix A, which indicates that Provincial/Territorial management of biosolids falls within the mandate of some form of Environmental Protection Act and

Environment Ministry. In Nova Scotia the Environment Act, S.N.S. 1994-95 designates land application as the only biosolids management option subject to Nova Scotia Environment, Designation Regulations (O.I.C. 95-286). The requirements for approval, authorization, and/or permission at various stages of biosolids production, use and disposal in Canadian jurisdictions are presented in **Table A2** and specific reference to Canadian guidance and other policy documents for regulation of biosolids is included in **Table A3**.

4.1.2 Regulated Parameters in Biosolids

The parameters used to assess the quality of biosolids in federal and provincial regulations/guidelines include; metals, pathogens and pathogen indicators and organic chemical contaminants and odour. But it is challenging to relate and compare the classes of biosolids and their qualities among the provinces, because they use different classification/categorization schemes and adopt different nomenclature for the various classes. For example, most provinces define one or two classes of biosolids, whereas Quebec and Ontario define several classes based on combinations of metal, pathogen and odour properties. Despite differences however, the regulations/guidelines for Canadian jurisdictions have much in common as evidenced by the following information.

Metals

There is general agreement among jurisdictions that the following metals; cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), zinc (Zn), arsenic (As), selenium (Se), molybdenum ("Mb" in Table **A4-A** is incorrect and should be "Mo") and cobalt (Co) in biosolids need to be regulated for land application (**Table A4-A**). Metals are limited in all jurisdictions and in most the limits are equal to or less than the CFIA limits for sale of product. However, some jurisdictions including Nova Scotia define two classes of biosolids based on metal limits: (1) high quality biosolids with very low metal concentrations that may be land applied without a metal loading restriction, and (2) lower quality biosolids with higher metal concentrations for restricted land application. The metal concentrations in Nova Scotia's lower quality biosolids equal the CFIA limits for which no metal contamination problem has been reported since their adoption in the mid-1970s.

In addition to biosolids metal limits, most jurisdictions have defined soil metal limits for land application (**Table A4-B**). The Nova Scotia soil metal limits are consistent with other jurisdictions for which no metal contamination of soils or crops has been reported following repeated biosolids applications (OMAFRA, 1995; Webber and Sidhwa, 2007; Pepper *et al.*, 2008a).

Nutrients

Most jurisdictions including Nova Scotia, recommend agronomic application rates to facilitate efficient use of biosolids nutrients (**Table A4-C**). Usually the application rate is based on crop need for either nitrogen or phosphorus, because most biosolids contain insignificant amounts of potassium in relation to crop needs. However, cement kiln dust employed in the N-Viro process contains considerable potassium which results in a NVSA product containing significant amounts of all three of these major plant nutrients.

Pathogens
Control of disease transfer to humans and animals is a major concern related to land application of biosolids (**Table A4-D**) and Canadian jurisdictions have either defined biosolids stabilization requirements for land application (e.g., QC, ON, BC) and /or have adopted part or all of the following US EPA (1993) pathogen standards for Classes A and B biosolids: Class A – either the density of fecal coliform in the biosolids shall be less than 1000 Most Probable Number per gram of total solids, dry weight basis (MPN/g DS) or the density of Salmonella sp. bacteria in the biosolids shall be less than 3 MPN/4g DS; and Class B – the density of fecal coliform in the biosolids shall be less than either 2,000,000 MPN/g DS or 2,000,000 Colony Forming Units (CFU)/g DS (e.g., NS, PEI, BC). Despite an occasional claim to the contrary, there are no documented cases of sickness resulting from land application of either Class A or B biosolids in Canada during the approximately 35 years that this practice has been regulated.

Organic Contaminants
To date there is no compelling evidence of the need for organic contaminant limits in land applied biosolids and most Canadian jurisdictions have not defined limits (**Table A4-E**). Dioxins are a particular concern because of the highly poisonous nature of some congeners (e.g., 2, 3,7,8-tetrachloro dibenzo–p-dioxin); however, following detailed risk analysis the US EPA (2003) concluded that there is no need for a dioxin limit for land applied biosolids. The Nova Scotia and Quebec limits of 17 and 50 ng TEQ/kg (parts per trillion) of dioxins and furans for high and lower quality biosolids are conservative and in the light of current scientific evidence, they are not necessary.

Other Requirements
In addition to biosolids metals, pathogens, organics and odour discussed above, Canadian regulations/guidelines include a number of environmental and crop production/use restrictions for land application. They include waiting periods and other requirements (**Table A4-F**) related to pasture, fodder and other crop production; separation requirements (**Table A4-G**) related to land slope, proximity to residences, etc; stability requirements and application rate (**Table A4-H**); frequency of sampling (**Table A5-A**); and land application monitoring, compliance and record-keeping requirements (**Table A5-B**). Nova Scotia's guidelines address all of these issues and the restrictions are consistently among the most conservative for Canada.

Odours
There is growing recognition that odour is an extremely important factor related to land application of biosolids. Frequently it is the factor that attracts public attention and elicits a negative reaction to biosolids applications. Most Canadian jurisdictions, including Nova Scotia have not accounted for odour in land application regulations/guidelines. However, Quebec and Ontario have defined three odour categories for biosolids and require increasing separation distances from residences, schools, etc. and /or special application requirements related to increasing odour (**Table A4-G**).

Since odour frequently is the factor that attracts public attention and elicits a negative reaction to land application of biosolids, odour management warrants careful attention and the following should be considered:

- Odour emissions should be minimized at all stages of operation and be appropriate for various spreading locations.
- Ideally, only low odour or moderately odorous biosolids would be surface applied.
- Strongly malodorous biosolids should be injected directly into soil but if surface applied there should be effective separation distances from residences, schools, etc. and incorporation into soil should occur on the day of application.
- Only low odour Class A biosolids either pure or as a component of manufactured soil should be used on horticultural or other land in urban areas.

Many of these odour considerations have been adopted in Ontario and have resulted in generally good public acceptance of biosolids land application practice (Hale, 2011: Bonte-Gelok, 2011; McComb, 2011; Payne, 2011).

Closure

In Canada, land application of biosolids according to regulations/guidelines that are much more conservative than the US EPA Part 503 regulations has been practiced since the mid-1970s (i.e., approximately 35 years) and despite occasional claims to the contrary, there is no documented evidence of human health effects (WEAO 2001 and 2010). Recently, CCME (Canadian Council of Ministers of the Environment) initiatives have generated reports on sewage sludge treatment, properties and management and a report recommending consistent sewage sludge management including land application of biosolids, across all regions of Canada is slated for publication late this year (2011).

Land application of biosolids is recommended agricultural practice and conservative estimates of the fertilizer value of biosolids supplied free-of-charge to farmers in Ontario alone are $250 per hectare and more than $5 million dollars per year. In some other Canadian provinces (e.g., British Columbia and Quebec), considerable quantities of biosolids are used to prepare manufactured soils and/or employed for land reclamation. Biosolids are particularly valuable for land reclamation (e.g., Van Ham *et al*., 2005) because in addition to supplying immediately available and slow-release nutrients, they supply a microbial population, organic matter and water holding capacity all of which are required to establish soil fertility and sustain plant growth. In particular, NVSA biosolids product supplies considerable liming value important for acid land reclamation.

4.2 International Regulations/Guidelines for Land Application of Biosolids

A detailed review of European regulations/guidelines for land application of biosolids is contained in Part III of a report (EC Europa 2010) entitled "Environmental, Economic and Social Impacts of the Use of Sewage Sludge on Land" (prepared for the European Commission's Directorate General Environment (http://ec.europa.eu/environment/waste/sludge/pdf/part_iii_report.pdf).

4.2.1 European Commission (EC) Legislation

The recycling of sewage sludge in agriculture in EC countries has been regulated by Directive 86/278/EEC since 1986 (http://eur-lex.europa.eu/Lex UriServ/LexUriServ.do?uri=CELEX:31986L0278:EN:NOT) that was set up to encourage and regulate sludge use in such a way as to prevent harmful effects on soil, vegetation, animals and man. The potential for metal accumulation in soil is addressed, and limit values are set for sludge and sludge-treated soil. In addition, the Directive specifies general land use, harvesting, and grazing restrictions, to provide protection against health risks from residual pathogens. It allows untreated sludge to be used on agricultural land if it is injected or worked into the soil. Otherwise sludge shall be treated to significantly reduce its fermentability and pathogen content prior to use in agriculture.

4.2.2 EC Member State Legislation and Policy

Development of guidelines, codes of practice and statutory controls has been an ongoing process at national level since the 1986 Directive was implemented and most countries have adopted more stringent limits and management practices than were originally specified by the Directive. In addition, standards for parameters not included in the Directive (e.g., pathogens and organics) are included in some national regulations.

Metals in Biosolids

Directive 86/278/EEC defines a range of concentration limits for the following "Potentially Toxic Elements (PTEs)"; Cd, Cr, Cu, Hg, Ni, PB and Zn in sludge treated soil. EC member state limits for these elements generally are within the Directive ranges but there are some variations related to soil pH and texture (**Table A5**). Nova Scotia's limits (mg/kg dry solids (DS)) for biosolids treated soil: Cd, 1.4; Cr, 64; Cu, 63; Hg, 0.5; Ni, 32; Pb, 60; and Zn, 200 approximate the lower values in the Directive ranges and are much smaller than calculated USA values. Nova Scotia's limits (mg/kg ds) for As, 12; Mo, 4; and Co, 20 are consistent with those defined by three EC member states.

Metals in Soils

Similarly, Directive 86/278/EEC defines a range of concentration limits for Cd, Cu, Hg, Ni, Pb and Zn in biosolids for application to agricultural land (**Table A6**). A considerable range of limits for these metals has been defined, even within countries e.g., Austria, by EC member states but a majority of them are conservative and are less than or equal to the lower values in the Directive ranges. Nova Scotia's limits (mg/kg ds) for these metals in both Class A and B biosolids: Cd, 3-20; Cr, 210-1060; Cu, 400-760; Hg, 0.8-5; Ni, 62-180; Pb, 150-500; and Zn, 700-1850 approximate the conservative EC limit values. Nova Scotia's limits (mg/kg DS) for As, 13-75; Mo, 5-20; and Co, 34-150 in biosolids are consistent with limits defined by eight EC member states.

Pathogens

Although Directive 86/278/EEC does not contain pathogen limits for land applied biosolids, some national regulations include them (**Table A7**) and in each case they are the detection limits for Salmonella and other pathogens and are similar to the US EPA (1993) and Nova Scotia's Class A biosolids limits.

Organic Chemicals
Directive 86/278/EEC does not contain organic contaminant limits for land applied biosolids and since 1986, EC limits have been proposed and withdrawn (**Table A8**). A majority of national regulations contains no limits for organics but some include limits for classes of these compounds and/or individual compounds. Nova Scotia's limits for PCBs; 0.8 mg/kg DS (Class A biosolids) and PCDD/Fs; 17-50 ng/kg DS (Class A and B biosolids) are conservative and consistent with those for EC member states.

Other Requirements
European monitoring, compliance and record-keeping requirements and their general land use, harvesting and grazing restrictions to provide protection against health and environmental risks are similar to those for Canada (Tables **A4-F, A4-G, A4-H and A5-A, A5-B**) and are not detailed here.

4.3 Conclusions from Regulatory Review of Biosolids Legislation

The above review indicates that the "Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia" (revised March 2010) are among the most conservative of the Canadian and International regulations/guidelines for land application of sewage biosolids and, particularly for metals, they are much more conservative than the US EPA (1993) Part 503 regulations.

5. Description of Biosolids Treatment Processes

5.1 Introduction

The terms sludge and biosolids are often used interchangeably, however, there are distinct differences.

"Municipal Sewage Sludge": Municipal sewage sludge is a mixture of solids and water that is generated from the treatment of municipal wastewater.

"Biosolids": Biosolids are municipal sewage sludge that has been treated by physical, chemical and/or biological processes to reduce pathogen and vector attraction potential, and that meet quality criteria such as metals and pathogens concentration. In Nova Scotia, the quality criteria for biosolids and standards for their application to agricultural land are set out in the Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia, Revised March, 2010.

5.2 Differentiation of Classes of Biosolids Processes

5.2.1 Class A Biosolids

The objectives of biosolids treatment processes are stabilisation and odour reduction, volume reduction, pathogen inactivation, and reduction in vector attraction. Processes are often referred to as Class A or Class B, based on designations originally prescribed by the U.S. EPA in the U.S. Federal Register Part 503 Biosolids regulations. These designations are based primarily on reduction of pathogenic organisms during treatment of wastewater sludges to produce biosolids. Although the terminology has become widely adopted throughout North America, the quality of Class A and Class B biosolids can vary among jurisdictions in Canada. As noted in Section 4, the Canadian Food Inspection Agency is responsible for the import and use of biosolids as a fertilizing agent, and ensures that quality is maintained in terms of nutrient levels and maximum metal concentrations.

Class A biosolids are those of "exceptional quality" that have been subjected to rigorous levels of treatment. Because of the high level of treatment, there are few restrictions on the use of Class A biosolids. **Table 5** defines the Processes accepted by the U.S. EPA for production of Class A biosolids. While there are six alternatives that can be used to produce Class A biosolids, a common feature is the pathogen limit requirements, which are that the density of fecal coliform in the biosolids must be less than 1,000 most probable number (MPN) per g of total solids (dry-weight basis), or the density of *Salmonella* spp. bacteria must be less than 3 MPN per 4 g total solids (TS, dry-weight basis) (EPA, 1994).

Alternative 5 in
Table 5 describes several technologies proven to produce Class A biosolids, called Processes to Further Reduce Pathogens (PFRPs). These technologies are summarized in **Table 6**. Processes

included in this alternative are composting, thermophilic aerobic digestion,

Table 5. Summary of the Six Alternatives for Meeting Class A Pathogen Requirements (EPA, 1994

In addition to meeting the requirements in one of the six alternatives listed below, the requirements in Table 2 must be met for all six Class A alternatives.

Alternative 1: Thermally Treated Biosolids

Biosolids must be subjected to one of four time-temperature regimes.

Alternative 2: Biosolids Treated in a High pH-High Temperature Process

Biosolids must meet specific pH, temperature, and air-drying requirements.

Alternative 3: Biosolids Treated in Other Processes

Demonstrate that the process can reduce enteric viruses and viable helminth ova. Maintain operating conditions used in the demonstration after pathogen reduction demonstration is completed.

Alternative 4: Biosolids Treated in Unknown Processes

Biosolids must be tested for pathogens—Salmonella sp. or fecal coliform bacteria, enteric viruses, and viable helminth ova - at the time the biosolids are used or disposed, or, in certain situations, prepared for use or disposal.

Alternative 5: Biosolids Treated in a PFRP

Biosolids must be treated in one of the Processes to Further Reduce Pathogens (PFRP)

Alternative 6: Biosolids Treated in a Process Equivalent to a PFRP

Biosolids must be treated in a process equivalent to one of the PFRPs, as determined by the permitting authority.

Table 6. Processes to Further Reduce Pathogens (PFRPs) (EPA, 1994)

Composting: Using either the within-vessel composting method or the static aerated pile composting method, the temperature of the biosolids is maintained at 55°C or higher for 3 days. Using the windrow composting method, the temperature of the biosolids is maintained at 55oC or higher for 15 days or longer. During the period when the compost is maintained at 55oC or higher, the windrow is turned a minimum of five times.

Heat Drying: Biosolids are dried by direct or indirect contact with hot gases to reduce the moisture content of the biosolids to 10 percent or lower. Either the temperature of the biosolids particles exceeds 80°C or the wet bulb temperature of the gas in contact with the biosolids as the biosolids leave the dryer exceeds 80°C.

Heat Treatment: Liquid biosolids are heated to a temperature of 180°C or higher for 30 minutes.

Thermophilic Aerobic Digestion: Liquid biosolids are agitated with air or oxygen to maintain aerobic conditions, and the mean cell residence time of the biosolids is 10 days at 55°C to 60°C.

Beta Ray Irradiation: Biosolids are irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (ca. 20°C).

Gamma Ray Irradiation: Biosolids are irradiated with gamma rays from certain isotopes, such as Cobalt 60 and Caesium 137, at room temperature (ca. 20°C).

Pasteurization: The temperature of the biosolids is maintained at 70°C or higher for 30 minutes or longer.

heat drying, heat treatment (of slurries), pasteurization, all of which involve a specified combination of retention times and operating temperatures. Gamma and beta ray irradiation are also allowed as PFRPs.

The Composting and Heat Drying alternatives are discussed below in this chapter. Although the ATAD process is not typically implemented at large WWTFs, due to high operating costs associated with aeration of the digesters, it is also discussed below. There are no known examples of Beta Ray or Gamma Ray Irradiation or of Pasteurization of biosolids currently operating in Canada.

In addition to the technologies listed in **Table 6**, other technologies may be applied to produce Class A biosolids. These processes, however, must meet a strict set of criteria to be approved by the EPA for Class A biosolids production. In particular, the processes must follow specific time-temperature operating regimes and meet high pathogen reduction requirements (EPA, 1994). **Table 7** and **Table 8** present the time-temperature regimes and pathogen reduction requirements listed within the Part 503 Rule.

Table 7. The Four Time-Temperature Regimes for Class A Pathogen Reduction (EPA, 1994)

Regime	Applies to:	Requirement	Time-Temperature Relationship*
A	Biosolids with 7% solids or greater (except those covered by Regime B)	Temperature of biosolids must be 50°C or higher for 20 minutes or longer	$D = \frac{131{,}700{,}000}{10^{0.14t}}$ (Equation 2 of Section 503.32)
B	Biosolids with 7% solids or greater in the form of small particles and heated by contact with either warmed gases or an immiscible liquid	Temperature of biosolids must be 50°C or higher for 15 minutes or longer	$D = \frac{131{,}700{,}000}{10^{0.14t}}$
C	Biosolids with less than 7% solids	Heated for at least 15 seconds but less than 30 minutes	$D = \frac{131{,}700{,}000}{10^{0.14t}}$
D	Biosolids with less than 7% solids	Temperature of sludge is 50°C or higher with at least 30 minutes or longer contact time	$D = \frac{50{,}070{,}000}{10^{0.14t}}$ (Equation 3 of Section 503.32)
*D = time in days; t = temperature in degrees Celsius.			

Table 8. Pathogen Requirements for All Class A Alternatives (EPA, 1994)

The following requirements must be met for *all* six Class A pathogen alternatives. **Either:** • the density of fecal coliform in the biosolids must be less than 1,000 most probable numbers (MPN) per gram total solids (dry-weight basis); • or, • the density of *Salmonella* sp. bacteria in the biosolids must be less than 3 MPN per 4 grams of total solids (dry-weight basis). ***Either of these requirements must be met at one of the following times:*** • when biosolids are used or disposed; • when biosolids are prepared for sale or give-away in a bag or other container for land application; or • when the biosolids or delivered materials are prepared to meet the requirements for EQ Biosolids (see Chapter 2 (EPA,1994)). Pathogen reduction must take place before or at the same time as vector attraction reduction, except when the pH adjustment, percent solids, vector attraction, injection, or incorporation options are met.

Certain other technologies have been shown capable of achieving quality that meets the Class A biosolids criteria outlined in the Part 503 Rule. Some are relatively new (e.g. solar drying), while others are documented frequently in the technical literature and have been applied often at large North American WWTFs. These technologies include:

- the alkaline stabilization process;
- the thermophilic anaerobic digestion process;
- the Temperature Phased Anaerobic Digestion (TPAD) process.

In addition to the above technologies, a proprietary 'advanced biosolids treatment' technology called the Lystek Process has gained interest at Southern Ontario WWTFs. The alkaline stabilization process is discussed in detail elsewhere in this report, and is not discussed further herein. The remaining four technologies will be discussed in more detail in subsequent sections of this chapter.

5.2.2 Class B Biosolids

The requirements for producing Class B biosolids are less stringent than those for Class A; the potential uses of Class B biosolids, however, are also more restricted. Criteria for Class B biosolids specify microbial limits and site restrictions. The pathogen reduction requirement for Class B biosolids is that the geometric mean of seven samples of the biosolids must be less than 2 million MPN per gram of TS (or less than 2 million colony-forming units (CFU) per gram of TS at the time of use or disposal (EPA, 1994). Processes that are accepted by the U.S. EPA for producing Class B biosolids include: aerobic digestion, air drying, anaerobic digestion composting and lime stabilisation. Land application site requirements for using Class B biosolids typically specify a waiting period between the time of application and use of the amended site, such as animal grazing, recreational use, planting of food crops, etc.

5.3 Issues Regarding Potential Alternative Processing Technologies

5.3.1 Dewatering

We have assumed that Halifax Water will retain an equivalent to Class A biosolids. Thus, dewatering will continue to be provided for each alternative considered. There is no indication that a concern has been expressed regarding the dewatering processes at Aerotech Park or any of the WWTFs that are using dewatering now.

5.3.2 Land Availability

All of the biosolids produced require adequate land availability in perpetuity. This is a key requirement common to all of the process technologies and is not considered further herein. However, Class A biosolids can be used with fewer limitations than Class B biosolids.

Land application of liquid or dewatered stabilized biosolids is practical if adequate land is available. Land application recycles organic material and nutrients (N,P,K) to the soil.

All Class A and Class B biosolids production need ultimate management sites, whatever process technology is selected. To meet requirements for land application of biosolids, all processing technologies include stabilization, volume reduction, and pathogen reduction.

5.3.3 Available Technologies

The need for Class A biosolids narrows the choice of processing technologies recommended. In all cases, a Sewer Use Bylaw is essential to regulate the quality of the sewage and biosolids. Halifax Water has in place such a bylaw as part of its Rules and Regulations.

The Class A biosolids processing technologies that have been used widely include:

- Autothermal Thermophilic Aerobic Digestion (ATAD),
- Thermal drying,
- Alkaline Stabilization and Drying (includes N-Viro and other providers, e.g. Lystek),
- Composting.

These processes are discussed in greater detail in **Appendix B**

5.4 Composting

5.4.1 Process Description

Composting is a biological process in which organic material undergoes biological degradation to a stable end product called humus. Composting has received increased attention as an option for enhanced stabilization and utilization of biosolids. This technology can be applied for stabilization of dewatered sludge (between 14% and 30% solids), supplied in undigested, digested or chemically stabilized forms. This self-heating aerobic process attains temperatures in the pasteurization range of 50^o to 70^oC and results in the inactivation of pathogens and the production of well-stabilized compost that can be stored indefinitely and has minimal odour (WEF, 1995). Drying during the composting process can produce solids concentrations of 50% to 55%. The high quality biosolids product can be used beneficially as a soil conditioner or organic fertilizer supplement for the horticultural and agricultural industry and/or as a biofuel for its energy value.

Composting under aerobic conditions, depending on the system design, involves the following steps:

1. Mixing of dewatered sludge with a bulking agent or amendment to ensure an adequate mixture porosity for proper aeration, structural integrity, acceptable mixture density, reduced bulk moisture content and to provide supplemental carbon to adjust the energy balance and carbon-to-nitrogen ratio,
2. Aeration and/or agitation of the mixture to promote the aerobic microbiological decomposition reactions (i.e., active composting),
3. Curing of the compost to complete the stabilization process.

5.4.2 Benefits of Composting

Composting is a cost-effective alternative for the production of well-stabilized, essentially pathogen-free biosolids for a number of potential beneficial uses. Maintenance of a minimum temperature of 55^oC for at least three days can achieve virtually complete inactivation of pathogens in aerated static pile systems (WEF & ASCE, 1992). Some fungi however (e.g., *Aspergillus fumigatus*) are able to survive the composting process because they are thermo-tolerant organisms.

Composting is a versatile sludge processing technology that, depending on process design, can treat dewatered undigested and/or digested sludge and produce a Class A biosolids product. This could defer or eliminate the need for future digester upgrades and expansions in the City and can represent a flexible option as part of a diversified biosolids management program. Additional volatile solids destruction and degradation of persistent organic substances in digested biosolids may be possible.

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5.4.3 Composting as an Alternative for Halifax Water's Biosolids

5.4.3.1 Potential Markets for the Compost

The Halifax Water biosolids does not exceed compost metal standards for unrestricted use, so that market for the composted biosolids could be for home and garden use as well as for commercial and institutional fertilizer uses. Another beneficial use for the compost is as a landfill cover. This, however, is not considered to be an active market since there is generally an excess of material which can be used for this purpose.

5.4.3.2 Storage Requirements

To provide an estimate of the area required for a compost facility, other compost facilities were examined. Facilities located in Edmonton (Fitchner, 2003, City of Edmonton, 2005), Marburg (Germany) (Fitchner, 2003) and Niagara (Ralph, 2002) are presented below in **Table 9**. The Edmonton facility co-composts biosolids and municipal solid waste. The Marburg facilities composts kitchen and yard waste and the Niagara facility composts organic materials but not biosolids.

Table 9. Size of Composting Facilities

Facility	Organic Material Processed (tonnes/yr)	Area of Facility (ha)	Normalized Area (ha/10000 tonnes)
Edmonton	220,000 (dry) (20,000 dry tonnes/year biosolids plus 200,000 tonnes / year of municipal solid waste)	25	1.1
Marburg (Germany)	12,000 (kitchen and yard waste – no biosolids)	0.6	0.5
Niagara (design)	20,000 (food processing residuals etc – no biosolids)	1.6	1.6

The Edmonton facility includes a composting pad, curing area, bulking agent storage, a surface water management pond and storage capacity for 4 to 6 months of compost production. It has a normalized surface area of 1.1 ha per 10,000 tonnes of biosolids processed. It was noted by Ralph (2002) that Niagara would have an on-site storage capacity of 12,000 tonnes. This represents approximately 60% of the annual production or 7 months storage.

Biosolids are generally composted with other materials (e.g. woodchips) and although there may be some organic solids reduction during the composting process, the overall volume of generated compost is greater than the initial volume of biosolids. The increase in volume is directly rated to the amount of other materials added. Guelph, Ontario added woodchips to biosolids in the ratio 1:2 and observed an increase of approximately 50% in volume. This has a direct influence on land space required for the composting facility.

5.4.3.3 Advantages and Disadvantages

The advantages and disadvantages for Halifax Water composting biosolids are presented below in **Table 10**.

Table 10. Composting Advantages and Disadvantages

Advantages	Disadvantages
Nutrient value of biosolids is reused.	The required compost bulking agent will offset the volume reduction due to the reduced water content in the finished compost.
The City has dewatering facilities required for composting.	The space required for a composting facility is likely greater than is available; an off-site facility is required.
There is Canadian expertise in biosolids composting	If biosolids are composted and metal standards are not met, the compost can only be landfilled.
There are many suppliers of composting systems.	

5.4.3.4 Applicability to Halifax

Composting is already provided in Halifax for organic wastes. In addition, Halifax Water currently dewaters biosolids in preparation for alkaline stabilization with the N-Viro system. This dewatering could be the pre-step to biosolids composting in place of alkaline stabilization. Although there does not appear to be a compelling reason to abandon the current alkaline stabilization process technology, composting may be an appropriate processing alternative in future compared to the other alternatives considered in this report.

5.5 Thermal Drying

5.5.1 Process Description

Thermal drying is the process of evaporating water from sludge or digested biosolids by the addition of heat. Complete drying typically results in a product with 5 to 10% moisture content, corresponding to a 30-fold volume reduction. The moisture content of thermally dried biosolids is the lowest of the process alternatives considered, and heat is one of the most effective pathogen destructors. Thermal drying is capable of biosolids disinfection and the product can be used on acid or alkaline soils. Fuel is needed to provide the drying, but the product itself can become a fuel if an end-user is identified. As well as being used as a fertilizer or soil conditioner, the dried biosolids (termed pellets or granules) can be used as a biofuel. The quality of the granules produced, drying system used and local economic factors are likely to determine the end use of the dried biosolids.

During drying, biosolids undergo several structural changes as the moisture content decreases. The most critical stage is called the plastic stage when the moisture content is between 40 to 60% Dry Solids (DS). In this stage, the dried product becomes sticky and difficult to manipulate. The power input required to move the product through this phase to higher solids concentrations is large. It is essential to minimize dust production or accumulation during the drying process due to the increased probability of fire or explosions, which have occurred in the past. Collection systems are used to capture the product dust.

The main benefits of drying sludge thermally can be summarized as follows:

- Increased pathogen destruction is achieved,
- Storage of dried sludge requires less volume and is easier to handle,
- Transportation costs are reduced,
- Sludge drying increases the number of final disposal or utilization options,
- The final product can be marketed more easily as a fertilizer or soil conditioner, and
- Dried sludge has a higher fuel value and can be incinerated or thermally converted.

5.5.2 Advantages and Disadvantages of Thermal Dryers

Table 11 presents an overview of the most significant advantages and disadvantages of the various heat-drying processes employed at municipal wastewater treatment works.

Table 11. Advantages and Disadvantages of Heat Drying Processes

Process	Advantages	Disadvantages
Direct Dryers	Dried product has low dust content Direct drying is a good choice if the end product will be used as a fertilizer or soil amendment More thermally efficient if a dry solids content above 90% is required Reduced seasonal storage compared to other options	Large volume of gas that needs to be treated in an odour control unit High power requirements Less thermally efficient than indirect dryers when incomplete biosolids drying is required Fire/explosion controls are necessary
Indirect Dryers	Low quantities of non-condensable gases Smaller size odour control units required Allow operation under a vacuum or closely controlled atmosphere More thermally efficient if partial drying is required (65-85% DS) Reduced seasonal storage compared to other options	Although less dust is produced during the drying process, the dried product has more dust than with direct dryers Often requires further granulation of the dried product to make it marketable Debris, such as plastic, hair, can be problematic Fire/explosion controls are necessary

5.5.3 Thermal Drying as an Alternative for Halifax Water's Biosolids

5.5.3.1 Storage Requirements

If the product is compliant with the Fertilizer Act, one potential management option for such a large volume is distribution through a third party. Depending on the terms of the contract, it is possible that the fertilizer distributor may be able to store the product. Since this possible contract negotiation is beyond the scope of this technical memorandum, it was assumed that storage would be provided at the thermal drying site.

Fertilizers for agricultural use are typically applied during the spring and fall. Since there is the potential of a spring or fall during which fertilizers could not be applied due to wet weather, storage requirements for the product are estimated to be 10 months (November to following September).

5.5.3.2 Time to Commission a Facility

It is estimated that the total time required to site, design, permit, build and commission an thermal drying facility is between 30 and 36 months.

5.5.3.3 Advantages and Disadvantages for Halifax Water

The advantages and disadvantages to Halifax Water for thermally drying biosolids are presented below in **Table 12**.

Table 12 Thermal Drying Advantages and Disadvantages

Advantages	Disadvantages
High degree of pathogen destruction.	Mixed success with respect to process reliability - breakdowns, fires.
There are several suppliers of thermal drying processes.	High capital and operating fuel cost.
Canadian operating experience is available (Smiths Falls, Communite Urbaine de L'Outaouais, Montreal, Toronto, Windsor).	Despite high degree of treatment, market for product may still be limited to agricultural uses.
Since the product has been treated beyond normal levels, there may be more acceptance of land application.	Solids/cake pumping is a key requirement in design, engineering, construction.

5.5.3.4 Applicability to Halifax

The thermal drying process was reviewed because Halifax Water already has a heat drying system in place as part of the existing N-Viro process, and thus has experience in its operation. In addition, dewatered biosolids are produced which are the feed to alternative drying systems such as pelletizers. The current drying system in the N-Viro process is a rotary kiln unit. A thermal pelletizer system would require a new drying process system. This would be capital and operating intensive as special equipment and operation is required. Fuel consumption would increase to dry the product to above 90% solids compared to the N-Viro process which attains heat with alkaline reactivity in the mixing process and sufficient heat to dry to about 60% solids, with less dust and fire potential from the end product. Reported disadvantages of pelletization indicate that other alternatives are more appropriate for Halifax Water. Thus, alternative drying such as pelletization is not recommended at the present time.

5.6 Autothermal Thermophilic Aerobic Digestion (ATAD)

5.6.1 Process Description

Autothermal thermophilic aerobic digestion (ATAD) involves mixing the wastewater sludge with excess air or oxygen in an insulated reactor. Extensive mineralization of biomass to carbon dioxide, water and nitrogen occurs in the endogenous respiration process. The endogenous respiration proceeds in a sufficiently fast exothermic reaction to maintain the process temperature between 40 to 80^{o}C, thereby achieving the pathogen reduction and 38% volatile solids reduction criteria to meet the Class A designation. The ATAD effluent is a liquid slurry that can either be applied off-site directly as a Class A product, or dewatered to produce a drier sludge cake for off-site management.

This modification of aerobic sludge digestion can achieve "Class A' biosolids quality. However, it requires at least 4% solids in the feed to become thermophilic, with the consequence that some form of sludge thickening is required (WEF, 2010).

The operational temperature is typically 40°C (35 to 60°C) in the first stage and 55°C (50 to 70°C) in the second. Retention time is typically 10 to 12 days. The reactors require effective aeration and mixing, with insulation to retain heat. Together, these factors can lead to 38% volatile solids reduction.

5.6.2 Advantages and Disadvantages

Advantages and disadvantages of the ATAD process are summarized in **Table 13**.

Table 13. Advantages and Disadvantages of ATAD

Advantages	Disadvantages
Short retention time	Prethickening required
Greater reduction of bacteria and viruses	Poor dewaterability
Can meet Class A quality	Odours
Stable process	Lack of nitrification or denitrification
	High unit capital cost
	Foaming and control needed
	Storage required for product cooling unless heat exchanger used

5.6.3 Applicability to Halifax

ATAD would likely be most appropriate at individual wastewater treatment facilities and this would decentralize treatment away from the AeroTech site, an option that offers no readily evident benefit. Moreover, some of the Halifax Water WWTFs would have difficulty implementing this process because of limited available space for construction. There is no benefit in terms of producing higher quality biosolids by the ATAD process. We would therefore not recommend the ATAD process as a replacement for the centralized N-Viro treatment of the Regional Municipality's biosolids.

5.7 Other Treatment Alternatives to Produce Class A Biosolids

The following sections provide a brief review of other biosolids stabilization alternatives that might be considered to be viable technologies for producing Class A biosolids. Use of these processes, however is not recommended for treatment of Halifax Water biosolids. The information is provided for background knowledge.

5.7.1 Thermophilic Anaerobic Digestion

Thermophilic anaerobic digestion occurs at temperatures between 50 and 75ºC. As the temperature increases in the stabilization process, biochemical reaction rates increase. This results in a shorter hydraulic retention time (HRT) in the thermophilic digestion process for biosolids stabilization as compared to conventional anaerobic digestion operated at mesophilic temperatures (30 to 40^{o}C). The reactor volume in a thermophilic digester is therefore less than that for a mesophilic digester.

The advantages of the thermophilic digestion over mesophilic digestion include the smaller reactor volume, an increased solids destruction rate, improved dewatering, and increased pathogen reduction rates (Metcalf and Eddy, 2003). Disadvantages of the thermophilic process compared to mesophilic digestion include higher energy requirements for heating the biosolids, poorer quality supernatant, and less process stability (Metcalf and Eddy, 2003).
While single stage thermophilic digestion is a possible alternative, this configuration is typically not used in municipal wastewater treatment applications (Metcalf and Eddy, 2003). Rather, thermophilic digesters are most commonly incorporated into a temperature-phased anaerobic digestion (TPAD) process (Moen, 2000).

5.7.2 Temperature Phased Anaerobic Digesters (TPAD)

Results reported in technical literature suggest that the temperature phased anaerobic digestion (TPAD) process may be a better alternative than thermophilic anaerobic digestion alone. The TPAD process consists of thermophilic digestion as the first phase, which is operated at temperatures above 55°C, followed by mesophilic digestion as the second phase, operated at a temperature range of 35 to 40°C. The third phase typically consists of a thickener used for digested sludge settling. The arrangement of the thermophilic and mesophilic reactors in series can take full advantage of both digestion processes. The thermophilic stage is able to enhance hydrolysis of materials encapsulated in cells and make the nutrients readily available for acidogenic and methanogenic bacteria. Subsequently, the mesophilic stage is able to decompose these acids and convert them to methane and carbon dioxide. Through this process, TPAD can be used to produce a high level of stabilization and Class A biosolids.

The TPAD process can be operated at a higher VS (volatile solids) loading and shorter hydraulic retention time in the first digestion phase compared to conventional mesophilic digestion. Based on published values, the first thermophilic unit is typically designed to operate at maximum VS loadings of 4,000 to 8000 g VS/m^3.d, and at an HRT typically in the range of 3 to 5 days, up to a maximum of 8 days (Holbrook *et al*., 2002; Krugel *et al*., 2002; Metcalf & Eddy, 2003). The second mesophilic digester is designed to operate at a minimum HRT of 10 to 12 days (Shafer and Farrell, 2000).

The TPAD process produces higher VS reduction rates than conventional mesophilic anaerobic digestion. In one study, results from three pilot-scale TPAD operations, and one full-scale TPAD operation in the United States were summarized and compared to conventional anaerobic digestion results utilizing the same equipment and tankage (Shafer and Farrell, 2000). The average VS reduction for the four systems was increased from 53.5 percent to 64 percent when operating in a TPAD mode. At the plant-scale operation in Neenah-Menasha, WI, the VS reduction was increased from 50 percent to 58 percent when operating in a TPAD mode. Performance summaries have indicated that TPAD biosolids have similar dewaterability as mesophilically digested biosolids (Shimp *et al*., 2000); however, cases were noted that reported TPAD processes produced a more highly dewaterable sludge (Schafer and Farrell, 2002).

The TPAD process has been shown to have high rates of pathogen kill, and to produce Class A biosolids if configured properly. For example, data available for the first year of operation of the TPAD process at the Village Creek WWTF, located in Birmingham, Alabama, indicated that the time-temperature relationship, VS reduction, and biosolids fecal coliform density consistently met Class A requirements.

The TPAD process results in higher methane gas production compared to conventional mesophilic anaerobic digestion. This gas could serve as an alternative energy source, and possibly provide a supplementary fuel source. Methane gas produced in the digestion process can be compressed, stored, and used to fuel electrical generators.

Thermophilic digestion has been reported to produce biosolids which occasionally are more odourous than those from conventional anaerobic digestion (Schaffer & Farrell, 2000). In temperature staged systems, however, the mesophilic stage seems to reduce odours generated during the upstream thermophilic stage to levels comparable to conventional anaerobic digestion (Shimp *et al*., 2000; Han *et al*., 1997). Higher ammonia loadings in the digester supernatant and dewatering centrate recycled to the liquid treatment train are anticipated for the TPAD process, as compared to conventional digestion (Schaffer & Farrell, 2000).

Because Halifax already has a Class A biosolids process with the N-Viro system, it is not recommended at this time to include TPAD as a recommended alternative. Not all plants operated by Halifax Water have anaerobic digestion, and those sludges untreated by anaerobic digestion are not all hauled to a larger plant which does use anaerobic digestion. This process could be reviewed in future again if changes occur that makes it a potential alternative.

5.7.3 Solar Drying

The solar drying system typically consists of a sophisticated "greenhouse" for drying biosolids in which the sun provides thermal energy for evaporation. A transparent cover is constructed that allows transmission of solar radiation, provides insulation, and protects against adverse weather conditions. Liquid or dewatered biosolids are spread out on the floor of the drying pens and are mixed and aerated by a robot called an "electric mole". Dewatered feed would be required due to the large facility size. The solar drying system typically consists of the following components:

- transparent cover;
- flaps for natural convection;
- exhaust air fans allowing short bursts of high rate air exchanges;
- "Electric Mole" for mixing and aerating;
- microprocessor for control and optimization of factors affecting the drying process;
- a drainage floor in the case of liquid biosolids application;
- air-circulation fans to achieve an optimal air speed across the surface of the biosolids; and,
- sensors for measuring temperature, relative humidity, solar radiation, air speed, etc.

Liquid or dewatered biosolids are applied in layers and are mixed up to twelve times per day. The controlled air-flaps and exhaust fans prevent the uncontrolled exchange of air and deliver large amounts of fresh air in short bursts when required. Odour control may be required to remove odours from air exhausted from the solar drying green houses.

The microprocessor allows the monitoring and control of the parameters affecting the drying process such as temperature of the drying air, the relative humidity of the drying air, the velocity of the drying air over the biosolids and the temperature of the biosolids.
The system requires a relatively large amount of land area, but can be implemented in a modular format to allow flexibility in construction/implementation. The typical range of dry solids content achieved by solar drying processes is 55 to 80%. Depending on cloud cover and temperatures, a medium-sized plant may achieve 50% dry solids in the autumn and winter and up to 93% dry solids in the spring and summer for similar application rates and operation. For larger WWTFs and colder climates, large areas of land are required.

A study (Bux *et al.*, 2001) indicated that solar drying plants could achieve a substantial volatile solids reduction (to 40% volatile solids) and pathogen reduction. While the end product from the solar drying process is well stabilized, it is not considered a pasteurized product. The technical literature has reported evidence that with proper design of the solar drying process, high biosolids stabilization efficiencies can be achieved, and Class A biosolids may be produced. The solar drying process can be modified to include lime addition. Lime can be added after a few days of drying (Bux *et al.*, 2001). The quantity of lime required to produce Class A biosolids is one-third of the amount required for lime stabilization of biosolids. The addition of lime increases the biosolids temperature to above 100^{o}C and the pH to above 12.5 for three days or more.

Halifax Water already produces a dewatered biosolids feed stream to the N-Viro system, which is also a condition for solar drying. The maximum benefit of solar drying is achieved in areas with high solar radiation year-round. The capital cost for areas with lower solar radiation would be high. Since Halifax water has an installed N-Viro system with extensive lifetime remaining, the solar drying alternative is not recommended at this time.

5.7.4 Lystek Process

The Lystek Process is a newer process involving alkaline addition with elevated temperature to produce liquid biosolids with low pathogen levels that meet or exceed the US EPA Class A biosolids standard (Singh *et al*, 2004). Currently, the Lystek process is used at the Guelph WWTF to treat biosolids which have been anaerobically digested and dewatered. The process is a batch operating system that involves specific sequenced application of heat, alkaline chemical addition and mixing. The process produces a liquid biosolids with a solids concentration of 15% and with low viscosity (less than 500 cP), making the treated product transferable using conventional pumping equipment. The Lystek process has a small footprint compared to other mainline process technologies. Recent discussions with Lystek International Incorporated (Singh, 2011), suggest that they have been able to run the process continuously and they will release information on that development once tests have been finalized.

In the Lystek process, dewatered anaerobically treated biosolids are pumped by progressive cavity pump to the mixing tank. There, the solids are conditioned to reach a concentration of 12% -15%, and the temperature and pH of the diluted biosolids are adjusted to an optimum range. After the biosolids are conditioned, the material is mixed for a specific retention time. Subsequent holding and retention times are described as relatively short (Singh *et al*, 2004).

Lystek-process treated biosolids can be stored for long periods of time without re-growth of pathogens and/or loss of the capacity to be pumped, transported and applied as a controlled liquid fertilizer following seasonal storage. The product is compatible with standard equipment for use in land application of biosolids (Singh *et al*, 2004).

Biosolids, which were stored for five months and had been previously treated by the Lystek process, were tested for odour. Low levels of ammonia and hydrogen sulphide was detected. Other odour causing compounds, such as mercaptans, dimethyl disulphide, carbon disulphide and sulphur dioxide, in addition to methane, were not detected (Singh *et al*, 2004).

The Lystek process has recently been installed at the St. Marys and Peterborough WWTFs in Ontario.

At present, Halifax Water already uses an alkaline process with elevated temperature (N-Viro), and because there is no obvious benefit from converting to a liquid biosolids treatment system, the process is not recommended for consideration as a treatment alternative at this time.

5.8 Class B Biosolids Treatment Processes

Use of any Class B process by Halifax Water is not recommended, as the higher allowable pathogen concentrations make use of the material more restrictive. It would also be seen as a step backwards in the quality of the product relative to the existing N-Viro process Class A biosolids.

The following sections are provided as background information.

5.8.1 Anaerobic Digestion

The anaerobic digestion process makes use of bacteria that thrive in the absence of oxygen to stabilize volatile solids and reduce levels of pathogens. The two most common types of anaerobic digestion are mesophilic digestion (temperature maintained at approximately 35^{o}C, and thermophilic digestion (typically between 50 and 57^{o}C). Although mesophilic digestion can result in volatile solids reduction greater than 40%, it does not result in a pathogen-free product, and so is considered a Class B process. Thermophilic digestion, either alone or as part of a temperature-phased (TPAD) system, with sufficient retention time can produce a Class A biosolids.

In the mesophilic anaerobic digestion process, the feed sludge stream (primary and/or secondary sludge) is pumped to the digestion tank on a semi-continuous basis, where it is maintained for a typical average detention time of 15 days or more. The digested sludge is a liquid slurry which can be used off-site directly as a Class B product, or dewatered to produce a sludge cake for off-site use. Biosolids can be designated as Class A following thermophilic digestion if they are held for a specified period of time at a temperature above 50 ^{o}C, as provided in Alternative 1 of the Part 503 regulations (WEF, 2009).

Anaerobic digestion is not recommended as a process for consideration by Halifax Water where it has not already been implemented because of high capital costs for construction.

5.8.2 Aerobic Digestion - Ambient and Mesophilic Temperatures

Aerobic digestion of wastewater solids uses aerobic micro-organisms to degrade organic matter (measured as volatile solids) and other organic components, to reduce mass and volume, and to reduce pathogenic organisms (WEF, 2009). The principle behind aerobic digestion is cellular endogenous respiration, in which the microbes are maintained in a process tank for an extended time period. During this period, the external food substrate is depleted, and so the microbes must consume their own protoplasm as the energy source for cell maintenance functions. This self-consumption, or endogenous respiration, is responsible for the observed reduction in the volatile fraction of the microbes.

Biosolids produced by aerobic digestion (mesophilic, i.e., 10 to 40 ^{o}C) are typically designated as Class B. WEF (2009) points out that the vector reduction criterion of 38% volatile solids reduction may be difficult to accomplish with aerobic digestion if the excess secondary sludge results from a secondary treatment unit with a long solids retention time, such as extended aeration.

Aerobic digestion is used for biosolids stabilization at a few of the small Halifax Water plants, but it is not recommended as a centralized biosolids treatment process due to the significant energy requirements for aeration.

5.9 Plasma Arc Gasification

This technology is a form of incineration. It uses high voltage electricity to raise the temperature to a high level (from 600°C up to 13,900°C) to gasify a waste stream creating an inorganic ash product requiring disposal in a landfill. Advantages and disadvantages of the process are listed in **Table 14**.

Table 14. Advantages and Disadvantages of Plasma Arc Gasification Technology

Advantages	Disadvantages
Breaks compounds down to the elemental level	Unproven technology; no municipal scale facilities yet
One article for Valleyfield Quebec demonstration indicates use of plasma-assisted sludge oxidation[1]	Most applications in literature for municipal solid wastes and tires, not biosolids
Brick liner may have greater life	Concern with liner life expectancy
Waste is an inorganic ash which could be landfilled	Non-gasified material in biosolids would result in a slag and/or ash to be landfilled
Potential for energy recovery	Higher water content of dewatered sludge compared to municipal solid waste = more energy required
Pathogen destruction	Nutrient value of sludge lost

Notes: 1. The (Montreal) Gazette Digital 22 Sep 2008 p.16

There are no known full-scale municipal facilities using the technology for biosolids gasification.

Efforts to examine this technology in Juneau, Alaska discounted it at the time (2009)[a] until more evidence is developed proving its capability.

[a]http://www.juneau.org/clerk/ASC/COTW/2009/documents/SCS_Engineers_Power_Point_Opinion_Letter_Regarding_Plasma_Arc_Gasification_and_Waste.pdf

A trial in Valleyfield, Quebec does not appear to have fledged into a full scale system at this time. Although the technology may have future promise, it is not yet a proven biosolids gasification technology and is not recommended for Halifax.

6. Review of Documents and Websites as Requested by HRM Council

Within the Terms of Reference for this study was a specific request to review certain documents and websites as stipulated by Halifax Regional Council. While there was no direction as to what was expected of this review, the Project Team has examined the requested documents and web sites and formulated this response based on their collective expertise.

The issues specified in the Terms of Reference are responded to in the order in which they were listed there.

1. "Energy from waste" : Plasma Market Solutions

Plasma arc gasification technology is a form of incineration. The process uses high electrical voltage to raise temperature to a high level (from 600°C up to 13,900°C) causing gasification of the waste stream. An inorganic ash or slag product that requires disposal (e.g., landfill disposal) is left from the waste. Applications appear to be directed towards solid wastes and tires, which have little or no water, compared to biosolids. Biosolids with 70% water content would generate significant steam in the process.

There are no known full-scale municipal facilities using the technology for biosolids gasification. A trial in Valleyfield, Quebec (The (Montreal) Gazette Digital 22 Sep 2008 p.16) does not appear to have expanded into a full-scale system at this time. Efforts to examine this technology in Juneau, Alaska discounted it at the time (2009) until more evidence is developed proving its capability [http://www.juneau.org/clerk/ASC/COTW/2009/documents/SCS_Engineers_Power_Point_Opinion_Letter_Regarding_Plasma_Arc_Gasification_and_Waste.pdf].

Although the technology may have future promise, it is not developed to the stage of being proven for biosolids gasification.

2. Dr. David Lewis, retired EPA microbiologist, to be used as a resource regarding interactions of pathogens and irritant chemicals in land-applied sludges (biosolids). www.biomedcentral.com/1471-2458/2/11
4. Class A Sewage Sludge – Sewage Sludge (Biosolids) is a Potential Killer: National Sludge Alliance, Fact Sheet #138 (date 6-1-2003) at http://deadlydeceit.com/NSA-138.html

The following is a combined response to websites/documents #2 and #4. Discussion of document #3 follows this combined response.

The Lewis *et al*. (2002) document (#2) details adverse health symptoms reported by 48 residents near 10 biosolids application sites in the United States and Canada. The wide range of symptoms listed include various combinations of coughing, burning eyes, sore throat, burning lungs, headache, congestion, difficulty breathing, flu-like symptoms, fever, nausea/vomiting, diarrhea, sinusitis, staphylococcal infection, pneumonia, skin rash, nosebleed and fatigue. Cause and effect between biosolids and reported adverse effects was not established but it was suggested that chemical contaminants in biosolids might irritate the skin and mucous membranes and thus increase pathogen host susceptibility. Similarly, a later 2007 study suggests a higher risk of certain respiratory, gastrointestinal, and other diseases among residents living near farm fields on which biosolids were applied. The National Sludge Alliance, Factsheet #138 suggests exotoxin allergic reactions among residents near biosolids application sites. The absence of solid scientific data for the statements in these documents weakens the validity of the arguments.

In contrast to the above, the findings of a health effects study of 47 biosolids application sites (annual applications) and 46 control sites on farms in Ohio indicated that risks of respiratory illness, digestive problems or other general symptoms did not differ between biosolids and non-biosolids farms. Moreover, studies conducted over the past 25 years with workers in contact with wastewater or biosolids indicate that infections from specific agents are not common http://www.wef.org/Biosolids/page.aspx?id=7522&ekmensel=c57dfa7b_125_0_7522_2.

Although some workers have been known to experience increased symptoms associated with gastrointestinal or upper respiratory illnesses in their first few years of employment, there is evidence that they build immunity over time against these types of illnesses and are generally healthier than the general population.

Two National Academy of Sciences expert panel reviews of the Part 503 regulations in 1996 and 2002 concluded as follows: http://www.nebiosolids.org/index.php?page=science%20
"In summary, society produces large volumes of treated municipal wastewater and sewage sludge that must be either disposed of or reused. While no disposal or reuse option can guarantee complete safety, the use of these materials in the production of crops for human consumption, when practiced in accordance with existing federal guidelines and regulations, present negligible risk to the consumer, to crop production, and to the environment." (National Research Council: *The Use of Reclaimed Water and Sludge in Food Crop Production*," National Academy of Sciences, 1996, p. 13.) and

"There is no documented scientific evidence that the Part 503 rule has failed to protect public health. However, additional scientific work is needed to reduce persistent uncertainty about the potential for adverse human health effects from exposure to biosolids. There have been anecdotal allegations of disease, and many scientific advances have occurred since the Part 503 rule was promulgated. To assure the public and to protect public health, there is a critical need to update the scientific basis of the rule to (1) ensure that the chemical and pathogen standards are supported by current scientific data and risk-assessment methods, (2) demonstrate effective enforcement of the Part 503 rule, and (3) validate the effectiveness of biosolids management practices" (National Research Council: *Biosolids Applied to Land: Advancing Standards and Practices*, July, 2002.)

In September, 2002, Dr. Thomas Burke, Chair of the panel that wrote the report, issued a statement clarifying the panel's findings. "First, we found no evidence of an urgent public health risk from exposure to land-applied biosolids, based on our review of the scientific literature. Currently, there are no studies documenting adverse health effects from land application of biosolids, even though land application has been practiced for years. But this finding was tempered by the fact that few studies are available on human exposure to biosolids, and that, even when they are investigated locally, there are no means of tracking health allegations nationally." In 2003, EPA responded to a petition that urged a moratorium on the use of biosolids on soils. The petition cited several cases that they claimed indicated harm from biosolids. In its response, EPA refuted the claims of the petitioners, undermining their allegations with contrary evidence from each case they cited.

Following up on the latter recommendation to update the scientific basis of the Part 503 Rule, a report entitled "Problem Formulation for Human Health Risk Assessments of Pathogens in Land-applied Biosolids" (U.S. EPA 2011) has been prepared. It provides concepts and planning considerations for conducting human health risk assessments for potential pathogens in land-applied biosolids.

Similarly, the Europa (2010) Part I Report includes summary sections for the biosolids constituents of concern (e.g., nutrients, metals, pathogens, organic contaminants, etc.) in relation to land application. Based on a review of numerous research studies and many years of practical experience, it is concluded that land application practised according to regulations/guidelines does not present significant risks to human and animal health and the environment and should be continued. Whereas there is general agreement that current information facilitates satisfactory management of nutrients and metals in land applied biosolids, continued research with emphasis on pathogens and emerging organic contaminants such as pharmaceuticals and personal care products is needed to reduce uncertainty about the potential for adverse human health effects from exposure to biosolids.

Thus, despite many years of study that have identified no causal effect between land applied biosolids and adverse health effects, effort continues in both North America and Europe to satisfy public concerns about the efficacy of this practice.

3. CCME report re: contract on ESOC's (Emerging Substances of Concern), specifically page 122 and conclusions 13, 14, 15 and 20.

Page 122 of the CCME report
Response: This page provides a summary of the process as it was explained to Hydromantis by N-Viro staff. It remains generally correct; however, the Herring Cove plant has come on-line since the CCME report was prepared. Liquid sludges from the smaller HRM plants are taken to the Aerotech facility, where they are dewatered and then transported to the nearby N-Viro site for processing. During a site visit to the N-Viro facility in April of this year, it was noted that sludges are still treated in batches rather than being blended at the facility. The operating summary as stated on page 122 of the CCME report appears to be factually correct.

Conclusion 13: "The thermal drying process (pelletisation) alone was not efficient in the reduction of ESOC, acknowledging that it was not intended for that purpose."
Response: The thermal drying process examined was operated in Smiths Falls, Ontario. It is a process substantially different than Halifax's N-Viro process, because the Smiths Falls process relies only on heat treatment for drying and pathogen reduction. The N-Viro process mixes

alkaline material, either cement kiln dust, lime or both which results in an exothermic (heat-liberating) reaction and raises the pH of the mixture to slightly above 12.0, liberating ammonia. Additional heat is then provided to dry the material to the product specifications.

Conclusion 14: "Mechanical sludge dewatering processes alone are among the least effective for reducing concentrations of ESOC in the feed sludge."
Response: Mechanical dewatering is used to increase the solids content of sludge, by removal of free water, for more cost-effective treatment and transport to a management site. This conclusion was based on examining the results from two facilities in Saguenay, QC and Gander, NL. Untreated sewage sludges were dewatered at these locations prior to disposal by methods acceptable to the respective provincial governments. Mechanical dewatering has never been considered as a biosolids treatment process, because no pathogen reduction is involved. Mechanical dewatering is practiced in the Halifax Harbour Solutions Project (HHSP) plants; however, liquid sludge from the other plants is transported to the Aerotech facility for dewatering. All dewatered sludge is then transported to the N-Viro facility for processing to turn it into biosolids acceptable as a soil amendment.

Conclusion 15: "A few pharmaceutical compounds appear to be removed readily by either aerobic or anaerobic biological treatment, including sulfamethoxazole, trimethoprim, caffeine and diltiazem."
Response: Biodegradation of pharmaceutical compounds is governed by a number of factors, including chemical structure, water solubility, temperature, and the presence of enzyme systems in aerobic and anaerobic microorganisms that are capable of degrading the compounds as an energy source. The compounds listed were those that appeared to undergo biodegradation in either aerobic or anaerobic environments. Other compounds were biodegradable in one of these environments, but not the other. Still other compounds appeared to be resistant to biodegradation in both of these environments.

Conclusion 20: "A combination of processes (e.g. anaerobic digestion plus dewatering plus composting as at Prince Albert; lime stabilisation plus composting as at Moncton) result in the highest reductions of many ESOC."
Response: A combination of processes, which can degrade ESOC by different pathways does in fact appear to offer the most effective reduction of these compounds. This approach is similar to the "multi-barrier" approach for the protection and treatment of drinking water supplies. Some HRM plants use a combination of processes, i.e., anaerobic digestion followed by the N-Viro process.

We emphasize Conclusion 12: "Of the physical processes (including physical-chemical processes), the N-Viro alkaline stabilisation process appeared to offer the best performance for ESOC removal".

We note that none of the biosolids treatment processes were specifically designed or intended to reduce concentrations of ESOC in the feed sludge material.

5. Is Sewage fertilizer safe? (dated July 12, 2008) by Carola Vyhnak
http://www.healthzone.ca/health/newsfeatures/article/459085--is-sewage-fertilizer-safe

Carola Vyhnak is a Toronto Star reporter who presents a summary of mainly negative information about land application of biosolids in Ontario, including a list of alleged adverse health effects. Absent in this article is information that land application of biosolids in Ontario is considered normal agricultural practice, which is carefully managed and monitored, and which is endorsed by the Ministries of Agriculture, Food and Rural Affairs and of Environment.

6. The Chronicle Herald article "Let's get the real poop on biosolid costs" – by Marilla Stephenson (2010-11-16).

Marilla Stephenson's lead comment in her column: "WELL, THEY HAVE to dump it somewhere" is absolutely correct. The options for dealing with HRM biosolids, however, are very limited: (1) incineration, (2) landfilling and (3) land application.

Incineration - would require enormous additional capital outlay, and waste the nutrient value of the biosolids. Halifax Water staff indicates that it is not a viable biosolids management option.

Landfilling – Most jurisdictions in Canada have moved to ban or at least reduce landfilling organic materials. In Nova Scotia, landfilling of unstabilized organics is against the law. Landfilling the HRM N-Viro soil amendment (NVSA) product would be a waste of a valuable soil amendment material as indicated under land application (see paragraph after next below).

Land application - Application on agricultural, forestry or disturbed lands may be the only options for management of the HRM NVSA product. The NVSA product contains approximately 50% lime, considerable organic matter and small amounts of nitrogen, phosphorus, and potassium – valuable plant nutrients - accompanied by acceptably low concentrations of heavy metals. Land applying this material to Nova Scotia's acid soils offers three beneficial effects as follows: increased soil pH, contribution to soil organic matter and supply of nutrients for crop production.

Field experiments conducted by Atlantic BioEnergy Corporation at 15 field sites in Central Nova Scotia during 2010 indicated that a combination of commercial fertilizer and NVSA product resulted in higher yields and more economic sugar production than either commercial fertilizer alone or a combination of commercial fertilizer and wood ash (LeBlanc 2011). Average costs per ton of sugar produced by these treatments were \$53.90, \$91.10 and \$63.40, respectively.

7. "Municipalities Can Ban Biosolids, Lawyer Says" by Gordon Delaney, The Chronicle Herald, at www.organicconsumers.org/articles/article_21882.cfm

It is true that municipalities may be able to ban the application of biosolids on private property. However, if they do, the question arises about what to do with the biosolids. As indicated in the response to question #6 above, HRM's biosolids management options are limited - and quality biosolids are valuable soil amendment materials.

HRM's NVSA product has low metal and pathogen concentrations and satisfies Nova Scotia's Class A biosolids guidelines. Numerous research studies conducted over many years have shown that land application according to regulations/guidelines of biosolids similar to HRM's NVSA product is safe practice.

Philosophically, it is reasonable to recycle urban organic waste materials to rural lands. Foodstuffs produced in rural areas and consumed in cities and towns represent losses particularly of nutrients from agricultural land. These losses can be reversed, at least partially, by recycling quality urban organic wastes back to rural lands. Moreover, as the world supply of phosphate rock becomes increasingly limited, recycling phosphorus in "waste materials" will become critical to agricultural production.

8. Nova Scotia Environmental Network – submission by Dr. Marilyn Cameron, DVM, Chair, Biosolids & Waste Water Caucus, dated October 18, 2010 (circulated to council).

The submission by Dr. Marilyn Cameron, DVM that the Nova Scotia Environmental Network exhibits a strong negative bias against land application of biosolids. Responses to various comments or queries in the submission of Dr. Cameron follow:

Page 3: Dunbrack Street citizen complaints were justified if malodorous biosolids product was applied to their boulevard. Malodorous biosolids product should not be used in an urban setting. Based on the review of information in this study, the NVSA was co-mixed with an organic material of questionable stability just prior to the application on Dunbrack Street, followed that night by rain. This set of circumstances was optimum for potential odour generation. There is no evidence, however, that the NVSA on its own was responsible for the malodour, and that the problem may in fact have resulted from the unknown organic matter that was co-mingled with the NVSA.

Lead-contaminated soils in the USA that supported no plant growth have been reclaimed and their productivity restored using biosolids. Numerous studies have proven the value of biosolids for restoring vegetative cover on, and reducing metal leaching from acid, metal-contaminated mine tailings. Similarly, numerous studies indicate that biosolids enhance the soil ecosystem rather than detract from it.

Page 5: Numerous studies have shown that virtually all metals added to soils in biosolids applied at recommended agronomic rates remain in the layer of incorporation and represent no significant risk to groundwater or crop quality.

The organic contaminants listed are pharmaceuticals and constituents of household products; human exposure to them in the household is orders of magnitude greater than from land applied biosolids.

Page 6: Detailed studies support the validity of the US EPA (1993) standards and to claim otherwise is to call into question the knowledge, integrity and expertise of a very large number of scientists and engineers, past and present, whose foremost interest has been maintenance of environmental and food safety. Present analytical equipment for organic contaminants is exceedingly sensitive and identification in biosolids does not imply environmental or human health risk.

Page 7: Almost all bacteria, good and bad in biosolids, are destroyed by the high alkalinity, heat, and high ammonia concentration experienced during the N-Viro process. Since pathogens live and multiply in animal bodies, they are much less likely to survive N-Viro processing than environmentally adapted organisms. Thus, regrowth of pathogens originating in the N-Viro product after mixing with soil is highly unlikely. It is possible however, that after application to land, NVSA can provide a medium for growth of pathogenic organisms deposited in the feces of domestic and wild animals, or birds.

Page 9: The Halifax NVSA has very low metal concentrations and is a high quality biosolids product. It contains lime, organic matter, nitrogen, phosphorus, potassium and micronutrients all of which are valuable soil amendments. Applied to soil at agronomic rates, it represents no significant environmental or animal health risk.

Page 13: There is no purpose in treating biosolids with cement kiln dust (CKD) prior to incineration and doing so would not "result in any net gain in energy production or environmental protection". The CKD would actually increase the quantity of ash that would require disposal in a landfill, a waste of the landfill capacity. Energy recovery from biosolids would require a large capital outlay in addition to that already expended for the N-Viro Process. Considering the high quality of the NVSA product, there seems little reason to do other than continue with land application of this material.

Page 15: The reported claim by Dr. Lewis "that the use of unreliable data by US EPA, USDA (US Department of Agriculture), NAS (National Academy of Science) and other federal agencies to defend their scientifically questionable policies in these areas is a common practice that is eroding scientific integrity" is a scientifically unsupported opinion that calls into question the knowledge, integrity and expertise of a large number of scientists and engineers, past and present, whose foremost interest has been maintenance of environmental and food safety.

7. Response to Questions Submitted to HRM Council

A substantial number of questions were posed by HRM Council regarding biosolids management leading to this review. The full list of questions is provided in **Appendix C**. As noted in the Appendix, questions related to HRM policy or procedures will be addressed separate from this report by HRM staff.

This section responds to the specific questions of a technical nature posed in the Terms of Reference for the process review, and are responded to by the Project Team in the order of listing there.

1. **Is the soil amendment product N-Viro currently being used on farms in and around HRM?**

   Yes. Most farms that are using N-Viro are within a 100 km radius of the plant with some as far as 200 km. These farms have seen a significant improvement in their soil health. They have increased their soil pH and nutrient levels which has increased their crop quality and yield. [Note: answer provided by Lise LeBlanc, LP Consulting, Ltd.]

2. **How are pollutants removed from the product to obtain a Class A soil (items such as "Drano", household cleaners, pharmaceuticals, etc.)?**

   The N-Viro process involves treating sewage sludge with a highly alkaline agent (e.g., quicklime (CaO), cement kiln dust) which is intended to reduce the levels of pathogenic organisms, and reduce the putrescible fraction and odorous materials in the sludge. Class A refers to a designation established by the United States Environmental Protection Agency (U.S. EPA) for pathogen reduction only.

   The N-Viro process is neither designed nor operated to reduce the household chemicals, pharmaceutical and personal care products noted in the question. However, N-Viro was one of 11 biosolids treatment processes investigated by the Canadian Council of Ministers of the Environment (CCME) to assess the effects of treatment process on emerging substances of concern (ESOC) (http://www.ccme.ca/assets/pdf/pn_1445_biosolids_esoc_final_e.pdf). In terms of overall reduction of the target analytes (pharmaceuticals, anti-microbials, alkylphenolics and synthetic fragrances), the N-Viro process ranked lower than aerobic composting, as practiced in Moncton and other sites, but higher than other sites using anaerobic digestion and thermophilic aerobic digestion, for example. Moreover, the N-Viro results that were observed should be considered as a minimum achievable by the process, because the samples for evaluation were collected following admixture of the alkaline material to raw sludges and from the finished product bin.

3. **Is there any difference between Sewage Sludge and Biosolids?**

   Biosolids are sewage sludge that has been treated to significantly reduce pathogens to levels that present either no significant human and environmental health risks (Class A) or reduced risks (Class B) when the Biosolids are land applied (Chapter 5 of "A Plain English Guide to the EPA Part 503 Biosolids Rule" http://water.epa.gov/scitech/wastetech/biosolids/503pe_index.cfm).

4. Could any of the pathogens/microbes in the N-Viro Soil Amendment be "reactivated" once introduced to heat/water?

The N-Viro process involves treating sewage sludge with a highly alkaline agent (e.g., calcium oxide (CaO), cement kiln dust) to produce Class A biosolids with no detectable pathogens. Pepper *et al*. (2008) suggest that regrowth of *Salmonella* bacteria is possible if Class A biosolids become saturated with water, and anaerobic (absence of oxygen) conditions develop. However, for normal agricultural land application rates, the depth of the biosolids layer is so thin that anaerobic conditions will not occur.

A more likely possibility is that opportunistic pathogens residing in animal droppings (e.g., dogs, waterfowl) or the soil, may grow and reproduce using available nutrients and energy from the surface applied biosolids (Brown, 2011).

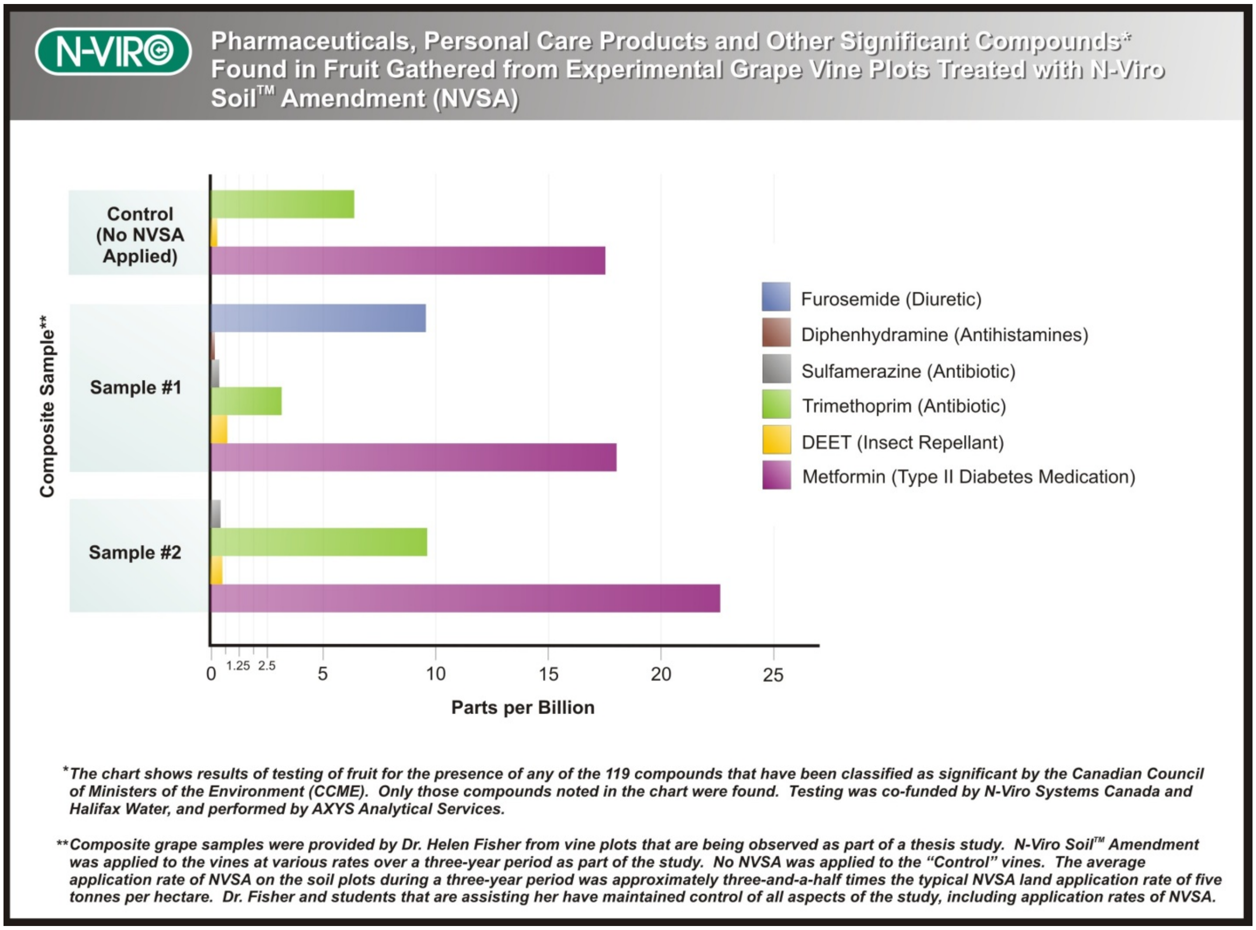
5. Research done by the Guelph University on use of N-Viro Soil Amendment on grape crops showed three pollutants found in the control test section. What were the three pollutants? Were these pollutants found in the grapes grown in that soil?

University of Guelph research at Vineland involved three annual applications of N-Viro Soil Amendment (NVSA) to grape vineyards at rates 3 to 7 times the 5 tonnes per hectare recommended rate for agricultural soils (http://www.n-viro.ca/nviro/research-reports). The research objective was to investigate the effect on grape vine growth and fruit bearing capacity and to test fruit for the presence of any of the 71 ESOC (Emerging Substances of Concern) included in the most detailed biosolids sampling programs that have been classified as significant by the Canadian Council of Ministers of the Environment (CCME).

Analyses indicated that 6 of the 71 (not 119 as is indicated in the Figure below) ESOCs were detected at concentrations ranging from 0.3 to 22 ppb (parts per billion = µg/kg) in the NVSA treated grape fruit (see Figure). The compounds detected were Furosemide (diuretic), Diphenhydramine (antihistamine), Sulfamerazine (antibiotic), Trimethoprim (antibiotic), DEET (insect repellent) and Metformin (Type II diabetic medication). Three of the compounds; Furosemide, Trimethoprim and Metformin also were detected in the control (untreated) grapes fruit indicating that their presence was unrelated to NVSA treatment.

Current analytical equipment for organic analyses is very sensitive and although concentrations shown in the Figure below appear significant, they are extremely small. They are expressed in "parts per billion" (ppb) which are one thousand times smaller than "parts per million" (ppm = mg/kg). Common examples of 1 ppm concentrations are: (a) 1 drop of water in 132 gallons of water; 1 gallon of paint in one million gallons of water; 1 pound of salt spread over 500 acres of land; and 1 gallon of sand in 495 dump trucks of soil (http://extension.missouri.edu/publications/DisplayPub.aspx?P=WQ427).

Considering that the 3 ESOC's attributed to NVSA application were medications taken orally by humans probably in milligram amounts, it is unlikely that the extremely small concentrations observed in grapes represent any health risk to humans.



6. Is the N-Viro Soil Amendment product suitable for use on athletic fields?

The lime, organic matter and nutrients in NVSA product would be beneficial for turf growth on athletic fields and since it contains no detectable pathogens, there is negligible risk of disease transmission to athletes. However, it is highly alkaline during treatment (pH>12) and because of unreacted alkali, remains so for some time after treatment during storage (pH>11) and can cause skin and respiratory irritation.

Following land application, the unreacted alkali in NSVA product is neutralized by contact with carbon dioxide from the atmosphere, reducing the pH to approximately 8 and eliminating any health concerns from dermal exposure or dust inhalation. The rate of neutralization depends on many factors including the initial pH, the depth of the applied NVSA, atmospheric temperature, wind velocity and precipitation and relative humidity. Thus, athletic field use should be delayed for at least 2-weeks following NVSA application to insure complete alkali neutralization and avoidance of health risks.

7. Once treated to a Class A Biosolid standard, is the product in any way considered "sludge"?

The distinction between "Biosolids" and "Sewage Sludge" is one of definition. As indicated in the response to question #3 above, biosolids are sewage sludge that has been treated to reduce pathogens to levels that present either no significant human and environmental health risks, or reduced risks when the biosolids are land applied. Class A biosolids are sewage sludge that has been treated to present no significant human and environmental health risks and, by definition, are not "sludge".

8. How does Class B Biosolids compare with commercial fertilizer? Are there any standards for fertilizer?

Class B Biosolids are mainly organic materials with small concentrations of major plant nutrients (e.g., 2% – 5% of nitrogen (N) and phosphorous (P)), trace concentrations of micronutrients (e.g., copper (Cu), molybdenum (Mo) and zinc (Zn)) and low levels of pathogenic organisms. By contrast, most commercial fertilizers are inorganic products with large concentrations of major plant nutrients (e.g., >10% each of N, P and K), no significant micronutrients and no pathogens. Some commercial fertilizers prepared primarily for home garden use, have significant organic contents but they have been treated to eliminate pathogens. Milorganite®, a commercial fertilizer that has long-standing use as a slow release organic nitrogen fertilizer, and sold locally in Halifax (see **Figure 7**), is biosolids produced by the Milwaukee Metropolitan Sewerage District.

Figure 7. Bag of Milorganite® Fertilizer Purchased from a Halifax Retail Outlet

There are standards for fertilizer and they are defined in Regulations (http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._666/index.html) under the federal Fertilizers Act (http://laws-lois.justice.gc.ca/eng/acts/F-10/). Commercial fertilizers must be registered and labelled to indicate minimum guaranteed concentrations of the nutrients, pesticides, inoculants, etc. they contain. Their quality is monitored by the Canadian Food Inspection Agency.

9. How does N-Viro Soil Amendment compare to commercial fertilizer.

NVSA and commercial fertilizer are similar in that they contain plant nutrients and few if any pathogens. However, NVSA has a much higher organic matter content and lower nutrient content than most commercial fertilizers and it is an effective soil liming material. NVSA has lower metal concentrations than various formulations of Milorganite, the biosolids-based commercial fertilizer from Milwaukee, as indicated in **Table 15** (provided by LP Consulting, Ltd.).

Most commercial fertilizers acidify rather than lime soils. Recent studies have shown that soil microbial activity (the health of soil microorganisms) is enhanced by soil amendment with biosolids as compared to commercial inorganic fertilizer (Pepper *et al*., 2008; Young *et al*., 2011).

10. Include information on the condition of the land in Nova Scotia in regard to it having been "overused" and some information on "balance" between the Class A product N-Viro produces and fertilizer.

Agricultural production involves changing the soil ecosystem from its natural forested or grassland state and generally results in reduced soil organic matter and nutrient contents and increased erosion risk. Although these effects may be interpreted as "overuse" or abuse of soils, they can be stopped and/or reversed and maintained using appropriate management practices. European soils, productive after centuries of agricultural use provide tangible evidence that soil quality and productivity can be sustained.

"Soil Health in Nova Scotia - Soil Test Indicators of Soil Health in Agricultural Soils, May 2009" (LP Consulting Limited 2009) reports that a large majority of Nova Scotia soils have optimum concentrations of organic matter, sulfur (S), zinc (Zn), copper (Cu), boron (B) and manganese (Mn) but less than optimum concentrations of phosphorus (P_2O_5), potassium (K_2O), calcium (Ca) magnesium (Mg) and pH levels for agricultural production.

Less than optimum pH, Ca and Mg levels in Nova Scotia soils result from leaching caused by a combination of acid rain from Ontario, Quebec and the eastern seaboard of the USA, and a lack of natural alkalinity in the water and soil systems. Less than optimum levels of phosphorus and potassium probably result from crop uptake and naturally low levels in the soils.

Table 15. Comparison of Metal Concentrations in NVSA, Livestock Manures and Commercial Fertilizers

Units DWB (mg/kg, ppm) * all numbers rounded to nearest decimal * colored cells indicate higher levels than HRM N-Viro

	Canadian Food Inspection Agency (CFIA) Regulation	Nova Scotia Class A	Halifax N-Viro 3 yr Avg	Milorganite Garden Care 6-2-0	Milorganite Organic N Fertilizer 5-2-0	Milorganite Classic with 4% Iron 6-2-0	Hog Manure	Poultry Manure	Nova Scotia Ag Lime	Acadian Seaplants Kelp Meal 1-0.15-2	Lawn Fertilizer 30-3-3	Organic Alaska Fish Fertilizer	Specialty Organic Fertilizer 5-4-5
Arsenic	75	13	4	13.0	9.6	7.2	1	30	10	15	10	7	12
Cadmium	20	3	0.2	6.1	7.0	6.1	2.5	1.3-7.8	0.7	0.1	0.5	0.7	4
Chromium	NA	210	15	No Data	No Data	No Data	2.4	20	164	No data	No data	No data	123
Cobalt	150	34	2	6.7	6.2	5.4	No data	No Data	No Data	0.2	7	0.7	No data
Copper	NA	400	119	No Data	No Data	No Data	364	1195	10	No data	0.05	No data	270
Lead	500	150	67	120	120	120	33	12 - 34	55	1	16	3.5	85
Mercury	5	0.8	0.1	2.7	2.7	2.7	No data	No data	0	0.05	0.05	0.1	0.4
Molybdenum	20	5	3	15	18	15	8	No data	24	7	4	No data	No data
Nickel	180	62	9	10	42	40	9	No data	20	1	25	1.4	31
Selenium	14	2	2	5.0	6.3	5.8	No data	No Data	No Data	6	10	No data	No data
Zinc	1850	700	267	760	840	760	403	631	113	18	2168	25	3488

CFIA – See table 2 (http://www.inspection.gc.ca/english/plaveg/fereng/tmemo/t-4-93e.shtml)
NS – See page 5 (http://www.gov.ns.ca/nse/water/docs/BiosolidGuidelines.pdf)
HRM N-Viro 3 year average - http://www.n-viro.ca/nviro/results-nova-scotia. Tested by SCC certified A&L Laboratories, Ontario.
NS Ag Lime – as reported by RPC, Science & Engineering, Fredericton, NB. http://www.rpc.ca/english/index.html
Manure data base – Trace Metals in New England Biosolids and averages in other materials (http://www.biosolids.com/Headlines/pdf/SavingSoilChapter3.5.pdf), Heavy metal contents in commonly used animal manure http://www.agridept.gov.lk/content/admin/pdf/Heavy%20Metal%20Contents%20in%20Commonly%20Usedanimal%20Manure.pdf, http://www.ramiran.net/doc98/FIN-ORAL/CHAMBERS.pdf
Fertilizer data base - Washington State Department of Agriculture, Metals in Fertilizers, Fertilizer Product Database (http://agr.wa.gov/PestFert/Fertilizers/Metals.aspx), (includes Milorganite) EPA Background Report on Fertilizer Use, Contaminants and Regulations (http://www.epa.gov/oppt/pubs/fertilizer.pdf)

The NVSA product contains significant amounts of lime, calcium, magnesium, phosphorus and potassium. Land application of this material would increase the pH of Nova Scotia soils and supply necessary plant nutrients. Moreover, it would act as a slow release fertilizer because the organic matter it contains would mineralize slowly, releasing nutrients over an extended period of time. By contrast, commercial inorganic fertilizers release nutrients (particularly nitrogen and potassium) rapidly, and contribute to soil acidification/degradation. Thus, land application of NVSA product offers several advantages over commercial inorganic fertilizer use on Nova Scotia soils.

11. What standards are used to determine if a biosolids is "safe"?

Sale of processed biosolids as fertilizer/soil amendment products is governed federally according to Canadian Food Inspection Agency Trade Memorandum "T-4-93 - Standards for Metals in Fertilizers and Supplements" (http://www.inspection.gc.ca/english/plaveg/fereng/tmemo/t-4-93e.shtml).

Biosolids give-away programs are regulated provincially; for this purpose, Nova Scotia has Ministry of Environment "Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia (revised March 2010)" which define biosolids quality criteria (metals and pathogens) and several soil and siting requirements for "safe" land application practice.

12. How are pharmaceuticals destroyed in biosolids products?

It is important to note that biosolids treatment processes are neither designed nor operated specifically to destroy pharmaceuticals. They reduce pathogens to levels that are safe for use as a soil amendment either as Class A or Class B biosolids (see discussion from questions #3 and #7). However, a recent study by the Canadian Council of Ministers of the Environment (CCME) examined the potential for different biosolids treatment processes to reduce the incoming mass of pharmaceutical, anti-microbial compounds, alkylphenolics and synthetic fragrances (emerging substances of concern, or ESOC) present in raw untreated sewage sludge (http://www.ccme.ca/assets/pdf/pn_1445_biosolids_esoc_final_e.pdf). Although aerobic composting appeared to be the most successful biosolids treatment process in terms of reducing the pharmaceutical and other compounds in raw sludges, the N-Viro process appeared to be the next most efficient process in terms of reduction of these ESOC. Heat drying alone was not very successful in reducing concentrations of pharmaceuticals and other ESOC in biosolids.

Pharmaceuticals have various physico-chemical properties which will affect their destruction during sludge treatment. Most are not very volatile, which means they are not lost to the atmosphere to any extent. Compounds with some water solubility (e.g. sulfamethoxazole) are susceptible to rapid microbial degradation. Compounds with little or no water solubility are likely to adsorb to the biosolids matrix and degrade very slowly if at all. Still others may be susceptible to ultraviolet light and are destroyed following surface application of biosolids on soil.

13. What are the heavy metals/pharmaceuticals that could be found in the product and what are the concerns associated with those materials?

The concerns associated with heavy metals and organic contaminants (including pharmaceuticals) in biosolids products are that when the products are applied to land, the contaminants will accumulate in the cultivated layer of soil and following repeated applications could theoretically accumulate to toxic concentrations which might adversely affect for example, crop growth and quality, soil fertility and the food chain.

The heavy metals of primary concern in biosolids products are cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), mercury (Hg) and zinc (Zn), arsenic (As), molybdenum (Mo), selenium (Se), cobalt (Co) and chromium (Cr). However, whereas all biosolids guidelines/regulations contain limits for Cd, Cu, Ni, Pb, Hg and Zn, not all contain limits for As, Mo, Se, Co and Cr (http://www.ccme.ca/assets/pdf/pn_1446_biosolids_leg_review_eng.pdf and http://ec.europa.eu/environment/waste/sludge/pdf/part_iii_report.pdf).

Present concerns about metals in biosolids are often a legacy resulting from practices in past decades when industries discharged metal-bearing effluents directly to municipal sewers. Due to implementation and enforcement of municipal sewer use bylaws, concentrations of metals in Canadian biosolids have declined greatly in the past 30 years. For example, the CCME survey of biosolids treatment processes found that relative to 1981 levels, concentrations of cadmium, chromium, nickel and lead have declined ≥93% while mercury, molybdenum and zinc have declined ≥76%. When biosolids are applied at appropriate agronomic rates, metal concentrations do not pose a human or environmental threat.

The list of potential organic contaminants that have been detected in sludge is extensive and includes: products of incomplete combustion (polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and dioxins), solvents (e.g. chlorinated paraffins), flame retardants (e.g. polybrominated diphenyl ethers), plasticisers (e.g. phthalates, Bisphenol A), agricultural chemicals (e.g. pesticides), detergent residues (e.g. linear alkyl sulphonates, nonylphenol ethoxylates), pharmaceuticals and personal care products (e.g. antibiotics, endogenous and synthetic hormones, triclosan, synthetic fragrances, insect repellents and sunscreens) (http://www.ccme.ca/assets/pdf/pn_1440_contam_invt_rvw.pdf and http://ec.europa.eu/environment/waste/sludge/pdf/part_iii_report.pdf).

Analytical instrumentation is capable of detecting minute quantities of these organic contaminants, at concentrations in the parts per billion or parts per trillion range. Most of these contaminants are therefore at concentrations that do not appear to pose a significant risk to humans or terrestrial organisms, although research is continuing to identify to confirm the absence of risk.

14. What are the environmental impacts of biosolids/biofuels?

The following two part response assumes that biosolids are used as: (1) fuel to be burned for energy (e.g., heat, electricity) production and; (2) fertilizer/soil conditioner for biofuel crop (e.g., poplar trees, quack grass) production.

As indicated in the response to question #12 above, a major concern about land application of biosolids is contaminant accumulation in soil resulting in adverse food chain effects. Biosolids use as fuel for energy production avoids this concern because the contaminants do not enter the food chain. Moreover, biosolids are a green energy source and they reduce the need for fossil fuels thereby avoiding release of fossil carbon dioxide, a major contributor to global warming. Biosolids contain a substantial fraction of inert matter that becomes ash upon combustion; this ash must be disposed of in some manner, usually in a landfill. Biosolids are valuable fertilizers/soil conditioners and these properties are wasted when they are used as fuel.

Using biosolids as fertilizer/soil conditioner for biofuel crop (e.g., poplar trees, quack grass, corn starch, sugar) production recycles valuable nutrients and organic matter to soils. In the absence of biosolids, the nutrients for production of these materials are supplied as commercial fertilizer, the production of which is energy intensive and involves large fossil carbon dioxide emissions.

15. Even though the product is not used on food crops, cows may ingest it. What are the implications for milk consumers, particularly children?

Since the NVSA product is a Class A material with no detectable pathogens the response to this question focuses on constituents of potential concern - heavy metals and organic contaminants.

As indicated in the response to question #13, the heavy metals of primary concern in biosolids products are cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), mercury (Hg) and Zinc (Zn), arsenic (As), molybdenum (Mo), selenium (Se), cobalt (Co) and chromium (Cr). Following a thorough review of research it was concluded that Ontario's land application guidelines for these metals "are adequate to protect the wellbeing of soils, crops, animals, humans and ground and surface water qualities" (http://www.weao.org/committees/biosolids/weao-report/weao-study.html). Since Nova Scotia's guidelines are equal to or more conservative than those for Ontario, they provide equal or greater protection. Similar protection is claimed for the more liberal risk-based U.S. EPA Part 503 heavy metal limits, which were derived based on a child directly ingesting biosolids. This pathway resulted in significantly lower limits than would have been the case had they been set by human food-chain pathways involving consumption of food crops, meat or dairy products (http://books.nap.edu/openbook.php?record_id=5175&page=6).

Hebert (2011) reported that concentrations of indicator metals copper and molybdenum in the milk from dairy cows grazing on fields in Quebec that had received long-term amendments of municipal biosolids (N=14 sites) were no different than levels in milk from cows grazing on control sites without biosolids amendments.

Studies of some marker compounds at long-term biosolids amendment sites suggest that organic compounds without a high degree of halogenation (i.e. without chlorine, bromine, fluorine or iodine) undergo rapid degradation in soils. For example, Xia *et al*., (2010) examined the fate of 4 anthropogenic organic compounds in a Chicago-area soil receiving biosolids over a 33-year period. Three of the four compounds, namely 4-nonylphenol and the antimicrobial compounds triclosan and triclocarban were subject to rapid transformation in the soil column, while the polybrominated diphenyl ethers (PBDEs) flame retardants underwent slow degradation. Of the four compounds, all but triclosan were found to be tightly bound to the upper 15 cm of soil and had limited mobility downwards in the soil column.

However, reviews to date (2011) of the approximately 20-year extensive body of research conclude that organic contaminants in land applied biosolids are unlikely to have an adverse effect on human and environmental health and will be increasingly controlled and their concentrations reduced by industrial regulation. However, contaminants such as diethylhexyl phthalate (DEHP) and chlorinated paraffins, found in biosolids at significant concentrations require further research as do contaminants such as pharmaceuticals, whose behaviour and fate in waste water, sludge and soil is unclear at present (http://ec.europa.eu/environment/waste/sludge/pdf/part_iii_report.pdf).

16. Include all CCME reports/documents as part of the research for this report.

Research for this report includes information from the following CCME reports:
Emerging Substances of Concern in Biosolids: Concentrations and Effects of Treatment Processes (http://www.ccme.ca/assets/pdf/pn_1440_contam_invt_rvw.pdf).
A Review of the Current Canadian Legislative Framework for Wastewater Biosolids (http://www.ccme.ca/assets/pdf/pn_1446_biosolids_leg_review_eng.pdf).
Emerging Substances of Concern in Biosolids: Concentrations and Effects of Treatment Processes - Field Sampling Program Final Report (http://www.ccme.ca/assets/pdf/pn_1445_biosolids_esoc_final_e.pdf).

17. Include information on implications of dermal contact and dust inhalation from the N-Viro Soil Amendment product, commercial fertilizer and animal manure.

NVSA product is produced by treating dewatered sewage sludge with approximately equal parts dry weight of highly alkaline cement kiln dust. During the treatment, a combination of the following biological stresses: alkaline pH, high temperature, accelerated drying and high ammonia (NH_3) and salt concentrations destroy pathogens. High pH (12+) is attained during treatment and it remains high (11+) following treatment.

The NVSA product is a Class A biosolids that presents no significant pathogen risk from dermal contact or dust inhalation. However, it contains considerable free lime (CaO, MgO, K_2O), which upon dermal contact and dust inhalation could cause dermal and respiratory irritation. Thus for example, it is recommended that personnel handling Halifax NVSA product wear a long-sleeved shirt, long pants extending over the tops of work boots, gauntlet type work gloves, eye goggles and a NIOSH (National Institute of Safety and Health) approved dust respirator (Halifax Product Label – October, 2008 http://www.n-viro.ca/bank/pageimages/Product%20Labels/HSA-label-2008-12-03-151934.pdf). Following land application, the unreacted alkali in NSVA product is neutralized rapidly by contact with carbon dioxide in the atmosphere, reducing the pH to approximately 8 and eliminating any health concerns.

Commercial fertilizers are sterile and handling them poses no pathogen risk. Similarly, dust is minimized because they are supplied as pellets or granules. However, they are chemical compounds that particularly in combination with moisture can irritate tissues such that precautions need to be observed when handling them.

Animal manures, like NVSA product and commercial fertilizers contain nutrients and organic matter and are valuable soil amendments. However unlike those products, animal manures generally receive no treatment prior to land application and they contain pathogens that can be transmitted to other animals and to humans through food supplies and water (http://www.ars.usda.gov/is/np/agbyproducts/agbycontents.htm).

Care should be taken to avoid dermal contact and to wash thoroughly after handling manure. In general, animal manures have high water contents and pose no dust inhalation problem although they may be highly odorous with a strong ammonia smell.

18. Include information on comparative risks of animal manure and fertilizer issues as well in the context of the report.

As indicated above (question #17), land application of animal manures can pose significant pathogen and odour risks whereas commercial fertilizers are odourless and sterile. **Table 16** is a summary of pathogen concentration data in livestock manures from several technical publications. In **Table 16**, concentrations of pathogens in manure are of a magnitude similar to raw municipal sludge. After biosolids treatment however, the pathogen concentrations are greatly reduced.

Table 16. Pathogen Concentrations in Livestock Wastes and Municipal Biosolids

	Waste Material				
Pathogen	**Dairy Manure**	**Poultry Manure**	**Municipal Sludge**[a]	**Class A Biosolids**	**Class B Biosolids**
Fecal coliform (MPN/g)	13,000,000[b]	5,000,000[b]	>2,240,000	76[b]	104,000[b]
E. coli O157 (cfu/g)	3-50,000[c]				
Salmonella (cfu/g)	20 - 50,000[c]				
Enterovirus			11,000		
Mycobacterium paratuberculosis (cfu/g)	1,000,000[c]				
Viable *Ascaris* eggs			407		

MPN – Most Probable Number
cfu – Colony Forming Units
[a] Smith and Surampalli, 2007.
[b] http://www.n-viro.ca/nviro/regulations
[c]http://www.vetmed.ucdavis.edu/vetext/INF-DA/Pathog-manure.pdf. (J.H. Kirk. Pathogens in Manure)

In addition to the pathogens for which there are data in **Table 16** above, Reference ``c`` (Kirk) indicates the potential pathogens shown in **Table 17** for livestock and humans found in bovine manure.

Table 17. Additional Pathogens Potentially Found in Bovine Manure

Bacteria	Protozoa	Viruses
Listeria monocytogenes	*Cryptosporidia parvum*	Bovine Diarrhea Virus
	Giardia spp.	Coronavirus
		Foot and Mouth Disease Virus

As well, manures often contain high levels of antibiotics and growth hormones used to ensure animal health and early marketability. **Table 18** provides representative concentrations of antibiotics detected in manure from swine and poultry lagoons.

Table 18. Concentrations of Antibiotic Pharmaceuticals in Swine and Poultry Manure Lagoons

Antibiotic	Concentration	
	Liquid basis	Dry Basis
Lincomycin	2.5 – 240 μg/L	
Chlortetracycline	68 – 1000 μg/L	0.1 mg/kg
		<0.5 – 1.0 mg/kg
Tetracycline/Oxytetracycline	25 – 410 μg/L	4.0 mg/kg
		14.1 – 41.2 mg/kg
Sulfamethazine	2.5 – 380 μg/L	0.13 – 8.7 mg/kg
		0.2 – 7.2 mg/kg
Sulfamethoxine	2.5 μg/L	
Erythromycin	2.5 μg/L	
Penicillin G	2.1 – 3.5 μg/L	

Chee-Sanford *et al*., 2009.

Table 19 lists concentrations of the natural estrogenic hormones estrone and 17β-estradiol in several types of livestock manures. For comparison, concentrations of these estrogens from the U.S. EPA's Targeted National Sewage Sludge Survey of 2009 are also provided. Manure from milk cows contains levels of the estrogens that are comparable to concentrations found in municipal sewage sludges [Note: the EPA did not distinguish between untreated sludges and biosolids in their survey.] Manure from bulls was understandably low in these female hormones, while concentration of the estrogens in swine manure were lower than for either dairy cow manure or municipal sludge.

Concentrations of metals in NVSA, livestock manures and commercial fertilizers were documented in **Table 15** in Question #9.

Table 19. Concentration of Estrogenic Hormones in Livestock Manures

Manure slurry	Concentration (ug/kg TS)	
	Estrone	**17β-Estradiol**
Milk cows [1]	225-640	170-1230
Bull [1]	<2	<2
Swine [1]	<2-84	<2-64
U.S. Biosolids [2] (74 facilities)	27-965	22-355

[1] Shore and Shemesh, 2003.
[2] U.S. EPA. 2009.

Otherwise, the risks associated with land application of manures and commercial fertilizers are similar. Overuse and/or inappropriate spreading can cause water pollution resulting from runoff and leaching losses, and application on growing crops can cause ammonia and /or salt burn and reduced productivity.

19. What is the experience regarding acceptance of biosolids products for land application in other jurisdictions (Moncton, New Brunswick was especially mentioned as having a positive experience)?

Current annual production of sewage biosolids in Ontario is approximately 300,000 dry tonnes of which 120,000 tonnes (40%) are spread on agricultural land as fluid or dewatered materials; 120,000 tonnes are landfilled and 60,000 tonnes are subject to other processes (e.g., pelletization, N-Viro, incineration). About 15,000 of the 60,000 tonnes (25%) are treated by pelletization and N-Viro processes and also are land applied. Thus, approximately 135, 000 tonnes or 45% of annual Ontario biosolids production is used beneficially as fertilizer/soil conditioner on agricultural land.

The annual fertilizer value of sewage biosolids applied free-of-charge to Ontario agricultural land is approximately $5 million. Considering agriculture's current economic stresses, sewage biosolids is coveted by farmers and demand frequently exceeds supply. The rural public, particularly former urban dwellers, are generally less enthusiastic about land application of biosolids than are farmers but a combination of improved application technologies, effective public relations programs involving the Ministries of Environment (MOE) and Agriculture, Food and Rural Affairs (OMAFRA), municipalities, industry and farm and environmental groups, and careful monitoring and control of spreading operations has facilitated a successful land application of biosolids program in Ontario (http://www.omafra.gov.on.ca/english/nm/nasm/info/brochure.htm). As a consequence, there have been few recent public complaints about land application of biosolids materials in Ontario (Hale, 2011; Bonte-Gelok, 2011; McComb, 2011).

Moncton, New Brunswick composts the Greater Moncton Sewerage Commission (GMSC) sludge using wood chips as bulking agent and produces approximately 8500 tonnes of product per year (Richard, 2011). The compost is BNQ "Class A" Certified (unrestricted use designation) and products are prepared with two levels of screening – 3/4" (Compost Mulch) and 3/8" (Compost Soil Conditioner) particle sizes. Local residents are invited to take the products free-of-charge; whereas, landscapers pay for them (see attached GMSC Product Price List for 2010). The 3/8" product is popular with residents and frequently in spring there are long line-ups to obtain it. Landscapers and the municipality use the products as is or in manufactured soils primarily for landscaping and horticultural plantings. Each year since initiating composting, the GMSC has distributed all of its compost products locally and has received no complaints concerning their use. The Moncton compost products are safer for direct public use than NVSA because the composting does not make use of the strong alkali materials used in the N-Viro process.

The province of Quebec promotes land application of biosolids and the practice is regulated under "Guidelines for the beneficial use of fertilizing residuals" (http://www.mddep.gouv.qc.ca/matieres/mat_res-en/fertilisantes/critere/guide-mrf.pdf). A policy was launched in March 2011 to require a minimum of 60% organic matter recycling through methanization/composting/land application by 2015 and ban landfilling and incineration of organic wastes including biosolids by the year 2020 (http://www.mddep.gouv.qc.ca/matieres/pgmr/presentation_en.pdf). To encourage recycling prior to the ban, a tax of $20/ dry ton of material landfilled or incinerated has been levied to fund improved organic waste treatment processes. Thus, the Quebec government is using a variety of means including: policies, subsidies and a tax to promote land application of quality organic wastes including biosolids and discourage disposal of these materials (Hébert, 2011a).

In British Columbia large amounts of biosolids as dewatered cake, compost and manufactured soils are used for mineland reclamation and landfill cover and for various horticultural purposes such as landscaping soil and potting media (Mofidpoor, 2011).

Acceptance of biosolids land application is very much a local issue. McIvor (2011) has shown that with public outreach and education, biosolids in an urban garden setting (Seattle-Tacoma, WA area) is welcomed by the citizens.

20. What are the facts concerning a reported ban on the use of biosolids in Switzerland/Sweden, etc?

Land application of biosolids from meat processing plants was banned in Switzerland May 1, 2003 and of all biosolids was banned completely by 2006, with some exceptions granted for very small wastewater plants in remote regions. One report claims the ban was related to concerns about transmission of mad cow disease (http://www.weao.org/committees/biosolids/Feb12/Precautionary_Principle.pdf) and a second report (http://woodsend.org/swiss-bann-on-biosolids-in-agriculture-slowly-taking-force) indicates it resulted from several years of successful activism against application of societal chemical residues to land. There is no technical or scientific basis for the Swiss decision to ban land application. Instead, it was a decision based on the precautionary principle and probably the availability of biosolids incineration capacity (Smith, 2011).

Similarly, there is no technical or scientific basis for very restrictive German land application regulations that are motivated based on the precautionary principle and probably the availability of incineration capacity (Smith, 2011).

In Sweden, a voluntary agreement was signed in 1994 between the Swedish Environmental Protection Agency (SEPA), the Swedish Federation of Farmers (LRF) and the Swedish Water and Waste Water Association (VAV) concerning quality assurances relating to the use of sludge in agriculture (http://ec.europa.eu/environment/waste/sludge/pdf/sludge_disposal1_xsum.pdf). However, in October 1999 the LRF recommended that their members stop using sludge because of concerns about its quality (i.e., the precautionary principle). As with Switzerland and Germany, there is no technical or scientific basis for the Swedish decision to ban land application (Smith, 2011). Further detail concerning the controversy surrounding sludge landspreading in Sweden is available at the following websites: http://www.safesoil.com/sludgefood.htm and http://www.safesoil.com/recycl.htm.

The Netherlands too has effectively banned land application of biosolids by setting very restrictive loading rates. Rates are based on the precautionary principle and the fact that there is an oversupply of animal manure for land application and no capacity for biosolids. Some animal manure is exported to avoid nutrient overloading and groundwater contamination (Smith, 2011). Overall in Europe approximately 40% of biosolids was land applied in 2010 and in France and the UK the figures for land application were 65% and 70%, respectively (http://ec.europa.eu/environment/waste/sludge/pdf/part_i_report.pdf). Thus, land application is still actively used in Europe, and in recent years has accounted for an increasing proportion of biosolids in the UK (Smith, 2011).

Action was taken in the UK in the 1990s to restore confidence in land application of biosolids and gain support from farmers, their customers and the public at large. The key to this action was recognition that the problem was market and customer driven and that market demands for food safety exceeded the regulatory legislation and guideline requirements. An agreement called the "Safe Sludge Matrix" (1999) was developed between Water UK (for the water utilities) and the British Retail Consortium (BRC) representing retailers wanting assurance that biosolids recycling to land is safe. The negotiations leading to the agreement included input from various stakeholders such as farm organizations, food manufacturers, food processors and government agencies.

The "Safe Sludge Matrix" has resulted in generally positive public reaction to land application and to recent increases in this practice which now accounts for more than 1 million dry tons of the approximately 1.4 million dry tons annual UK biosolids production (Smith, 2011).

21. Is it fact/fiction that Class A sewage sludge is a potential killer?

There is no documented evidence that "Class A sewage sludge" is a potential killer. On the contrary, numerous detailed international studies conclude that land application of sewage biosolids whether Class A or B done according to existing regulations/guidelines is a safe and environmentally beneficial practice (http://www.weao.org/committees/biosolids/biosolids.html; http://extension.missouri.edu/publications/DisplayPub.aspx?P=WQ427; http://ec.europa.eu/environment/waste/sludge/pdf/part_i_report.pdf; http://www.ars.usda.gov/is/np/agbyproducts/agbycontents.htm and http://books.nap.edu/openbook.php?record_id=5175&page=R1.

The last reference is a report entitled "**Use of Reclaimed Water and Sludge in Food Crop Production"** and was prepared by a Committee on the Use of Treated Municipal Wastewater Effluents and Sludge in the Production of Crops for Human Consumption; Water Science and Technology Board; Commission on Geosciences, Environment, and Resources; National Research Council; and published by the National Academy Press; Washington, D.C.; 1996 and concludes as follows:

"In summary, society produces large volumes of treated municipal wastewater and sewage sludge that must be either disposed of or reused. While no disposal or reuse option can guarantee complete safety, the use of these materials in the production of crops for human consumption, when practiced in accordance with existing federal guidelines and regulations, presents negligible risk to the 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. Established numerical limits on concentration levels of pollutants added to cropland by sludge are adequate to assure the safety of crops produced for human consumption. In addition to health and environmental concerns, institutional barriers such as public confidence in the adequacy of the regulatory system and concerns over liability, property values, and nuisance factors will play a major role in the acceptance of treated municipal wastewater and sewage sludge for use in the production of food crops. In the end, these implementation issues, rather than scientific information on the health and safety risks from food consumption, may be the critical factors in determining whether reclaimed wastewater and sludge are beneficially reused on cropland."

22. Is there a risk of Listeria/E. coli outbreaks as a result of the use of N-Viro Soil Amendment product in land applications? What are the risks in regard to quality assurance? How safe is the cement kiln dust "additive"?

The NVSA is a Class A biosolids product that has been treated to significantly reduce pathogens to levels that present no significant human and environmental health risks such that it is recommended for use on land without site restrictions (http://water.epa.gov/scitech/wastetech/biosolids/503pe_index.cfm). There is no significant risk of a *Listeria*/E. coli outbreak as a result of recommended use of N-Viro soil amendment product in land applications.

For commercial sale, the quality of NSVA product is regulated under the Fertilizers Act and Regulations (http://laws-lois.justice.gc.ca/eng/acts/F-10/) and it must contain the minimum percentages of nutrients (e.g., N, P_2O_5 and K_2O) shown on a product label. The fertilizer also must not exceed maximum concentrations of certain metals, as discussed below. Quality assurance is provided by Agriculture and Agri-Food Canada's Food Inspection Agency (CFIA) whose staff sample and analyse commercial products to ensure compliance with the Fertilizers Act and Regulations. Approximately each calendar quarter, based on NVSA production rates, samples are analyzed for regulated metals, pathogens and other product quality parameters to ensure product safety.

Cement kiln dust is an industrial by-product that contains low levels of heavy metals. Concentration data in **Table 20** below indicate that the cement kiln dust "additive" used to prepare the Halifax NVSA is safe because heavy metal concentrations in the product comply with current Agriculture Canada regulations and Nova Scotia Class A guidelines for land application of biosolids.

Table 20. NVSA product and regulation/guideline heavy metal concentrations (mg/kg DS)

Heavy Metal	Halifax NVSA (Average 2007-2010)	Agriculture Canada/CFIA	Nova Scotia Land Application Guidelines	
			Class A	Class B
Arsenic (As)	4.0	75	13	75
Cadmium (Cd)	0.2	20	3	20
Chromium (Cr)	15	1100	210	1060
Cobalt (Co)	1.9	150	34	150
Copper (Cu)	122	850	400	760
Lead (Pb)	70	500	150	500
Mercury (Hg)	0.2	5	0.8	5
Molybdenum (Mo)	3.2	20	5	20
Nickel (Ni)	11	180	62	180
Selenium (Se)	2.0	14	2	14
Zinc (Zn)	267	1850	700	1850

23. Is there a risk of *Listeria*/*E. coli* outbreaks as a result of use of commercial fertilizer and animal manure in land applications? What are the risks in regard to quality assurance?

There is no risk of *Listeria*/*E. coli* outbreaks as a result of commercial fertilizer application to land because the production processes result in sterilized products. There is a high degree of quality assurance associated with production of commercial fertilizers and they must contain the minimum percentages of nutrients (e.g., N, P_2O_5 and K_2O) shown on their product labels. Agriculture and Agri-Food Canada's Food Inspection Agency (CFIA) sample and analyse commercial fertilizer products to ensure compliance with the Fertilizers Act and Regulations (http://laws-lois.justice.gc.ca/eng/acts/F-10/).

There is a risk of *Listeria/E. coli* outbreaks as a result of animal manure application to agricultural land because, other than possible storage for an extended period of time during which there may be some die-off of these pathogens, manure is not treated prior to spreading. Moreover, it generally is used on the land of farms on which it is produced, and there is unlikely to be any quality assurance associated with its management. Because of their close contact with manure, the handlers (usually the farm operators) are likely to be at greatest risk of *Listeria/E. coli* infection but animals grazing treated land also are at risk from possible manure and pathogen ingestion. Long experience, however, has shown these risks to be small because untreated manure application to agricultural land has been practiced for centuries without widespread human and animal disease problems and it remains accepted practice. *Listeria* spp are not monitored routinely to assess the quality of Class A or B biosolids. **Table 21** below reports on the concentrations of monitored pathogens in the Halifax NVSA over a three-year period, and compares them to the Nova Scotia Guidelines for land application of Classes A and B biosolids. Further research on the presence of bacterial species such as *Listeria, Helicobacter and Yersinia* in biosolids has been recommended.

Table 21. Comparison of Pathogen Levels in NVSA with Regulatory Guidelines

Pathogen	**Halifax NVSA (Average 2007-2010)**	**Agriculture Canada/CFIA**	**Nova Scotia Land Application Guidelines**	
			Class A	**Class B**
Fecal coliform cfu/g	<10	Not applic.	<1,000	<2,000,000
Salmonella cfu/g	Negative to <3	Not applic.	<3	Not applic.
Viable helminth ova #/4 g	<1	Not applic.	<1	Not applic.
Total culturable enteric viruses #/4 g	<1	Not applic.	<1	Not applic.

8. Review of Recent Research Addressing Concerns about Biosolids and Soil Amendment

This Chapter updates the most recent research on a variety of topics related to contaminants in biosolids, and biosolids management issues.

8.1 Metals

(Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), zinc (Zn), arsenic (As), selenium (Se), molybdenum (Mo) and cobalt (Co) in biosolids need to be regulated for safe land application of biosolids.

In a report prepared for the Water Environment Association of Ontario (WEAO, 2001), the authors indicated that there is a very large base of US and international research on the effects of regulated heavy metals in land applied sewage biosolids compared to Canadian studies. They noted, however, that Canadian and in particular, Ontario recommended practices are among the most conservative in the world. The report also included concentration data for unregulated metals in biosolids. Considering the absence of detrimental effects in studies with high metal concentrations and application rates, the authors concluded that recommended land application practices in Ontario present no significant risk to humans and the environment. While the study was commissioned for Ontario, metal criteria for land-applied biosolids in Nova Scotia are at least as conservative as other Canadian jurisdictions, and so the conclusions of the WEAO report would be as applicable in NS as in Ontario.

In an update to the 2001 WEAO report, Monteith *et al*. (2010a) determined that after iron and aluminum, the non-regulated metals of highest concentration were barium and titanium. There were few data characterizing concentrations of these two and other elements such as silver, thallium, antimony, vanadium, yttrium and others in biosolids. The lack of information on the fate, transport and bioaccumulation of these non-regulated metals in the terrestrial environment due to land application of biosolids was considered a knowledge gap.

Recent evidence indicates that concentrations of regulated metals in Canadian biosolids have declined substantially between 1981 and 2009 (Monteith *et al*., 2010b). Thus, the WEAO (2001) conclusions concerning these metals remain valid. Recent data for non-regulated metals in Ontario biosolids (Monteith *et al*., 2010b) were similar to or lower than values included in the 2001 report.

Hebert (2011b) reported the metal accumulations in the soil surface layer (0-20 cm) of 26 farm fields that received a cumulative mean loading of 20 tonne dry solids/ha between 1991 and 2006. Cumulative biosolids applications on the soils had no impact on cadmium and aluminum concentrations, but did cause a significant increase in the upper 20 cm layer of total mercury and extractable copper, lead and zinc. In all cases, however, final soil concentrations were well below agricultural soil reference criteria used in Quebec.

Metal impact on human health
Sampling of 14 dairy farms applying biosolids in the Saguenay region of Quebec indicated no impact on copper and molybdenum concentrations in milk, as compared to control farms that did not receive any biosolids applications (Hebert, 2011b).

McFarland *et al* (2011) developed a groundwater risk characterization screening tool (RCST) to estimate a non-carcinogenic human health risk associated with the chronic (long-term) exposure to metal pollutants released from biosolids land application sites. The screening tool was based on the United States Environmental Protection Agency's (EPA) Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment (3MRA) technology. Applying the screening tool to biosolids land application sites in Yakima County (Washington State), the most significant factors affecting potential groundwater quality impairment were found to be the soil depth to groundwater, concentration of the regulated pollutant, and biosolids application rate. Selenium was found to be the most mobile of the regulated metals in biosolids. The authors concluded, however, that public health risks would only be characterized as significant under extreme biosolids applications and pollutant concentration conditions, such as when the biosolids application rate was increased from 90 to 900 tonne dry solids/ha and the biosolids pollutant concentrations were increased to a level equivalent to 10 times the ceiling concentration limit. McFarland *et al*. (2011) also concluded that modeling results demonstrated the effectiveness of the current U.S. EPA's Part 503 rule, as well as EPA recommended best management practices, in protecting public health from metal pollutants associated with land applied biosolids.

8.2 Pathogens

Staphylococcus aureus is a bacterium that can result in significant pathological effects in humans including a wide variety of skin and wound infections, food poisoning, septicemia, toxic shock syndrome, pneumonia, meningitis and other infections. Pepper *et al* (2003) collected samples of biosolids from across the U.S., and bioaerosols from application equipment called "slingers" in the U.S. Southwest to measure concentrations of *S. aureus*. No detectable levels of *S. aureus* were observed in 23 samples of either Class A or B biosolids (including aerobic and anaerobic digestion, lime stabilization, heat-dry pelleting and/or composting) or 27 samples of bioaerosols. Pepper *et al*. (2008a) determined that the downwind risk from bacteria-associated biosolids application is very small, and that aerosolization of soils carries greater risk for transport of bacteria and endotoxins than do biosolids.

With respect to viral transport in groundwater from biosolids-amended soils, viruses are generally bound tightly to biosolids, such that groundwater contamination was considered unlikely, with the exception of porous karst soils (Pepper *et al*., 2008a). Soil bacterial resistance to four antibiotics (ampicillin, cephalothin, ciprofloxacin, and tetracycline) was assessed using data from soil samples collected before land application of Class B biosolids, and up to 450 d following land application. The data showed that the influence of biosolids on the incidence of soil-borne antibiotic resistant bacteria was negligible (Pepper *et al*., 2008a). Regrowth of *Salmonella* bacteria was found possible if Class A or B biosolids were dampened to a high moisture content (greater than 20% moisture, and allowed to become anaerobic). For that reason, Pepper *et al*. (2008a) cautioned that care should be taken to prevent re-growth of *Salmonella* by covering the biosolids to prevent saturated anaerobic conditions from developing.

A study by Viau *et al*., (2011) primarily investigated Class B biosolids. They determined that the risk from airborne pathogens in aerosols was greatly reduced by many orders of magnitude (also expressed as $logarithmic_{10}$ units or "logs") when Class B biosolids were treated to Class A quality. Risks of pathogens from drinking contaminated groundwater or ingestion of contaminated food were also very low. Viau *et al.* (2011) also determined, however, that the indicator organisms, fecal coliforms and *Salmonella* spp., are not good indicators of biosolids safety. There are other organisms that survive much better than these, including viruses (especially norovirus and adenovirus, but also reovirus) and other types of bacteria (*Clostridia* spp., campylobacter, *Listeria* spp, *S. aureus*). Their conclusion is that a combination of buffer zones between application sites and receptors, treating biosolids to Class A standard, and modifications to land application practices (liquid vs. dewatered biosolids) can result in dramatic reductions in exposure to aerosolized pathogens, by as much as 4-9 logs (i.e., $10^4 – 10^9$) if all options are adopted.

8.3 Emerging Substances of Concern

The Halifax N-Viro site was one of 11 locations across Canada included in the CCME field study of the effects of treatment processes on emerging substances of concern (ESOC). (Monteith *et al*., 2010b). Mean concentrations of ESOC in the Halifax NVSA product are provided in **Table 22**.

Table 22. Occurrence and Concentrations of Emerging Substances of Concern in Halifax NVSA.

Compound	Frequency of Detection in Sampling Campaigns (out of 3)	Detected Concentrations (ng/g ds)	
		Median	Range
Pharmaceuticals			
Furosemide	1	259 [a]	<153-259
Gemfibrozil	**3**	**13.8**	9.86-21.9
Glipizide	0	NA	<23 [b]
Glyburide	0	NA	<11.5 [b]
Hydrochlorothiazide	1	91.4 [a]	<40.5-91.4
2-Hydroxy-ibuprofen	1	189 [a]	<162-189
Ibuprofen	**3**	**522**	369-528
Naproxen	**3**	**178**	126-212
Triclocarban	**3**	**1590**	1260-1790
Triclosan	**3**	**6120**	4780-6520
Warfarin	0	NA	<5.74 [b]
Acetaminophen	0	NA	<230 [b]
Azithromycin	**3**	**36.8**	5.27-157
Caffeine	**3**	**240**	143-386
Carbadox	0	NA	<5.74 [b]
(continued)			

Table 23 (cont'd)

Pharmaceutical	**Frequency of Detection in Sampling Campaigns (out of 3)**	**Detected Concentrations (ng/g ds)**	
		Median	**Median**
Carbamazepine	**3**	**79.4**	40.7-100
Cefotaxime	0	NA	<161 [b]
Ciprofloxacin	**3**	**587**	560-605
Clarithromycin	1	11.5 [a]	<3.05-11.5
Clinafloxacin	0	NA	<67 [b]
Cloxacillin	0	NA	<11.5 [b]
Dehydronifedipine	2	2.36	<1.22-2.79
Diphenhydramine	**3**	**140**	87.4-216
Diltiazem	0	NA	<1.15 [b]
Digoxin	0	NA	<57.4 [b]
Digoxigenin	0	NA	<69.4 [b]
Enrofloxacin	0	NA	<24.8
Erythromycin-H_2O	**3**	**8.88**	6.02-14.6
Flumequine	0	NA	<5.74 [b]
Fluoxetine	2	9.23	<3.05-9.67
Lincomycin	0	NA	<24.6 [b]
Lomefloxacin	0	NA	<13.7 [b]
Miconazole	**3**	**319**	230-400
Norfloxacin	2	99	<30.5-99.2
Norgestimate	0	NA	<15.3 [b]
Ofloxacin	**3**	**276**	125-325
Ormetoprim	0	NA	<2.27 [b]
Oxacillin	0	NA	<11.5 [b]
Oxolinic Acid	0	NA	<2.9 [b]
Penicillin G	0	NA	<11.5 [b]
Penicillin V	0	NA	<11.5 [b]
Roxithromycin	0	NA	<1.79 [b]
Sarafloxacin	0	NA	<279 [b]
Sulfachloropyridazine	0	NA	<5.74 [b]
Sulfadiazine	0	NA	<5.74 [b]
Sulfadimethoxine	0	NA	<6.64 [b]
Sulfamerazine	0	NA	<2.33 [b]
Sulfamethazine	0	NA	<4.72 [b]
Sulfamethizole	0	NA	<3.97 [b]
Sulfamethoxazole	1	2.22 [a]	<1.22-2.22
Sulfanilamide	1	49 [a]	<30.5-49
Sulfathiazole	0	NA	<5.74 [b]
Thiabendazole	**3**	**7.7**	5.61-8.03
Trimethoprim	1	17.2 [a]	<11.6-17.2
Tylosin	0	NA	<154 [b]
Virginiamycin	1	409 [a]	<90.3-409
1,7-Dimethylxanthine	1	378 [a]	<305-378
(continued)			

Table 23 (continued)

Pharmaceutical	Frequency of Detection in Sampling Campaigns (out of 3)	Detected Concentrations (ng/g ds)	
		Median	Range
Alkylphenolics[c]			
Bisphenol A	**2**	**790**	770-810
Octylphenol	0	NA	<20
Nonylphenol	0	NA	<140
Fragrances[c]			
DPMI	1	50	<40-50
ADBI	0	NA	<20
AHDI	0	NA	<30
HHCB	**2**	**4115**	2880-5350
AHTN	**2**	**690**	620-760
ATII	**2**	**110**	70-150
Musk Moskene	0	NA	<50
Musk Tibetene	0	NA	<80
Musk Ketone	0	NA	<120
Musk Ambrette	0	NA	<140
Musk Xylene	0	NA	<70

[a] 1 sample with detected concentration
[b] lower than detection limit
[c] 2 samples analyzed rather than 3
Note: compounds in **bold font** were detected in 100% of samples

Of the 71 target analytes tested in the N-Viro biosolids samples, 40 (over half) were never detected, while 18 (approximately one-quarter were detected in all samples.

The fate of estrogenic activity, nonylphenol, and PBDEs in soil was determinedfollowing 20 years of land application of Class B biosolids at a university research site in southern Arizona (Quanrud *et al*. 2011). It was determined that estrogenic activity and nonylphenol do not accumulate over time in biosolids-amended soils and that PBDEs do accumulate. However the major PBDE congener concentrations in surface soil after 20 years of biosolids-amendment at the highest loading rate (3 times agronomic rate) were in all cases less than 100 parts per billion. A risk assessment was completed and the health risk associated with exposure (inhalation, dermal) to PBDEs in biosolids-amended soil was found to be negligible in comparison to risk from other PBDE sources (e.g. household dust).

At a site near Chicago receiving long-term biosolids applications over 33 years, Xia *et al*. (2010) observed that PBDEs degrade very slowly, but compounds such as triclosan, triclocarban and 4-nonylphenol underwent rapid biotransformation in the soil. Unlike triclosan, the PBDEs, nonylphenol and triclocarban were tightly bound to the top 30 cm of soil.

Young (2011) investigated the effect of the anti-microbial compound triclosan on soil microbial activity, using measures such as microbial diversity, ammonia-oxidizing capacity and nitrogen-cycling, with and without biosolids amendment. In all tests, increasing dose rates of triclosan in the soil resulted in decreased microbial activity, as expected. However, the microbial activity in the plots receiving biosolids applications was so much higher than in the control plots that it more than compensated for the negative effect of the triclosan additions.

Some critics of measuring specific contaminant concentrations in biosolids-amended soils as an indicator of possible risk suggest that the cumulative or inter-active effects of mixtures of contaminants are not accounted for by measurement of individual concentrations. McCarthy (2011) reported results of testing different types of plants and animals for adverse biological effects resulting from amending soils with biosolids. Test organisms included earthworms, springtail insects, corn, string beans, soya beans and Chinese clover. End-points for the plants included days-to-flowering, germination rates, number of seed pods and weight, root lengths, stem widths and shoot lengths. Statistical testing of end-point data from the biosolids-amended and control soils revealed no significant difference in all cases, i.e., soil amendment with biosolids had no effect on any of the plant end-points. Similar results were obtained using the earthworms and springtails from the animal kingdom.

Coors *et al* (2011) examined the effects of biosolids additions to soils, compared to commercial chemical fertilizers, on two soil invertebrates, namely nematodes and enchytraeids. Several beneficial effects of biosolids were observed including a large increase in nematode and enchytraeid abundance, enrichment of the community structure and enhanced nutrient cycling. Potential but unconfirmed adverse effects included an impact on nematode persistence (an observed non-statistical difference), and a significant difference (reduction) in feeding activity of the soil organisms on the biosolids-amended plots two years after the application.

Twenty years of land application of Class B biosolids in Arizona resulted in beneficial effects on the soil microbial community, as evidenced by increased microbial diversity and enhanced activity of common microbial transformations (e.g., nitrification, sulfur oxidation, and dehydrogenase activity), compared to control plots without biosolids additions (Pepper *et al.,* 2008).

8.4 Odours

Under normal conditions, properly stabilized biosolids have an odour that ranges from slightly ammoniacal (alkaline stabilization) to musty and earthy (aerobically stabilized biosolids, e.g. compost) to tar-like (anaerobic digested biosolids). There is no putrid odour associated with well-stabilized biosolids. Pepper *et al*. (2008a) noted that under a combination of adverse factors (high moisture content and on-set of anaerobic conditions), microbial regrowth can occur even in Class A biosolids. Consumption of the organic carbon and nutrients in the biosolids associated with this regrowth could lead to development of odourous compounds, chiefly volatile nitrogen and sulphur-bearing compounds (e.g. amines, mercaptans, disulphides and heterocyclic N-containing compounds).

[Rain fell the night prior to the numerous odour complaints regarding use of the N-Viro product on Dunbrack Street. The rain could have provided sufficient moisture for anaerobic conditions and odour generation to occur. However, there are no data to determine whether anaerobic conditions occurred, and the situation is further clouded by the addition of a compost of questionable or unknown quality. Efforts to determine the source, quantity and quality of the compost have not met with success.]

According to the WEF-NBP report (Camp Dresser and McKee, 2011) public perception of biosolids management will continue to be closely associated with odours from processing, handling, and end use/disposal. In America, odour concerns are driving state and local regulatory activities, including odour management plans. In some U.S. locales, "zero tolerance" approaches are being proposed for biosolids odours. For land-applied products, there remain concerns that compliance with the EPA 503 rule [for pathogen and vector reduction] does not necessarily mean that product odour will be acceptable; some suggest that modifications to current stabilization criteria might be warranted.

8.5 Drivers of Biosolids Management

The Water Environment Federation, in collaboration with the National Biosolids Partnership, released a major report in May 2011(Camp Dresser and McKee, 2011). The report identified three over-arching themes that would drive future decisions on biosolids management in the United States. [The Project Team believes the observations of the WEF-NBP report are applicable to Nova Scotia and the rest of Canada.] The three identified themes include:

- Expanding the view of biosolids as a renewable resource and source of nutrients and energy;
- The need for enhanced communications regarding regulations, environmental impacts, and health concerns due to increasing public involvement in solids management;
- Promoting technology drivers and trends emphasizing sustainability and technologies that leverage biosolids as a renewable source of organic matter, nutrients, water, and energy.

Two additional "external" drivers are likely to affect the future of biosolids management: (1) the nature of future wastewater treatment infrastructure renewal and replacement investments; and (2) wastewater treatment impacts on biosolids quality. With respect to infrastructure and renewal, changing population densities and elimination of combined sewer overflows can affect the quantity and quality of wastewater to be treated, thereby affecting wastewater solids production. Perhaps more importantly, required changes in effluent quality to secondary treatment levels as proposed in the CCME effluent strategy, or even more stringent levels, can impact the quantity and quality of wastewater solids requiring biosolids treatment.

8.6 Perception and Communications

MacIvor (2011) has studied the acceptance and use of biosolids as a supplement for urban gardening in the U.S. Pacific Northwest. She noted that public understanding of the term "biosolids" is poor. Such lack of understanding causes people initially to be uneasy about biosolids recycling, because they cannot accurately assess the risks posed by use of biosolids. In turn, this can lead to mistrust of the product.

Another factor identified by MacIvor (2011) was that many of those involved in wastewater treatment are engineers and other technical professions, who are unprepared to deal with a concerned public. The WEF-NBP report on the future of biosolids management (Camp Dresser and McKee, 2011) noted that due to cutbacks at the federal and state level, biosolids managers and others in the profession are becoming the primary educators of the public on biosolids issues and regulations.

The Tacoma, WA biosolids product called Tagro has been sold to the public for close to 20 years and distributed in some form since the 1970s. Tagro is a mixture of dewatered Class A biosolids, sawdust and sand that serves as a soil product suitable for use by the home gardener. The City of Tacoma has developed a widespread network of users that creates enough demand to utilize all of its product within a 60-mile radius. Over the years, The City has worked to build public support for using Tagro by focusing primarily on good relationships with consumers and implementing a strategy that relied on widespread use in small quantities, as opposed to a few large-scale users (MacIvor, 2011).

The King County (Seattle, WA) biosolids program involves collaboration with a private company (Sawdust Supply) to produce a Class A biosolids compost (GroCo) by mixing anaerobically digested Class B biosolids cake with sawdust. The solids are blended with wood chips, and composted for a period of 9 months to further reduce the pathogen levels and meet Class A standard for home use with no restriction (MacIvor, 2011).

The experience of Hartford County is interesting for the outreach used for their Class B biosolids (Ludwig, 2010). The program there involves proactive and annually updated farmer networking, a dedicated contractor monitoring program and timely public education presentations. The intent of the outreach is to the make biosolids program as public as possible, using non-technical jargon, with a fully involved and informed wastewater system staff from Operator to Director.

Biosolids have been used extensively in mine land reclamation in British Columbia, and Van Ham *et al*. (2005) detailed the necessity of stake-holder and public involvement to gain project acceptance. Activities included continuing stakeholder consultation, bi-monthly newspaper advertisements, year-round site tours, community involvement in seeding, planting and tending the vegetation, and an annual Open House.

Perhaps one of the best-known biosolids products is Milorganite®, which is produced and marketed by the City of Milwaukee, WI since 1926 (Crawford, 2011). Other similar products include Bay State™ (Boston), Oceangro™ (Ocean County New Jersey), and Louisville Green™ (Louisville, KY). Milorganite has been and continues to be accepted as a "commercial" fertilizer for home use. It is ironic that several North American jurisdictions have proposed or implemented bans on use of locally produced biosolids while allowing the use of Milorganite imported from Milwaukee. Milorganite can be purchased in Halifax at home improvement retail outlets.

9. Best Management Practices for Biosolids

9.1 Introduction

The introduction in the compendium of best management practices for biosolids management programs, prepared jointly by the Federation of Canadian Municipalities and the National Research Council of Canada (FCM-NRCC, 2003), states that biosolids management is a controversial issue for municipal governments. While the practice of putting biosolids to beneficial use, particularly in applications to agricultural land, has taken place for decades without documented adverse effects to human health or the environment, the public has become concerned and is now questioning the safety and sustainability of biosolids management programs. As a result of the growing concerns of the public, biosolids programs are under scrutiny. By implementing best management practices for biosolids, municipalities improve their chances of realizing these benefits:

- compliance with regulatory requirements;
- improved biosolids quality;
- improved odour management;
- improvements in safety;
- wider public acceptance;
- improved cost effectiveness; and
- sustainability.

The following discussion contains numerous excerpts from the compendium of best management practices for biosolids management programs (FCM-NRCC, 2003). Although the guide listed 13 management issues, only those related to biosolids quality and application to land are considered here (solids stabilization, thickening and dewatering practices were not considered as part of this BMP review).

While the FCM-NRSS publication focuses on all aspects of best management practices for biosolids, other jurisdictions take a more focused view. For example, the BMPs of the State of Missouri (Arnold et al., 1994) are almost entirely devoted to the site of biosolids application, and those of the State of Tennessee (Eash et al., 1997) address transport and site considerations. Other BMPs for biosolids are available from other jurisdictions; however, they overlap significantly with the documents reviewed herein. This review therefore summarized elements from the FCM-NRCC, Missouri and Tennessee BMP documents.

9.2 Regulatory Issues

The key element of good practice in regard to compliance with biosolids regulations is a thorough knowledge and understanding of applicable laws and regulations, including certificates of approval or permits that govern the biosolids program. Investments, both financial and in terms of management time, will be required to provide for and maintain the training of management and staff (FCM-NRCC, 2003).

Although compliance with applicable legislation is a minimum requirement, in some cases, operations may need to go beyond the legal requirements to address public concerns or because the municipality believes it is appropriate to do so, and chooses to do so voluntarily (FCM-NRCC, 2003).

9.3 Source Control

Source control refers to the control of the characteristics of the influent to the wastewater treatment facility, particularly with respect to non-domestic (industrial/commercial) wastewater generators. This element of biosolids management directly affects the quality of the final biosolids product with respect to contaminants, including heavy metals, priority organic compounds (such as furans and dioxins), and radionuclides (FCM-NRCC, 2003).

The elements of a best practice for source control program are (FCM-NRCC, 2003):

- enactment of a by-law;
- monitoring and enforcement;
- education and awareness;
- codes of practice;
- wastewater rates; and
- pollution prevention programs.

Source control programs are effective in assisting how the public perceives the biosolids management program. Municipal governments that have and enforce source control will be perceived as proactive when the public considers biosolids quality and the potential effect on public health and the environment (FCM-NRCC, 2003).

9.4 Biosolids Storage

Siting of biosolids storage facilities should consider buffer zones and future land use plans. Some jurisdictions require a minimum amount of solids storage to allow for winter restrictions on some end uses such as agricultural land application. The storage facility will have to operate in a manner that avoids both public nuisances and impacts on the environment. Facilities should be designed to prevent runoff from the site, and landscaped to screen operations from public view (FCM-NRCC, 2003).

According to the State of Missouri (Arnold *et al*., 1994), BMPs for biosolids storage facilities include:

- Provision of adequate sludge and biosolids storage as needed to match the application windows for crop planting, harvesting and inclement weather conditions.
- Operation of storage basins so there is no discharge to waters of the state.
- Recommended biosolids storage for grassland sites ranges from 60 to 120 days according to geographical location within the State.

- Storage should be increased for tilled cropland application sites depending on the crop rotations and ratio of tilled land to grassland. Recommended storage is 180 to 365 days if all sites are tilled crop land.
- Any storage area located off-site of the sludge or biosolids generating facility must have a separate individual permit for the storage site, except for temporary stockpiles.
- Use temporary stockpiles for solid or semi-solid materials (no free liquids) only. Limit the stockpile to two weeks per year at any one application field. Locate stockpiles at least 300 feet from drainage ways or they must have runoff collection berms at least 6 inches high around the pile.

9.5 Odour Management

9.5.1 Biosolids Management Facilities

Odour generation and management are major concerns at storage sites in proximity to the general public. Factors that affect the impact of odours include proximity of the receptors, weather conditions, size of storage facility, and site topography. Covering storage units is helpful when possible. A good neighbour policy should be in place to notify the nearby community of upsets or activities that may have an impact, even if it is only for a short duration (Arnold *et al*., 1994).
A number of technologies have been employed to treat odorous emissions from biosolids management facilities, including packed tower wet scrubbing, fine mist wet scrubbing, activated carbon adsorption, biofiltration, thermal oxidation, and diffusion into activated sludge aeration tanks. The success of each of these technologies depends on the effectiveness of capture of the odorous emissions (FCM-NRCC, 2003).

9.5.2 Land Application Sites

In land application situations, odour concerns can be reduced by direct injection of liquid biosolids, or by incorporating dewatered biosolids into the soil as soon as possible after spreading, weather permitting (FCM-NRCC, 2003).

According to Eash *et al*., (1997), potential for odors at biosolids application sites can be reduced by utilizing the following BMPs:

- Incorporate or inject liquid biosolids soon after application to the site;
- Avoid application to wet or waterlogged soil;
- Minimize the time biosolids are stockpiled at the application site;
- Use proper application rates (e.g. agronomic rates), as over-applying biosolids can result in runoff and pools of liquid biosolids in low areas that can generate odors;
- Isolate application sites from residential, public access and commercial areas.

9.6 Transportation of Biosolids

9.6.1 Prevention of Spills and Leaks

For transportation of liquid biosolids, sealed tankers complete with internal baffles to minimize the movement of the liquid should be used to minimize odour and spill potential. Dump trucks, tractor-trailers, and roll-off containers used for transporting dewatered biosolids should be leak-proof and covered to minimize odour emissions and leaks/spills. Where feasible, the use of covers designed to prevent odour emissions or, alternatively, an on-board odour control system should be considered. The exterior of the trucks especially the tires should be cleaned, before entry to public roadways, to minimize the tracking of mud or biosolids (FCM-NRCC, 2003).

Guidance provided by the State of Tennessee is similar to that in the FCM-NRCC document. Trucks hauling biosolids must be designed to prevent spillage onto roadways. Biosolids should not be loaded into dump trucks unless the truck bed is leakproof for the type of biosolids to be transported. Any biosolids that are spilled onto highways must be cleaned up immediately. Some lime-stabilized biosolids are very slippery when wet, causing potentially hazardous conditions. Trucks must not be overloaded, and transfer hoses must be completely emptied before entering roadways. It is mandatory that a proactive maintenance program on all biosolids application and hauling equipment are enacted and repairs are made before hazardous conditions result Eash *et al*., 1997).

9.6.2 Impact on Roadways and Public

Trucking of biosolids will also have impacts on roads, and provisions for maintenance and construction standards will have to be adjusted accordingly for the routes in use by the biosolids program. Loading restrictions are a consideration when planning transportation routes. A public communication/information program may also be required to promote biosolids management and educate the public as to the management of biosolids transportation. Trucking times and routes to minimize impacts on the community need to be considered where land application is practiced (FCM-NRCC, 2003). Because trucks used for biosolids application are heavy and can cause considerable damage to roads if the same traffic patterns are used often, dialogue with the local traffic department before haul routes are established may help avoid future problems (Eash *et al*., 1997).

Guidance from Tennessee (Eash *et al*., 1997) also suggests that vehicles bearing biosolids should avoid:

- residential areas for all haul routes, especially before or after school;
- use of exhaust brakes (i.e. operate vehicles quietly to avoid excessive noise),
- exceeding speed limits; and
- early morning and late evening hauling.

Additional considerations from Tennessee include a recommendation that all vehicles should be clean and routinely washed. If biosolids are spilled onto the vehicle during loading, hose off the vehicle before hauling to the application site. Haul vehicle beds should be cleaned thoroughly before hauling other materials. Mud tracked onto roadways should be promptly removed to eliminate any hazardous conditions on roadways.

9.7 Biosolids Application Sites

There is no guidance in the FCM-NRCC (2003) document on site considerations of biosolids application, presumably because the requirements are imbedded in the various provincial acts and guidelines governing biosolids application. The State of Missouri (Arnold *et al*., 1994) has set out as BMPs many of the considerations that are found in Canadian guidelines and regulations, as indicated next. Many of the recommended practices at the biosolids application sites are common to Canadian Provincial guidelines and regulations, including:

- soil limitations for nitrogen, phosphorus and pH;
- buffer zones;
- slopes of application sites;
- storm water runoff;
- frozen, snow-covered or saturated soils; and
- soil depth to bedrock and groundwater.

Some interesting practices of note from Missouri (Arnold *et al*., 1994) include:

Containment of Discharge (Runoff)
Biosolids must not discharge from the application site, except during catastrophic or chronic precipitation exceeding the 1-in-10 year rainfall level.

Public Contact Sites and Public-Use or Distribution of Biosolids

- Class A biosolids applied to public-use sites, distributed for general public use or used on vegetable crops, root crops or home gardens must comply with 40 CFR 503 Subpart B.
- A biosolids management plan or engineering report for Class A biosolids used on public sites must be approved by the State Department of Natural Resources before use or distribution.
- Do not apply Class B biosolids to public contact areas, residential lawns or turf farms unless the biosolids are incorporated. Restrict public access for 12 months. Approval must be granted from the permitting authority.

Crop Restrictions
Do not apply Class B biosolids to root crops, home gardens or vegetable crops whose edible parts will come in contact with applied biosolids, unless the crops are not used for direct human consumption.

Harvest and Grazing Restrictions
Do not apply biosolids to land within 30 days of harvest or grazing by cattle. Applicators are also subject to requirements of the Missouri Department of Agriculture State Milk Board concerning

grazing restrictions of lactating dairy cattle.

Threatened or Endangered Species
Applying biosolids must not adversely affect a threatened or endangered species or its designated critical habitat. This is in accordance with section 4 of the U.S. Endangered Species Act.

Application Rates
Evenly spread the biosolids over the entire application site. Do not dump the material in batches or spread a pile using a blade, disc or similar equipment.

Application Equipment
Properly operate and maintain application equipment. Visually check the equipment each day during operation. Apply biosolids during daylight hours only, unless approval is obtained from the permitting authority.

Record Keeping
Sludge applicators must keep detailed records for at least five years on each location and amounts of biosolids applied. Landowners are not required to keep records. However, it is highly recommended that biosolids application records be incorporated into your total nutrient management plan.

Further guidance from Tennessee (Eash *et al*., 1997) recommends always evaluating carefully the site, and increasing the border area around application sites near home sites, schools or other public areas. Potential problems should be evaluated critically (e.g., applying lime-stabilized biosolids near a school should not be a problem. However, if the biosolids dry and become dusty and if the wind direction changes and recess occurs while downwind of the application site, some children will probably experience burning eyes from the lime dust.) As application sites become more urban, more planning is mandatory.

9.8 Contingency Planning/Emergency Response

The development and implementation of a contingency plan and emergency response procedures are very important, both for increasing the public acceptance of a biosolids management program, as well as to demonstrate to the public that their safety and the environment will be protected. As a minimum, the following contingency plan and/or emergency response procedures should be addressed (FCM-NRCC, 2003):

- inclement weather (longer than normal winter, excessively wet spring or summer)
- changes in biosolids quality that render a particular end use unsuitable;
- equipment or process failure;
- transportation breakdowns;
- spills; and
- a labour disruption.

The contingency plan and procedures should be reviewed and updated at least annually. The contingency plan should also account for potential cases of vandalism with appropriate emergency response procedures (FCM-NRCC, 2003).

9.9 Quality Management

The development and implementation of a biosolids management program should be carried out using the principles of a quality management system. The overriding principle of the quality management system is continuous improvement brought about by the implementation of a "Plan - Do - Check - Act" approach. Thus, a process of continuous improvement is built into the quality management system (FCM-NRCC, 2003).

A key component of the quality management system is transparency, (i.e., affected stakeholders should be made fully aware of all aspects of the biosolids management program). This open sharing of information within the context of a continuous improvement program can result in significant increases in public acceptance of the biosolids management program (FCM-NRCC, 2003).

Another key component of quality management is monitoring and record keeping. Process control parameters need to be monitored as well as product quality parameters. Management resources will be required to plan, develop, and implement the quality management system. In addition, staff resources will be needed to carry out monitoring and recording functions (FCM-NRCC, 2003).

9.10 Public Participation and Communication

The communications plan for biosolids management needs to include a public awareness program as well as a consultation strategy. The public awareness program will evaluate existing communication activities and tools within the organization and propose additional ones to increase the awareness of wastewater treatment plants and the environmental protection programs. The consultation strategy, while also offering a greater understanding of the issues, will encourage dialogue and feedback and involve people in the process so that they have more of an ownership of the outcome (FCM-NRCC, 2003).

From the earliest planning stages, it is important to identify and involve all stakeholders in the planning, development, and implementation of the biosolids management program. It is crucial that the need for the biosolids management program is clearly and strongly communicated to all stakeholders as early in the process as possible (FCM-NRCC, 2003).

Once the initial planning and development stages have passed, it is still important to communicate openly, clearly, and often with the public and the elected officials with respect to the progress of the program addressing any concerns that may have arisen and to continue with a communication/education program of the biosolids program, the wastewater treatment in general and the environmental protection programs of the municipal government (FCM-NRCC, 2003).

Representatives of the key stakeholders should be formed into a liaison committee or advisory group to address the issues and concerns, assist in the dissemination of information, and provide ongoing input to the development and implementation of the biosolids management process. Information can be disseminated to the public in a variety of ways, such as newsletters, brochures, fact sheets, videos, Web sites, newspaper and television advertising, information meetings, open houses, site tours, and one-on-one or very small group meeting in a formal or informal setting (FCM-NRCC, 2003).

10. Conclusions

The conclusions arising from this review of Halifax's N-Viro biosolids treatment process are as follows:

1. Nova Scotia guidelines for application of Class A biosolids are as restrictive as, or more restrictive than the guidelines and regulations in other Canadian and international jurisdictions

2. The N-Viro process for biosolids stabilization is accepted by jurisdictions in North America for production of Class A biosolids when operated according to the design intent.

3. An on-site inspection of the Halifax N-Viro technology in late April, 2011 determined that operation was occurring according to the design intent.

4. The cause of the odour incident on Dunbrack Street could not be attributed directly to application of NVSA product. There is reason to believe that the NVSA was blended with source separated organics which may not have been fully composted and cured prior to use.

5. Analytical data for the period between March 2010 and April 2011 indicate that the Halifax NVSA product does not exceed any Class A criteria for metals, pathogens or organics, with the exception of selenium (a few values of 2.5 mg/kg DS compared to the guideline value of 2.0 mg/kg DS). It is suggested that the NVSA is acceptable for use as a Class A material.

6. Based on conclusions #4 and #5 above, there is no regulatory basis for continuing the moratorium on application of NVSA product on HRM properties.

7. A technical review of potential alternatives to the N-Viro process currently used by Halifax Water determined that there was no benefit at this time to replacing the N-Viro process with another, either in terms of biosolids quality, or in the logistics of transporting and treating sludge from Halifax Water's numerous small wastewater treatment facilities.

8. A review of the recent literature identified numerous observations on positive effects of biosolids on microbial activity in soils, and an absence of adverse effects on plant and animal species growing in biosolids-amended soils.

9. Questions submitted to council ranged from seeking factual information to reflecting a negative opinion of beneficial use of biosolids.

10. The NVSA product is most suitable for large, commercial agricultural operations rather than local public give-away programs because of the potential presence of free

alkali material in the product, and the potential for irritation of skin and breathing passages of the public, who might be unaware of the handling risks.

11. Successful biosolids beneficial use programs are associated with pro-active and dedicated public outreach programs.

11. Recommendations

Based on the foregoing conclusions, the following recommendations are proposed:

1. Halifax Water should continue with the N-Viro technology, and ensure that it meets all design and operational specifications for acceptable product quality.

2. The moratorium on use of NVSA on HRM properties should be lifted based on implementation of the recommendations provided herein.

3. In conjunction with Recommendation #2, tests plots should be established on HRM property using NVSA to track potential odour formation or dissipation, pH neutralization rates and effects on vegetative growth to demonstrate to the public the safety and effectiveness of the NVSA product.

4. The procedure and specifications for blending the NVSA product with other components such as compost or other organics should be codified, strictly managed and tracked to ensure that only well stabilized materials are included in any blend.

5. Halifax Water should conduct an ongoing review of NVSA quarterly analytical data to better understand the variability of the product quality.

6. Halifax Water should initiate efforts to reduce levels of selenium in the NVSA through monitoring, an aggressive sewer use control program, and public outreach and education programs.

7. Halifax Water and N-Viro should promote Best Management Practices to minimize odour emissions from NVSA land application sites, and to demonstrate sincere and dedicated efforts to ensure public acceptability of this practice.

8. NVSA analysis should continue to include non-required regulatory parameters, such as total neutralizing value and sieve mesh size, TPHC, volatile fraction of total solids and total organic carbon to characterize the product for potential agricultural applications.

9. Halifax Water, HRM and N-Viro should establish a more enhanced public outreach program for the N-Viro technology and NVSA product use, including facility tours, demonstration cropping experiments, downtown exhibitions, featured expert guest speakers, and speaking engagements in classrooms and other venues to obtain buy-in from the public concerning the safety and effectiveness of the NVSA product as a soil amendment material.

12. References

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Appendix A: Tables Supporting Review of Regulatory Limits and Guidelines for Biosolids

Table A1. Biosolids Management in Canada: Legislation and Regulatory Authorities (CCME, 2010)

Jurisdictions/ Department	Acts and Regulations	Scope of the regulatory authorities
Federal		
Environment Canada (EC)	*Canadian Environmental Protection Act, 1999*	Releases of National Pollutant Release Inventory (NPRI) substances are required to be reported to Environment Canada.
Canadian Food Inspection Agency (CFIA)	*Fertilizer Act and Regulations*	Products when **sold or imported** into Canada as fertilizers and supplements are regulated under the *Fertilizers Act and Regulations*. Fertilizer and supplement use, transport, and storage are not regulated under the Act. The Act does not regulate products that are not sold (i.e. given away) or sale of products that do not meet the definition of a fertilizer or supplement (e.g. potting soil)
Provincial/ Territorial		
Alberta (AB) Alberta Environment	*Environmental Protection and Enhancement Act;* *Wastewater and Storm Drainage Regulation;* *Activities Designation Regulation;* *Code of Practice for Wastewater Systems Using a Wastewater Lagoon*	The Acts and Regulations support and promote the protection, enhancement and wise use of the environment. It includes collecting, treating and disposing of wastewater and includes wastewater sludge treatment and disposal facilities, also includes municipal wastewater collection systems and wastewater systems using wastewater lagoons and land application of biosolids
British Columbia (BC) Ministry of Environment	*Environmental Management Act and Health Act;* *Organic Matter Recycling Regulation, 18/2002; amendments 321/2004*	The Regulation governs the production, quality and land application of certain types of organic matter. In the past, this organic matter have been predominantly burnt, buried or otherwise disposed of. It applies to the construction and operation of composting facilities and the production, distribution, storage, sale and use or land application of biosolids and compost. The regulation covers treatment, quality, land application and storage of biosolids. The regulation includes criteria for Biosolids Growing Medium (topsoil)
Manitoba (MB) Manitoba Conservation	*The Environment Act, E125, 1998;* *The Nutrient Management Regulation under the Water Protection Act*	The Acts regulate processes or works to abate or control pollution or other environmental damage including but not limited to waste disposal grounds, landfills, sewage collection and treatment, sewage or industrial sludge handling and disposal, incinerators, and recycling systems
Newfoundland and Labrador (NL)	*Environmental Protection Act;* *Reference to Part VIII of the Act on Dangerous Goods is also made.*	The EPA deals only with disposal of biosolids. Biosolids and septage are considered as semi hazardous materials and require cartage to be in enclosed truck such as a vacuum sludge truck that is licensed through the Department of Government Services.

Cont'd

Table A1. cont'd

New Brunswick (NB) Department of Environment	*Water Quality Regulation 82-126 under the Clean Environment Act*	Biosolids and/or sewage sludge would be considered a waste under the Act. Regulation only applies to activities that impacts or may impact waters of the province. Therefore, regulation only covers disposal. Sewage sludge or biosolids that are composted to meet CCME Guidelines for Compost Quality or meets equivalent standards would no longer be considered a waste.
Nova Scotia (NS) Nova Scotia Environment	*Section 50(2) of the Environment Act, S.N.S. 1994-95;* Section 3(1) of the Activities Designation Regulations (O.I.C. 95-286); *Section 23 of the Activities Designation Regulations (O.I.C. 95-286);* *Section 8(2)(b) of the Environment Act, S.N.S. 1994-95,*	The Act and Regulations covers the application to land of non-livestock generated wastes, wastewater and wastewater sludges. The only biosolids management option is land application. Source control is addressed via municipal sewer use bylaws, although a model sewer use bylaw was developed by the Province and forms the template used by the municipalities. Exemptions: Biosolids that meet Class A criteria do not require an Approval for land application; Biosolids that do not meet Class A criteria (Class B) require an approval for land application and are restricted from use on agricultural land.
Nunavut (NU)	*Water licence from Nunavut Water Board*	All water uses in Nunavut require a water licence from the Nunavut Water Board, which sets out criteria for effluent discharge, monitoring etc. Biosolids management may be covered under the water licence.
Ontario (ON) Ministry of the Environment	*O. Reg. 267/03 General Regulation under the Nutrient Management Act, 2002;* *Ontario Regulation 347*, under the *Environmental Protection Act;* *Ontario Water Resources Act*	Ontario's regulatory authority covers handling, disposal, and storage of biosolids. It does not extend to discharges into sewers; pollutants in wastewater discharge to sewers are controlled through municipal sewer use bylaws or sewer use agreements. Ontario policies on municipal wastewater effluent quality or industrial discharge are implemented through a Certificate of Approval issued under the *Ontario Wastewater Resources Act* (OWRA). However, accidental discharges or spills into the environment are regulated under Ontario's *Environmental Protection Act.* An exemption exists under Regulation 347 for a waste that is wholly used in an ongoing commercial process for purposes other than waste management when the process does not involve combustion or land application of the waste.
Quebec (QC) Environment Québec	*Articles 20, 22 and 32 of the Environment Quality Act;* *Regulation respecting agricultural operations;* *Regulation respecting groundwater catchment*	Under this Act, Article 20 stipulates not to pollute. Article 32 stipulates the need for a C of A for wastewater treatment plant construction. The provincial government prohibits disposal of some hazardous wastes in the sewer, like used oil. Mucipalities are responsible to implement by-laws for on source control of pollutants discharge in the sewers. Québec has a regulation that covers landfilling and incineration of residuals, which includes solid sludge. Large scale composting of biosolids is covered by Lignes directrices pour l'encadrement des activités de compostage and requires a C of A according to article 22 of the Act... For land application: a C of A is generally required under article 22 of the Act. The Agricultural Operations Regulation and the Groundwater Catchment Regulation also apply to biosolids land application.

Table A1 cont'd

Prince Edward Island (PEI) PEI Department Environment, Energy and Forestry	*PEI Environmental Protection Act; Sewage Disposal Systems Regulations section 22 through 24.*	Currently, the regulatory authority for biosolids applies only to the disposal including application of the product, separation distances, slope restrictions for land application. *http://www.gov.pe.ca/law/regulations/pdf/E&09-15.pdf* When dealing with source control (inputs to sewer) the regulatory authority falls within the By laws of Charlottetown, Summerside, Cornwall and Stratford. For the other utilities they follow the Prince Edward Island Municipal Sewerage Utilities, General Rules and Regulations administered by the Island Regulatory and Appeals Commission - http://www.irac.pe.ca/document.asp?file=utilities/srandr.asp#4.8 It is the responsibility of the individual utility to enforce their bylaw/regulation. It may be within the authority of the department to suggest or require changes to the bylaws if warranted
Saskatchewan (SK) Saskatchewan Environment	*Environmental Management Protection Act 2002 (EMPA); Water Regulations, 2002*	Saskatchewan Ministry of Environment is the sole regulatory agency in the province in regulating biosolids or Municipal Sewage Sludge in the province. The levels of pollutants released in untreated wastewater are covered through the Water Regulations.

Table A2. Approval/Authorization/Permission at Various Stages of Biosolids Production, Use and Disposal (CCME, 2010)

	Regulatory Compliance/Approval /Authorization/Permission required for					Nutrient Management Plan or Land Application Plan	Public Consultation		
	Receiving /processing waste water	Operating treatment facilities	Land application	Composting	Other methods of disposal (landfilling; incineration)		Operating/ managing facilities	Land application	Other disposal methods
AB	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes[1]	
BC	Yes	Yes	Yes	Yes	Yes	Yes - LAP	Yes	Yes	Yes
MB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/No [2]
NL	Yes	Yes	Yes					No	
NB	No	Yes	No, if composted	Yes	Yes-landfilling			No, if composted	
NU	Yes	Yes	Yes	No	No	No	No	No	No
NS	Yes	Yes	Class B only	Yes	Banned	Yes	Yes	Yes/No [3]	
ON	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes[4]	Yes
QC	Yes	No permit	Yes	Yes	Yes	Yes			Yes
PEI	Yes	Yes	Yes	Yes	No	No	No	No	No
SK	Yes	Yes	Yes	Yes	Yes			Yes	
If blank, information not available									

[1] limited to landowner permission

[2] MB-Any disposal method that is considered a major alteration to the development as Licensed would require additional public consultation. If the proposed disposal method is considered to be a minor alteration, no additional public consultation would be required.

[3] If the biosolids producer has a LONO to the sale of the product from CFIA, then no approval and no public consultation is required. Land application of class B biosolids must obtain an approval from Environment, which generally includes a requirement for public consultation and posting of the site.

[4] As an operational practice, Ontario notifies the municipal clerks from lower and single tier municipalities. MOE does not require public notification, which is up to the discretion of the municipalities

Table A3. Guidance and Other Policy Documents for Regulation of Biosolids in Various Provinces and Territories (CCME, 2010)

	Guidance and other Policy documents
Federal	
EC	*Environment Canada Guidelines for Effluent Quality and Wastewater Treatment at Federal Establishments.* (1976). The purpose of these guidelines is to indicate the degree of treatment and effluent quality that will be applicable to all wastewater discharged from existing and proposed Federal installations. Use of these guidelines is intended to promote a consistent wastewater approach towards the cleanup and prevention of water pollution and ensure that the best practicable control technologies are used. These guidelines apply to all effluents discharged from land based establishments under the direct authority of the Federal Government. http://www.ec.gc.ca/eu-ww/0FB32EFD-73F9-4360-95EE-CB856FB4D971/1976_Guidelines_En.pdf *National Pollutant Release Inventory Guidance Manual for the Wastewater Sector* The purpose of this guidance manual is to provide information on which facilities must report, and how they should calculate releases to be reported. The Guidance manual states that facilities engaged in waste or sewage sludge incineration, municipal waste water collection and treatment, must determine if a report is required. http://www.ec.gc.ca/pdb/NPRI/2002guidance/WW2002/WW_2002_e.cfm *Guide for Reporting to the National Pollutant Release Inventory 2002, and the CAC Supplementary Guide.* This includes guidance related to NPRI reporting for activities such as stationary combustion equipment operations, sewage sludge incineration, non-hazardous solid waste incineration, and hazardous waste incineration. http://www.ec.gc.ca/pdb/npri/2003Guidance/Guide2003/toc_e.cfm http://www.ec.gc.ca/pdb/npri/2002guidance/cac2002/cacs_2002_e.cfm
CFIA	*T-4-120-* Regulation of Compost under the *Fertilizers Act* and *Regulations* The purpose of this document is to provide information on the regulatory requirements for compost under the *Fertilizers Act and Regulations*, and describe the safety, efficacy and labelling standards that must be met in order to legally sell or import compost into Canada. This document is also designed to assist compost producers, facility operators, importers, and retailers in meeting the regulatory requirements prescribed by the Acts administered by the Canadian Food Inspection Agency (CFIA). http://www.inspection.gc.ca/english/plaveg/fereng/tmemo/t-4-120e.shtml T-4-112- Information Required for the Assessment of By-products and Other "Waste" Materials Sold as Fertilizers or Supplements. This document outlines the information required for the assessment of by-products and other "waste" materials sold as (in) fertilizers or supplements. Once the information is received, CFIA will conduct a preliminary screening of the safety and efficacy of the product. Any additional requirements will then be outlined. http://www.inspection.gc.ca/english/plaveg/fereng/tmemo/t-4-112e.shtml
Provincial/ Territorial	
AB	*Industrial Release Limits Policy* covers Alberta Environment's approach to developing standards and guidelines for the release of substances into the environment. This policy document outlines the approach followed by Alberta Environment (AENV) staff to develop industrial release limits for approvals under the Environmental Protection and Enhancement Act. The policy supports the Alberta Government's "Commitment to Sustainable Resource & Environmental Management" by outlining how pollution prevention/control requirements are established for industrial releases to the

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Table A3. continued

	environment. http://environment.alberta.ca/711.html *Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands,2001* The guidelines were intended for the use of municipalities considering or practicing land application as a method of municipal wastewater sludge disposal. After fifteen years since the guidelines were developed, the focus of the program still remains the same, i.e.; land treatment of sludge is agriculturally beneficial and environmentally acceptable. http://environment.gov.ab.ca/info/library/6378.pdf *Standards and guidelines for municipal waterworks, wastewater and storm drainage systems* Alberta Environment is responsible for the Drinking Water and Wastewater Programs for large public systems in Alberta. This document sets out the regulated minimum standards and requirements for municipal waterworks in Alberta. http://environment.gov.ab.ca/info/library/6979.pdf
BC	Best Management Practices Guidelines for the Land Application of Managed Organic Matter in British Columbia *Incineration and Landfilling:* http://www.env.gov.bc.ca/epd/epdpa/mpp/incin_landfill.htm#top
MB	The policies are site specific Environment Act licences with limits, terms and conditions which include the nutrient controls as stated in the Nutrient Management Regulation. Information bulletin-guidance document available: http://www.gov.mb.ca/conservation/eal/publs/info_eal.pdf http://www.gov.mb.ca/conservation/eal/publs/info_eap.pdf
NL	The Pollution Prevention Division adopts the requirements established in the USEPA Part 503 Biosolids Rule and BNQ Standard 0413-400-2009 on Soil Amendments – Alkaline or Dried Municipal Biosolids when reviewing proposals and issuing Certificates of Approval for disposal to solid waste disposal sites or composting. Currently no guidance document is available
NB	*CCME Guidelines for Compost Quality. http://www.ccme.ca/assets/pdf/compostgdlns_1340_e.pdf* Guidelines for the Site Selection, Operation and Approval of Composting Facilities in New Brunswick http://www.gnb.ca/0009/0373/0001/0007-e.asp *Policy: The direct land application of municipal biosolids that do not meet an equivalent standard to the CCME Compost Quality Guidelines requires an approval from the Department. It is the Department's practice to not approve these types of applications as there as there are available compost facilities to treat this waste to a suitable standard for general use.*
NS	Guidelines For Land Application and Storage of Municipal Biosolids in Nova Scotia, March 2010 https://gov.ns.ca/nse/water/docs/BiosolidGuidelines.pdf Codes of Practice for the Application of Non-Agricultural Organic Wastes (NAOW) on Agricultural Land. (May 2005)
NU	The Government of Nunavut has an Environmental Guideline for Industrial Waste Discharges that set criteria for landfilling of process residuals such as sludge. The Environmental Guideline for Industrial Waste Discharges is mandated under the (territorial) Environmental Protection Act to prevent contaminants from entering the environment. http://www.gov.nu.ca/env/industrial.pdf

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Table A3. cont'd

ON	MOE/OMAFRA's *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land, 1996*, provide guidance to establish requirements for Certificates of Approval in order to ensure that the biosolids and their application are safe. http://www.ene.gov.on.ca/envision/gp/3425e.pdf The *NASM Odour Guide* sets out an odour classification system for NASM that are applied to agricultural land. http://www.omafra.gov.on.ca/english/nm/regs/nmpro/odourtoc_09.htm The *Sampling and Analysis Protocol* sets out the proper sampling and analytical techniques that are critical to accurately determine the nutrient content and other properties of materials applied to the land for the purpose of improving the growing of agricultural crops. http://www.omafra.gov.on.ca/english/nm/regs/sampro/samprotc_09.htm The *Nutrient Management Protocol* provides technical and scientific details and standards that are complementary to and in addition to those set out in the Regulation. http://www.omafra.gov.on.ca/english/nm/regs/nmpro/nmprotc_09.htm Septage The *Provincial Policy Statement, 2005* directs that municipalities no longer approve new development that is dependent on septic systems unless capacity to treat the septage from that development is available. The factsheet on the *Provincial Policy Statement, 2005: Reserve Sewage System Capacity for Hauled Sewage*. The *Provincial Policy Statement* directs that municipalities no longer approve new development that is dependent on septic systems unless capacity to treat the septage from that development is available. http://www.ene.gov.on.ca/en/publications/forms/6316e.php
PEI	Sewage Disposal Systems Regulations This regulation deals with the requirements for human waste. It is used to regulate the septic and sludge haulers working in PEI. http://www.gov.pe.ca/law/regulations/index.php3 Atlantic Canada Wastewater Guidelines Manual for Collection, Treatment and Disposal, 2006. This manual is used by engineers for design guidance of wastewater systems including the design of sludge treatment and dewatering processes. As well, this manual is referenced for the design and land application of Biosolids for facilities that put in place Class A or Class B Biosolids treatment systems as the current Sewage Disposal Systems Regulations do not define the treated sludge to this level. The guidelines document is used for human and industrial waste treatment systems design. http://gov.ns.ca/nse/water/docs/AtlCanStdGuideSewage.pdf
QC	Guidelines for the beneficial use of fertilizing residuals The Guidelines for the Beneficial Use of Fertilizing Residuals includes the applicable standards and criteria. This Guide is used to prepare a request for a certificate of authorization when required http://www.mddep.gouv.qc.ca/matieres/mat_res-en/fertilisantes/critere/index. The Guide covers most types of beneficial use as soil amendment/fertilizer, with the exception of use on degraded sites (high rates). This activity is covered by another guide (French only) http://www.mddep.gouv.qc.ca/matieres/mat_res/fertilisantes/vegetal/index.htm Other French and English documents are available on MDDEP web-site (Statistics, factsheets, questions and answers, scientific studies, etc.) http://www.mddep.gouv.qc.ca/matieres/mat_res-en/fertilisantes/index.htm

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Table A3. cont'd

	Policy: Politique québécoise de gestion des matières résiduelles 1998-2008 http://www.recyc-quebec.gouv.qc.ca/upload/Publications/politique_quebecoise_sur_la_gestion_des.pdf This policy states that eventually no sludge should be landfilled unless its beneficial use is economically non viable. Following this policy, a regulation established a $19.50 tax for each ton of sludge landfilled/incinerated. This is an incentive for beneficial use.
SK	Guideline for Sewage Works Design, EPB 203: This guideline doc contains information on permit requirements for wastewater works, design parameters for wastewater treatment units, sludge generated from various units and sludge treatment. http://www.saskh2o.ca/DWBinder/EPB203GuidelinesSewageWorksDesign.pdf Land application of Municipal Sewage Sludge Guidelines, EPB 296 - This guideline document is useful for the municipalities who intend to apply their treated sewage sludge onto lands for beneficial use. The guideline doc has details like sludge treatment, sludge quality, buffer zones, MAC levels in sludge and soil, and monitoring requirements. http://www.saskh2o.ca/DWBinder/EPB296LandApplication_of_MunicipalSewageSludge.pdf

Table A4. Standards and Requirements of Biosolids under Federal, Provincial and Territorial Jurisdictions (CCME, 2010)
Table A4A. Standards for Metals in Biosolids in Canada

Jurisdictions	Concentration in Biosolids (mg/kg DM)										
	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	Se	Mb	Co
NL	Currently uses USEPA Part 503 Biosolids Rule and BNQ standard 0413-400/2009 on Soil amendments										
NS (Class A)	3	210	400	0.8	62	150	700	13	2	5	34
NS (Class B)	20	1060	760	5	180	500	1850	75	14	20	150
PEI (EQ)	39	1200	1500	17	420	300	2800	41	100	-	-
PEI (A&B)	85	-	4,300	57	420	840	7,500	75	100	75	-
NB	3	210	400	0.8	62	150	700	13	2	5	34
QC (Category C1)	3	210	400	0.8	62	150	700	13	2	5	34
QC (Category C2)	10 Note: Liming materials with a NV:Zn ratio > 0.027 or a NV:Cd ratio > 2.5 (% CCE/mg metal/kg) are also considered C2, according to the criteria in the BNQ standard (2005) on liming materials.	1060	1000 Note: The maximum limit is raised to 1500 mg Cu/kg for residuals > 2.5 % P2O5, d.w., and for biosolids from municipal lagoons.	4.0	180	300	1850 Note:Liming materials with a NV:Zn ratio > 0.027 or a NV:Cd ratio > 2.5 (% CCE/mg metal/kg) are also considered C2, according to the criteria in the BNQ standard (2005) on liming materials.	41	14	20	150
Ontario [1] (NMA: 22 tonnes/ha/5 years)	20	1060	760	5	180	500	1850	75	14	20	150

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Table A4A. cont'd

Ontario [1] (Under valid CofA and current NMA: 8 tonnes/ha/5 years)	34	2800	1700	11	420	1100	4200	170	34	94	340
Ontario (CM1, as of January 1, 2011)	3	210	100	0.8	62	150	500	13	2	5	34
Ontario (CM2, as of January 1, 2011)	34	2800	1700	11	420	1100	4200	170	34	94	340
MB	Metal limits are based on the cumulative weight per hectare of each heavy metal in the soil, as calculated by adding the amount of each heavy metal in the biosolids applied to the background level of the same metal in the soil to which biosolids are applied. Metal limits are specified as kg/hectare for cadmium, copper, nickel, lead, zinc, mercury, chromium (total and VI) and arsenic.										
SK	20	1060	760	5	180	500	1850	75	14	20	150
AB	1500/600	20/8	15/6	3000/1100	100/40	20/8	10/4	NB: metal levels are as ratio to nitrogen & phosphorous, respectively			
BC (Class A)	3	100	400	2	62	150	500	13	2	5	34
BC (Class B)	20	1060	2200	15	180	500	1850	75	14	20	150
NWT (Class A)	3	210	400	0.8	62	150	700	13	2	5	34
NWT (Class B)	20	1060	760	5	180	500	1850	75	14	20	150
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines										
CFIA[3]	20	1060 (interim)	757 (interim)	5	180	500	1850	75	14	20	150
BNQ 0413-400/2009 - biosolids	15	1000	1500	4	180	300	1850	41	25	20	150
BNQ 0413-200/2005 - Compost	20			5	180	500	1850	75	14	20	150
USEPA-EQ biosolids	39		1500	17	420	300	2800	41	100	75	

1 The application rate can be increased to 22 dry tonne/ha/5 years, if material meets more stringent metal concentration under NM regs. Maximum permissible metal addition to soil also exists.
2 -NWT uses CCME Guidelines for Compost Quality for composted manures
3 CFIA – The CFIA criteria are based on cumulative addition and therefore depend on application rate. These values assume an annual application rate of 4400 kg/ha of dry product

Table A4B. Standards for Allowable Metal Concentrations in Soil in Canada (CCME, 2010)

Jurisdictions	Concentration in Soils (mg/kg DM)										
	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	Se	Mb	Co
NL	1.6	120	100	0.5	32	60	220	14	1.6	4	20
NS	1.4	64	63	0.5	32	60	200	12	1.6	4	20
PEI[4]	1.6	120	100	0.5	32	60	220	14	1.6	4	20
NB											
QC	For agricultural land application, Québec MDDEP considers bioavaillable metal as better indicator of risk than total metals. Québec Ministry of agriculture has developed criteria for bio-available metals that may be used by agronomists, especially to monitor Cu and Zn build-up in soils.										
ON	1.6	120	100	0.5	32	60	220	14	1.6	4	20
MB (kg/ha)[1]	2.5	115	113	11.9	90	126	360	22	N/A	N/A	N/A
SK	1.4	64	63	6.6	50	70	200	12	1	5	40
AB - Class 1 (kg/ha)[2]	1.5	100	200	0.5	25	100	300				
AB - Class 2 (kg/ha)	1.1	75	150	0.4	19	75	200				
AB - Class 3 (kg/ha)	0.8	50	100	0.2	12	50	150				
BC	See Contaminated Sites Regulation (B.C. Reg. 375/96) for soil standards										
NWT (kg/ha) [3]	4			1	36	100	370	15	2.8	4	30
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines										
CCME	4	210 (interim)	150 (interim)	1	36	100	370	15	2.8	4	30

1 Based upon soil bulk density of 1200 kg/m3 and soil depth 15cm
2 Class 1 soil - slope 2% or less, > 5 m to water table, soil texture CL,SiCL, SiL,Si,SiC,L,SCL,SC Class 2 - slope 2-5%, 3-5m to water table, soil texture C, HC Class 3 - slope 5-9%, 2-3 m to water table, LS,SI all soil pH > 6.5
3 Based upon CCME Guidelines for Compost Quality & NWT Guideline for Agricultural Waste Management
4 PEI does not have requirements currently, but propose to move forward with plan consistent with the Atlantic Canada Guidelines Manual in May 2009

Table A4C. Requirements on Application Rate for Land Application of Biosolids (CCME, 2010)

Jurisdictions	Application Rate
NL	N/A
NS	Agronomic rate, otherwise not specified
PEI	Currently - none, proposed - Agronomic Rate based on nitrogen content
NB	No net degradation
QC	Agronomic rate, on basis of N & P, however, for forestry use the limit is 200 kg available N/ha/yr. C2 residuals= max 22 tonnes dry weight/ha/5 years.
ON	As of January 1, 2011 new approvals are limited to an application rate of a maximum of 22t/ha dry weight per 5 years as well as restricted by the most restrictive parameter for metals (CM1 or CM2 levels), the agronomic rate for nutrients (N, P, K) and maximums of: boron - 1kg/ha/yr; fats oils and grease - 5000kg/ha/yr (hydrological soil groups A or B) and 2500kg/ha/yr (hydrological soil group C or D); and sodium - 200kg/ha/yr (hydrological soil group A or B) and 500kg/ha/yr (for hydrological soil group C or D).
MB	Agronomic rates for N and P, assuming metals concentrations are not limiting. The nitrate nitrogen, prior to the application of biosolids must be less than the applicable nitrogen limit (157.1 kg/ha for Zone N1, 101 kg/ha for Zone N2, or 33.6 kg/ha for Zone N3) in the upper 60 cm of soil and the sodium extractable bicarbonate phosphorus, as P, must be less than 60 ppm in the upper 15 cm of soil.
SK	agronomic rate based upon nitrogen content
AB	Digested - 10-25 t solids/ha/ 3 yrs, Wastewater lagoon 5-10 t solids/ha/ 3yrs, undigested 2.5-5 t/ha/ 3 yrs - dependent on soil type and slope. Testing biosolids is not specified, however, the soil has to be tested and meet specified criteria prior to reapplication every 3 years.
BC	agronomic rate
NWT	agronomic rate, based upon Nitrogen content
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines

Table A4D. Standards for Pathogen and Pathogen Indicators in Biosolids in Canada (CCME, 2010)

Jurisdictions	Pathogen	Pathogen indicators			Comments
	Salmonella MPN / 4 g	Fecal coliforms MPN / g	*E. coli* CFU/g TS dw	Other	
NL	Currently uses USEPA Part 503 Biosolids Rule and BNQ standard 0413-400/2009 on Soil amendments, if applicable				
NS (Class A)	< 3	< 1000			
NS (Class B)		< 2,000,000			
PEI- Current					No sampling required currently
PEI -EQ -Proposed	< 3	<1000			Required to meet either Salmonella or Fecal requirement. There are no current restrictions. Numbers given are for the proposed program
PEI- Class A - Proposed	< 3	<1000			
PEI- Class B- Proposed		<2,000,000			
NB	< 3	< 1000			New Brunswick biosolids must meet CCME Compost Standards prior to use.
QC (Category P1)	For residuals contaminated with human fecal matter 1) Thermal drying: - Salmonella not detected in 10 g wet weight for residuals with dryness greater or equal to 15% (or in 50 g wet weight for other residuals) - AND drying temperature of at least 80 ˚C - AND final dryness greater or equal to 92% 2) Any other equivalent combination according to the USEPA to satisfy the class A requirements for pathogen reduction (including mandatory salmonella analysis) and vector attraction reduction.				
QC (Category P2)	a) Lime to pH >= 12 for at least 2 hours and maintain at pH >= 11.5 for at least 22 hours b) E. coli < 2 000 000 MPN/g (d.w.) and aerobic biological treatment and O_2 uptake rate of <= 1 500 mg O2/kg organic matter/hour. c) E. coli < 2 000 000 MPN/g (d.w.) and incorporation of residual into soil in less than 6 hours. d) E. coli < 2 000 000 MPN/g (d.w.) and biological treatment with sludge age >= 20 days old. e) E. coli < 2 000 000 MPN/g (d.w.) and and biosolids from a lagoon not emptied since >= 4 years ago. f) Salmonella not detected in 10 g wet weight, for residuals with a dryness >= 15% (or in 50 g wet weight for other residuals) and O1 or O2 odour category g) Any other USEPA-approved combination that meets Class B requirements for the reduction of pathogens and vector attraction. E. coli: geometric mean				
ON*			< 2,000,000		The 1996 Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land require that pathogens be stabilized.
Ontario (CP1: as of January 1, 2011)	<3		<1000		Also requires testing of Viable Helminth Ova and total culturable enteric virus of not detectable in 4g TS dw or in 100ml for materials containing human body waste.
Ontario (CP2: as of January 1, 2011)			< 2,000,000		

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Table A4D. cont'd

MB					Pathogen level is not specified - anaerobic digestion (30 days retention, temperature >20C) or equivalent processing (e.g., isolated storage for 1 year, effective composting) is required.
SK	< 3	< 1000			
AB					Pathogen levels are not specified - three levels of treatment - digested, wastewater lagoon, undigested
BC (Class A)		< 1000			Acceptable methods - Thermophilic anaerobic digestion at 55°C for more than 30 minutes, thermophilic anaerobic at no less than 50°C for at least 10 days, heat treatment processes depending on total solids content, alkaliine stabilization with pH > 12 for 72 hrs with the temperature in excess of 52oC for at least 12 hrs, or composting to produce class A compost
BC (Class B)		< 2,000,000			Acceptable methods - aerobic digestion were residence time and temperature must be between 40 days at 20°C & 60 days at 15°C, air drying for a minimum of 3 months , anaerobic digestion were residence time and temperature must be between 15 days at 35°C to 55°C and 60 days at 20°C, composting to produce Class B compost, or lime stabilized by raising pH to 12 after 2 hrs
NWT	< 3	< 1000			NWT has no standard for biosolids, however, composted manure requires approval and must comply with CCME Guidelines for Compost Quality.
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines				
CFIA	Not detectable	1000 MPN/ g			
BNQ 0413-400/2009 - biosolids	Not detectable	Thermal Drying: Drying temperature of at least 80 °C Alkaline treatment: pH ≥12 for at least 72 consecutive hours; and/or maintained at 52 °C for at least 12 consecutive hours			
USEPA- Class A	< 3	<1000			
USEPA- Class B		< 2,000,000			
MPN - most probable number; MPCN - most probable cytophatic number					
* NOTE – Currently new, expanding and phased-in farms must follow the Nutrient Management Regulation 267/03 as amended; all other applications of biosolids and septage are regulated under Certificates of Approval and follow the Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land.					
*NOTE - Current *E.coli* limit only applies to wastewater treatment plants with design capacity greater than 45,400 cubic meters per day.					

Table A4E. Standards for Organic Contaminants in Biosolids in Canada (CCME, 2010)

Jurisdictions	Contaminant				Comments
	Dioxins & Furans (ng TEQ/kg)	PCB	PAH	Other organic chemicals	
NL	Currently uses USEPA Part 503 Biosolids Rule and BNQ standard 0413-400/2009 on Soil amendments, if applicable				
NS (Class A)	17	Levels of contaminants not specified			
NS (Class B)	50	Levels of contaminants not specified			
PEI	Levels of contaminants not specified				
NB	Levels of contaminants not specified				
QC (Class C1)	17	rarely detected - not deemed of concern	rarely detected - not deemed of concern		
QC (Class C2)[1]	50				
ON	Levels of contaminants not specified				
MB	Levels of contaminants not specified				
SK	Levels of contaminants not specified				
AB	Levels of contaminants not specified				
BC	Risk is managed by site specific review by medical health officers				
Yukon	Not Available				
NWT	Levels of contaminants not specified				
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines , if available				
CFIA	27 (interim)				
BNQ 0413-400/2009 - Biosolids	27				

1 For fertilizing residuals with dioxin / furan content of 51 - 100 ng TWQ/kg is allowed for non agricultural use

2 - CFIA - The CFIA criterion is based on cumulative addition and therefore depends on application rate. This value assumes an annual application rate of 4400 kg/ha of dry product

3- CAN/BNQ standard has an appendex on organic contaminants that explains why no criteria has been set, except for dioxins and furans.

Table A4F. Waiting Periods and Other Requirements for Land Application of Biosolids in Canada (CCME, 2010)

	Pasture	Forage	Livestock Feed	Food Crops (below soil)	Food Crops (above soil)1	Sod	Silviculture	Reclamation	Green Areas	Application Rate (tonnes DM/ ha)	Comments
NL	Currently uses USEPA Part 503 Biosolids Rule and BNQ standard 0413-400/2009 on Soil amendments, if applicable										
NS (class A)	No restrictions					recom-mend: 12 mo.		recommend: 2 mo. for public lands, 6 mo. forest, 2 mo. construction sites, 2 mo. recreational lands			
NS (class b)	Not permitted					12 mo.		2 mo. for public lands, 6 mo. forest, 2 mo. construction sites, 2 mo. recreational lands			
NB	No Restrictions Class A Compost Only - No net degradation from the use of Class A Compost										
PEI - current	not same calendar year					not specified					Proposed: To be developed - possibly consistent with Table G-6 Atlantic Canada Wastewater Guidelines
QC	No municipal biosolids on pastures, unless certified by the BNQ.	all classes permitted, but for P2 > 30 days wait before harvest		No municipal biosolids allowed to be spread for fertilizer for human food crops (current season), unless certified by the BNQ.		P2: 12 month wait until harvest	All classes (Cx-Px-Ox) can't exceed 200 kg of available nitrogen / ha/ yr.	All classes C1/C2, P1/P2, O1/ O2/O3	Cx-P1-Ox for landscaping (no P2). No public access >=12	Mainly limited by P needs of crops. Maximum 22 tonnes dry weight / ha /	Restrictions vary according to the risk as expressed by the CxPyOz classification (C=contaminants. P=pathogens,

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Table A4F. cont'd

				For previous applications of P2 biosolids on the same soil, wait 36 months before harvesting.	For previous applications of P2 biosolids on the same soil, wait 14 months before harvesting.		Restrictions on picking edible products (e.g. fruits and mushrooms)		months for P2.	5 years for C2.	O=odours).
ON	3 weeks for CM1 and CP1 and 2 months for CM2 and/or CP2 for horse, beef or dairy cattle 3 weeks for CM1 and CP1 and 6 months for CM2 and/or CP2 for swine, sheep or goats		3 weeks for hay and haylage	3 weeks for CM1 and CP1 and 3 months for CM2 and/or CP2 for tree fruits & grapes 3 weeks for CM1 and CP1 and 15 months for CM2 and/or CP2 for small fruits 3 weeks for CM1 and CP1 and 12 months for CM2 and/or CP2 for tobacco	3 weeks for CM1 and CP1 and 12 months for CM2 and/or CP2 for vegetables	3 weeks for CM1 and CP1 and 12 months for CM2 and/or CP2 for vegetables and commercial sod Home lawns are not recommended	not specified		Requires MOE review and Certificate of Approval/ No application of biosolids on established golf courses under the NMA.	Under Certificate of Approval: - anaerobically digested - 135 kg N/ha/5years - aerobically digested or stabilized - max 8 t/ha/5 years dry weight; - dewatered or dried - max 8t/ha per 5 years dry weight, Currently, under the Nutrient Management Regulation: 22t/ha/5yrs dry weight or 8t/ha/5yrs dry weight based on regulated metals content and subject to maximum permissible metal addition to soils per hectare over a five year period. As of January 1, 2011 under the Nutrient Management Regulation application of sewage biosolids cannot exceed 22t/ha/5yrs dry weight. Maximum application rates may also be restricted by other parameters such as metals, PAN and PAP (or boron, sodium, and fats, oils and grease upon Director request). The most restrictive rate will govern.	

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Table A4F. cont'd

MB	Application is limited to lands with the following crops grown for three years following the application of biosolids: cereals, forages, oil seeds, field peas, and lentils. There is no restriction on frequency of application assuming all biosolids and soil quality limits would be met.									An Environment Act Licence is required prior to application of biosolids to land. Site-specific restrictions are imposed through the conditions of the Licence, which may or may not include an expiry date or restrictions on frequency of application.	
SK	30 days	60 days	60 days	38 months	18 months/ 60 days if food crop not in contact with biosolids/ soil	not specified	60 days (fibre production)	not specified			
AB	3 years	3 years - forage land can't be pastured for 3 years	3 years - forage land can't be pastured for 3 years	not permitted		3 years		3 years	not likely, must be incorporated	Dependent upon level of treatment (undigested - wastewater lagoon - digested), soil classification (silt, sand, loam, clay), & slope. Between 2.5 & 25 t/ha dry weight	
BC	60 days	not specified	not specified	38 months	18 months	not specified					These restrictions apply to Class B biosolids with fecal coliforms level in excess of 1000 MPN/g.
NWT	NWT within their Guidelines for Agricultural Wastes does not impose any restrictions on manure or composted manure, advises on avoiding areas prone to flooding, steep slopes									Agronomic loading based upon Nitrogen	Does not have biosolids standard, however, composted manure requires permission for land application
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines, if applicable										
CFIA	Not applicable as it does not regulate use										

Table A4G. Separation Requirements for Land Application of Biosolids in Canada (CCME, 2010)

	Distance (m) From					Comments
	Residential/ Institutional/ Commercial/ Uninhabited Structures (barns)	Schools/ Parks and playgrounds	Surface Water/ Water Table/ Wells	Bedrock Outcrop/ Ditches or Swales/ Roads/ Property Line	Other	
NL: Distance would depend on the location of the facility and surrounding activities and developments that will be established in development of biosolids management regulatory requirements.						
NS	Residential – 90 m Institutional – 200 m Commercial – 90 m Uninhabited Structures (barns)- 30 m	Schools – 200 m Parks/playgrounds – 90 m	Surface Water- 90 m (perennial) / 60 m (intermittent) - slope less than 3%, 125 (slope 3-6%), 180 (6-8% slope), not permitted (slope > 8%0 Wells – 150 m (public) / 90 m (private)	Bedrock Outcrop- 10 m Ditches or Swales- 15 m Roads- 30 m (primary / secondary) / 10 m (unimproved) Property Line- 10 m		
PEI- Current	Business - 300 m. From any Dwelling 300 m	Schools - 300 m	Surface Water- 15 m less than 2 % 37 m 2 to 5 % 107 m 5 to 10 % 213 m >10 % Wells- 500 m	Provincial Highway Right of Way- 15 m		**Proposed:** To be developed - possibly consistent with Table G-6 Atlantic Canada Wastewater Guidelines Proposed to have no restrictions for Biosolids that meet EQ standards
NB	No setbacks for composted biosolids meeting class A CCME Compost Quality					

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Table A4G. cont'd

QC (see tables 10.2 and 10.3 of the FR Guide for spreading restrictions)	Residential-Dwelling: P2=50m, O2=75 m, O3=500 m (for O2 & O3; restriction lifted if immediate incorporation) Institutional- Protected immovable: P2=100 m Urbanization perimeter of a municipality: P2=250 m. See the glossary of the FR Guideline for a definition of protected immovable Commercial – Protected immovable: P2=100 m Urbanization perimeter of a municipality: P2=250 m	Schools- Protected immovable: P2=100 m Urbanization perimeter of a municipality: P2=250 m Parks and playgrounds: Protected immovable: P2=100 m Urbanization perimeter of a municipality: P2=250 m	Surface Water- Agricultural ditch: 1 m Non-agricultural ditch: P1=1 m, P2=10 m Watercourse, lake, swamp >10 000 m2 or pond: 3m Soils in flood zone: P2=prohibited Wells: 100 m (30m for products certified by the BNQ. Field stockpiling: 300 m Wells - There are other restrictions for collective groundwater catchment works	Bedrock Outcrop- 100 m during storage in heaps in field. Ditches or Swales- Agricultural ditch: 1 m Non-agricultural ditch: 1 m, P2=10 m Roads- P2=5 m Property Line - P2=5m	- Incorporation in the soil < 48 hours if the spreading is done on bare soil - Maximum hydraulic load for liquid residuals: < 100 m3/day - Spreading equipment (liquid residuals): Specialized equipment that minimizes soil compaction if a post-harvest spreading operation is involved. - Frozen or snow-covered soil: Land application prohibited (standard in the RRAO). - Ground slope: < 9% (< 5% if the residual is liquid).	For temporary storage in heaps, see tables 9.1 and 9.2 of the FR Guide. For a list of all the spreading requirements, see tables 10.2 and 10.3 of the FR Guide.
ON (Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land)	450 m (residential area) 90 m (individual residence) Institutional- No specification Commercial –No specification Uninhabited Structures (barns)- No specification		Surface Water - 0-3% slope - 50 m for rapid to moderately soils and 100 m for moderate to slow soils 3-6% slope - 100 m for rapid to moderately soils and 200 m for moderate to slow soils 6-9% slope - 150 m for rapid to moderately soils and not permitted for moderate to slow soils slope > 9% all soil	Bed Rock Outcrop – 1.5 m (depth to bedrock)	Prohibition on land application when the ground is frozen, snow covered and in winter (between Dec 1 and March 31st of the following year)	

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Table A4G. cont'd

			permeabilities not permitted Water table- 0.9 m Well- 15 m (drilled greater than 15m) / 90 m (all other wells)			
Ontario (as of January 1, 2011)	Residential (single dwelling): - OC1 – no application <25m - OC2 – no application <25m, 25-90m injection or spreading & incorporation within 6 hours, >90m no restriction - OC3 – no application <100m, 100-450m injection or if injection not possible spreading & incorporation within 6 hours, >450m injection & incorporation within 24 hours. Uninhabited Structures (barns): no specification.	Residential areas, commercial, community or institutional uses: - OC1 - <50m no application - OC2 – no application <50m, 50-450m injection or spreading and incorporation within 6 hours, >450m no restriction i -OC3 – no application <200m, 200-900m injection or spreading and incorporation within 6 hours, >900m injection or spreading and incorporation within 24 hours	Surface Water: -CM1 and CP1 - 13m or up to 3 m vegetated buffer if injected, incorporated within 24 hours or applied to a living crop or on a field with at least 30% crop residue. 20m if no vegetated buffer. - CM2 and/or CP2 – 20m Water Table: -CM1 and CP1 – no application <30cm - CM2 and/or CP2 – no application <30 cm, 30-90cm based on risk of groundwater contamination Wells: CM1 and CP1- Municipal – 100 m Drilled (6m water tight casing & ≥ 15m well depth) – 15m Other – 30m	15 m (field drainage tile). Ditches and swale are not defined in NMA. It is either surface water or not. Some ditches and swale are not surface water as defined in NMA.	Prohibition on land application anytime when the ground is frozen, snow covered and in winter (between Dec 1 and March 31st of the following year)	

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Table A4G. cont'd

			CM2 and/or CP2 – Municipal – 100m Drilled (6m watertight casing & ≥ 15m well depth) – 15 m Other – 90m Depth to Bedrock: <30cm no application 30-100cm based on material quality and state (solid vs liquid) >100cm no restriction based on bedrock			
MB (Separation distances are specified in a site-specific Licence)	300 m (from occupied residences) and 1 km (from residential areas)		- 15 m from first order waterways - 30 m from 2nd and higher order waterways - 100 m from the identifiable boundary of an aquifer which is exposed to the ground surface		Other land restrictions include: - lands cannot be subject to flooding - depth of clay or clay till must be at least 1.5 m between the soil surface and the water table - pH of the soil must be greater than 6.0 slope of the soil surface must not be greater than 5%	
MB (Additionally, a Nutrient Management Regulation under the Water Protection Act, prohibits application of nutrients (including biosolids) within the Nutrient Buffer Zone)			- 15 m of the edge of a groundwater feature (20 m if the area is not covered with vegetation) - Land within a roadside ditch or an Order 1 or 2 drain - Land between the water's edge and the high water mark of a wetland, bog, marsh or swamp - Land adjacent to a listed water body (distances vary based on type of water body and presence/absence of vegetation) but maximum distance is 35 m from a lake or reservoir designated as vulnerable with no permanent vegetative cover.		The Nutrient Management Regulation prohibits application of a substance containing nitrogen or phosphorus to land between November 10 of one year and April 10 of the following year (i.e., no winter application). An exception may be granted for application of wastewater sludge or biosolids from a municipality in unusual circumstances.	

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Table A4G. cont'd

SK	450 m (residential area) 90 m (individual residence) 200 m (hospitals) 90 m (Commercial)	Schools- 200 m Parks and playgrounds- 90 m	Surface Water- 90 m (0-3% slope) 200 m (3-8% slope) Wells- 90 m (0-3% slope) 200 m (3-8% slope)	Roads- 30 m		
AB[2]	500 / 165 m (zoned residential areas) 60 / 20 m (occupied dwelling) 10 / 3 m (public building perimeter) 60 / 20 m (public Building)	Schools- 200 / 66 m (in session) 20 / 7 m (out of session) Parks and playgrounds 200 /66 m	Surface Water- 30 / 10 m Water Table- potable aquifer must be >2 m, application rates depend in part on depth to potable aquifer Wells-20 / 20 m		No application on ice or snow covered or frozen ground	Minimum distance for surface application and subsurface injection respectively
BC	Residential ≥ 30m		Water Table- ≥1 metre of the surface Wells- ≥ 30m	Roads- ≥ 20 m to major arterial roads or highways and ≥10 m to minor public roads excluding logging roads Property Line-≥ 30m		Theses restrictions apply to Class B biosolids with fecal coliforms level in excess of 1000 MPN/g.
NWT	Currently uses CCME guidelines, if applicable					
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines, if applicable					
1 separation from water courses based upon soil permeability						
2 surface application / subsurface application						

Table A4H. Stability Requirements and Application Rate for Land Application of Biosolids (CCME, 2010)

Jurisdictions	Indicators of Stability
NL	N/A
NS	Volatile solids reduction of 38%, specific oxygen uptake rate < 1.5 Of/hr/g, pH > 12 for 2 hrs
PEI	Currently - Minimum sludge > 30 days held can be applied to land. Proposed - Sludge Volatile solids reduction of 38%, specific oxygen uptake rate < 1.5 Of/hr/g, pH > 12 for 2 hrs or other approved method meeting Atlantic Wastewater Guidelines.
NB	Must be Category A Compost Quality or equivalent with respect to stability to be land applied.
QC	The biosolids must meet criteria for P1 or P2, which include parameters for vector attraction reduction (related to odours). The biosolids must also meet specific odour criteria(O categories) which are also linked to stability/VAR.
ON	Only biosolids stabilized through the MOE approved process can be applied, but method of testing for stabilization not specified. As of January 1, 2011, new approvals for the land application of biosolids under the Nutrient Management Regulation will have to meet one of the following minimum beneficial quality standards: organic matter content of 15% of the total weight of the NASM, NASM used to increase the soil pH, total concentration of plant available nitrogen, plant available phosphorus and plant available potassium is more than 13,000 mg/kg of NASM (for solids) or more than 140mg per L of NASM (liquids), or to be used as irrigate crops between June 15 and September 30, where the NASM is more than 99% water by weight. Pathogen levels as specified in pathogen comment section.
MB	Must be stabilized by anaerobic digestion for a period of 30 days at a minimum temperature of 20°C or equivalent process (e.g., isolated storage of sludge solids for a period of 1 year; effective composting) before being land applied.
SK	Volatile solids reduction of 38%, specific oxygen uptake rate < 1.5 Of/hr/g, pH > 12 for 2 hrs, additional bench scale anaerobic digestion demonstrates that the volatile solids reduction of the anaerobically digested sludge is < 17%, additional bench scale aerobic digestion demonstrates that the volatile solids reduction of the aerobically digested sludge is < 15%, or aerobically composted for 14 days
AB	Three differing degrees of stabilization - digested, wastewater lagoon, and undigested. Testing biosolids is not specified.
BC	Stabilization achieved by pathogen & vector attraction reduction. Pathogen levels as specified in pathogen comment section , vector reduction by volatile solids reduction of 38%, SOUR uptake of less than 1.5 mgO2/hr/g, pH of 12 or higher for 2 hours and then at 11.5 or higher for an additional 22 hours.
NWT	Would have to meet CCME Guidelines for Compost Quality with respect to stability
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines

Table A5A. Frequency of Sampling of Biosolids in Canada (CCME, 2010)

Jurisdictions	Frequency of sampling (indicate units) for Metals	Pathogens	Organic Pollutants	Dioxins	Comments
NL					No requirements
NS	2000 tonnes	2000 tonnes			Biosolids must be sampled from each source and every 2000 tonnes for each source
PEI -current					No requirements
PEI -Proposed	none	none			Currently there are no requirements for sampling. Proposed 290 to 1500 tonnes/yr - quarterly or rep samples, 1500 to 15000 tonnes/yr – 6 times per year for metals and pathogens
NB	Treatment plants are required to sample 3/yr.				All finished compost must be shown to meet CCME Guidelines
QC	Other parameters(2)	Salmonella or E. coli(2,3)		Dioxins and furans(4,5)	Quantity produced annually or accumulated by type of residual and production place (tonnes, dry weight)(1)
QC (0-300 tonnes)	2	2		1	Please see the notes at the bottom of the table.
QC (301- 1500 tonnes)	4.	4		2	
QC (1501 - 15000 tonnes)	6.	6		3	
QC (> 15000 tonnes)	12.	12		4	
ON	Materials sampling frequency set out in approval issued under the *Environmental Protection Act* or *Ontario Water Resources Act* or in Nutrient Management Regulation whichever is most restrictive. Under the Regulation, sewage treatment plants with design capacity > 45,400 m^3 sample twice per month and sewage treatment plants with design	Pathogen sampling frequency set out in approval issued under the *Environmental Protection Act* or *Ontario Water Resources Act*			Nutrient Management Regulation applies if sewage treatment plant is phased-in.

Cont'd

Table A5A. cont'd

	capacity < 45,400 m^3 sample once per month. As of January 1, 2011, soil sampling required for the preparation of a NASM Plan must be taken within 5 years from when the material is applied.				
MB	Set out in an Environment Act Licence. For lagoons, an approved sampling program is required prior to each application event. Samples are required from each lagoon cell and from each field onto which biosolids will be applied.				
SK	prior to application to the field, tonnage not specified				Sampling frequency not specified.
AB					Sampling frequency not specified. Guideline states that a sample must be collected that is representative of the material to be land applied.
BC	1 per 1000 tonnes	7 per 1000 tonnes			also can sample at least once a year, whichever comes first
NWT					
NU	Currently uses Guidelines, Regulations and Acts of NWT and the CCME guidelines, if available				
CFIA	Random sampling of fertilizers and supplements sold in Canada				
(1) Amount produced by the wastewater treatment plant. See table 6.2 of the FR Guide for more details. Minimum number of composite samples over the 12 months preceding the CA application.					
(2)For biosolids from lagoons, the frequency is reduced by half. Otherwise, the older analyses are acceptable (up to 3 years) to complete an analysis made over the last 12 months. For other FR, the frequency may be reduced by 50% if over the last 24 months, the alleged category has not been exceeded (C1 or C2), and if the procedure has not been modified during this period. Notwithstanding what precedes, at 2 analyses are always required to determine the category of any residuals, except for D&F.					
(3)For E. coli and salmonella analyses, a grab sample (continuous process) or a spot sample (static environments) is substituted for the composite sample. Spot sampling involves taking a set of samples representative of a particular sector or batch during a time period generally of less than 15 minutes. The number of samples may vary in these particular cases (see Section 8.3.2).					
(4)For municipal biosolids, the D&F analysis is not necessary if the residual is already in the C2 category due to levels of another trace metal, or if we assume C2 levels of D&F to avoid having to analyse for D&F. The number of analyses for D&F may be reduced to once every two years if over the last 36 months the analysis results are always lower than the category stated in the CA application (C1 or C2).					
(5)For the year prior to land application, dioxin/ furan sampling may be reduced to 1 every two years if below C1 or C2 standard.					

Table A5B. Monitoring, Compliance and Record-Keeping Requirements in Federal, Provincial and Territorial Jurisdictions (CCME, 2010)

Jurisdiction	Monitoring and compliance	Record-keeping requirements
Federal		
CFIA	The Fertilizers Program has market place monitoring programs in place for ensuring compliance of biosolids and composted products that are sold as a fertilizer or supplement.	Not applicable
Provincial/Territorial		
AB	Follow-up sampling is not required. If a review of post- disposal rate reveals a discrepancy with the application, the applicant will be contacted. The letter of authorization requires reporting of any spills into water courses or onto land not authorized to receive biosolids. Alberta Environment would follow up any reports with an investigation. In addition, the letter of authorization requires the applicant to submit a summary report on the year's biosolids spreading program. The report is typically required by Feb. 28 of the following year. These reports are not routinely reviewed when they come in, but they are reviewed prior to periodic inspections that are carried out by our compliance inspectors. If problems are identified in the report (e.g. wrong disposal rate, biosolids applied to wrong location, complaints noted, etc.) these would be followed up during the compliance inspection and forwarded to our enforcement staff for enforcement action if necessary.	The *Wastewater and Storm Drainage Regulation* requires the operator to keep a copy of the land application annual report for 5 years. Under the Code of Practice, the operator must retain a copy of the application for authorization to land apply and the written authorization. No time period for maintaining the records is specified. Under operating approvals, the operator is required to prepare monthly and annual reports that include the volume of biosolids going to landfill. There are no requirements for retaining these reports.

Cont'd

Table A5B. cont'd

BC	All required analyses must be carried out at intervals of at least every 1 000 tonnes dry weight of organic matter, or once per year, whichever occurs first. The director may increase the frequency of sampling required based on provincial organic matter sampling guidelines. Analyses must be in accordance with the procedures described in A British Columbia Laboratory Methods Manual: 2003 for the Analysis of Water, Wastewater, Sediment, Biological Materials and Discrete Ambient Air Samples, (2003, Ministry of Water, Land and Air Protection), or by suitable alternate procedures authorized by a director.	Temperatures and retention times must be monitored and recorded each working day during the production of Class A biosolids. The results of analysis required by this regulation must be kept at the facility for at least 36 months after the production of Class A biosolids, Class B biosolids and biosolids growing medium. Besides this data, the land application plan signed by a qualified professional as required by Division 1 of Part 3 of the regulation must be kept at the facility, or kept by the registered owner of the land application site, for at least 36 months after application must be made available for inspection by an officer, or sent to a director or an inspector or officer authorized under the *Agricultural Land Commission Act*, or the *Soil Conservation Act*, upon request. A director may request a sampling report from the facility operators or the registered owner of the land for at least 36 months after application of managed organic matter. The "discharger" is responsible for complying with the OMRR including reviewing sampling results. The OMRR Schedule 6 indicates that sampling results must be kept at the facility for inspection for at least 36 months after land application and sent to the director upon request; the director may also request a sampling report. Environmental - Protection staff may also conduct compliance and enforcement activities consistent with the inspection policy http://iwww.env.gov.bc.ca/epd/policy/manual/compliance/pdf/70106.pdf and compliance and enforcement policy/procedure http://www.env.gov.bc.ca/main/prgs/docs/ce_policy_and_procedure.pdf
MB	Pre and post application testing is required and must be undertaken by the licensee. The licensee is required to control the cropping practice on the land that has received the sludge for a period of 3 years and to maintain appropriate records.	Record keeping requirements are listed in each licence. Records that must be kept are legal description of land, background levels of macro-nutrients and metal content of soils, nutrients applied to lands, residual metal content of soil, and crops grown on lands receiving biosolids for a 3 year period.
NL	Regulatory inspections are conducted by the Agency issuing Permit B DOEC	Record keeping requirements are as per requirements of the Permit.
NB	Inorganic parameters are monitored regularly and the Municipal wastewater treatment facilities are required to submit this information to the Department annually. Facilities are audited periodically (~every 2 yrs) for compliance with their Approval. Compost facilities have approvals to operate and must submit analyses of the finished compost to the department.	Wastewater treatment facilities need to record biosolids analytical results and the location where all biosolids are sent for disposal. Compost facilities must demonstrate and record that all finished compost meets CCME Guidelines for Compost Quality.

Cont'd

Table A5B. cont'd

NS	The Inspection staff designated Under the Environment Act of Nova Scotia Environment, have the ability and authority to sample, verify and enforce any condition of the Approval to ensure compliance. The approval holder must submit an annual report with respect to the biosolids they accepted during the year including: date of receipt, the source of the biosolids, biosolids analysis, stabilization methods, location of application, volumes applied, soil sampling, water sampling, and a copy of the nutrient management plan. Department staff also undertakes a site visit as part of the review of the annual report. Staff will visit the application and storage sites in response to complaints by the public.	Records must be kept for a minimum of 5 years and shall include: Biosolids, soil, and water analysis, sampling procedures, dates biosolids received including amount and generator information, Land application details, Site plans, Cropping information, Records of complaints and how they were addressed.
NU	Water licences are enforced by the Department of Indian Affairs and Northern Development Canada (DIAND) through on-site inspections and sampling is by Land and Water Inspectors.	No other record keeping requirements indicated. The Nunavut Water Board uses CCME-Guidelines or other guidance documents as a starting point where applicable

Cont'd

Table A5B. cont'd

ON	The MOE is responsible for compliance and enforcement under the EPA and the NMA (e.g. MOE is responsible for the potential impacts of farm activities on drinking water sources and has the responsibility for conducting inspection of farms for compliance with the NMA). MOE staff undertake compliance and enforcement activities such as: Reviewing applications for site and hauler approvals; Conducting pre-approval site assessments (this is a standard practice in the site approval process); Conducting inspections once sites have been approved to assess compliance with conditions on the approval; and Responding to reports of pollution or other incidents resulting from the storage, transport, and land application of NASM and septage. MOE will maintain its compliance and enforcement role under the new system of approvals, beginning January 1, 2011.	*Biosolids Guidelines* Currently, the person who holds the Organic Soil Conditioning Site Certificate of Approval is required to keep permanent records of: - The location of all fields receiving biosolids or other wastes. - The amount of biosolids or other wastes applied to each field. - Biosolids or other waste analyses. A report is to be provided to the hauler. The report shall include data on the waste material's average nutrient content per cubic metre. A copy of this report is to be held by the waste generator. The generator must supply the farmer with information on the annual average quantities of metals per cubic metre (ppm, g/tonne, mg/kg) of biosolids or other waste, if requested. (*Biosolids Guidelines*, section 8.1.1) Detailed records must be kept for each agricultural field that receives sewage biosolids. The farmer needs this information to make appropriate nutrient management planning decisions. It must also be available to MOE staff during a site inspection. As of January 1, 2011, approvals will no longer be issued for "Organic Soil Conditioning Site" Certificate of Approvals and all record keeping requirements for NASM Plans will be under the NMA. NMA: Currently, operators of sewage treatment plants with a designed capacity of more than 45,400 cubic metres per day are required to create and maintain (for 2 years) a record of the NMS and prepare yearly updates as necessary to ensure that it accurately reflects the anticipated operation on the farm unit during the following year. If phased-in, brokers are required to keep a four year record of the type and quantity of prescribed materials transferred and the date of transfer, a description of the operation to which the materials are transferred, the operation identifier for the operation or for the farm unit where the operation is carried out and the approval or registration number assigned by the Director to the NMP for the farm unit or operation. As of January 1, 2011, operators of sewage treatment plants will no longer require a NMS and brokers will no longer need a Broker's Certificate or to keep records under the NMA. Brokers will continue to follow requirements stipulated in their Waste Management System Certificate of Approval for the transportation of sewage biosolids. Under the NMA, for land application of material, copies of the NASM Plan, annual update and summary, site characterization, and records of the NASM application area, quantity applied, source of material, dates on which it was applied and sampling and analysis results must be kept for 2 years.

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Table A5B. cont'd

		Septage: Septage haulers are required to conduct regular inspections of the equipment under their care and control to ensure that all equipment is maintained and operated in a manner that the hauled sewage will not negatively impact the environment. - Also, required to note in a log book any deficiencies that might negatively impact the environment. - Log entries include: name and signature of personnel conducting the inspection; date and time of the inspection(s); and recommendations for remedial action and actions undertaken. - Septage haulers also must complete an Annual Report by February 28 of each year, covering the previous calendar year. - This report must include a list of all septage management sites and-volumes of septage spread, stored or disposed at each site and must be provided when requested. Annual Reports must be retained indefinitely at the company's place of business.
PEI	The enforcement is dealt with as defined in the Sewage Disposal Systems Regulations. Typical, enforcement actions are setbacks B wells, property, water course, etc - application without licence, application of specific crop, etc. Charlottetown and Summerside are required through their management plans to sample the Biosolids.	Currently, there are no requirements for record keeping. In future, proponents may require public reporting of the quality of the biosolids. As well, recently, there was a Nitrate Commission assembled in PEI to provide recommendations on the current status and future trends for PEI. In this report one focus issue was nutrient management plans. It is proposed that this will be incorporated with the biosolids in the future.
QC	The Québec Ministère du Développement durable et de l'Environnement et des Parcs is responsible for enforcement. All requests for C of A are registered in a database with specific information targeted to site control and statistics. Spreading and storage sites may be inspected by MDDEP staff, as part of regular inspection routine or following complaints. Biosolids that are claimed to be virtually pathogen free (category P1) must also be counter-verified once a year by an organization accredited organization to fertilizer residue sampling. Biosolids certified by BNQ are sampled twice a year by this organization.	For Biosolids generators, analysis results are needed for the last 12 months for chemical contaminants and pathogens (C categories and P categories), whereas for farm application, the nutrient management plan of the farm must be up-to-date and made available anytime and records retained for at least 3 years.
SK	The guideline document for land application has monitoring requirements that is included in the permit. The municipality has to do monitoring as per permit and furnish the results periodically to respective Environmental protection Officers. The officers will verify the results and inspect the facility once a year. Environmental Protection Officers and Drinking water Enforcement Specialist are responsible for the enforcement.	The municipalities are responsible for record keeping related to biosolids production and/or use.

Table A6. Maximum permissible concentrations of potentially toxic elements in soils (mg kg^{-1} dry soil in EC Member States and US

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Directive 86/278/EEC	1-3	100-150(4)	50-140	1-1.5	30-75	50-300	150-300
Austria							
Lower Austria	1.5/1h)	100	60	1	50	100	200
Upper Austria	1	100	100	1	60	100	300/150(9)
Burgenland	2	100	100	1.5	60	100	300
Vorarlberg	2	100	100	1	60	100	300
Steiermark	2	100	100	1	60	100	300
Carinthia if 5<pH<5.5	0.5	50	40	0.2	30	50	100
if 5.5<pH<6.5	1	75	50	0.5	50	70	150
if pH>6.5	1.5	100	100	1	70	100	200
Belgium, Flanders	0.9	46	49	1.3	18	56	170
Belgium, Walloon	2	100	50	1	50	100	200
Bulgaria							
pH=6-7.4	2	200	100	1	60	80	250
pH>7.4	3	200	140	1	75	100	300
Cyprus	1-3	100-150	50-140	1-1.5	30-75	50-300	150-300
Denmark	0.5	30	40	0.5	15	40	100
Finland	0.5	200	100	0.2	60	60	150
France	2	150	100	1	50	100	300
Germany (6)	1.5	100	60	1	50	100	200
Germany (7)							
Clay	1.5	100	60	1	70	100	200
Loam/silt	1	60	40	0.5	50	70	150
Sand	0.4	30	20	0.1	15	40	60
Greece	3	-	140	1.5	75	300	300
Ireland	1	-	50	1	30	50	150
Italy	1.5	-	100	1	75	100	300
Luxembourg	1-3	100-200	50-140	1-1.5	30-75	50-300	150-300
Estonia (10)	3	100	50	1.5	50	100	300
Hungary	1	75/1 (8)	75	0.5	40	100	200
Latvia	0.5-0.9	40-90	15-70	0.1-0.5	15-70	20-40	50-100
Lithuania	1.5	80	80	1	60	80	260
Malta							
pH 5<6	0.5	30	20	0.1	15	70	60
pH 6-7	1	60	50	0.5	50	70	150
pH >7	1.5	100	100	1	70	100	200
Netherland	0.8	10	36	0.3	30	35	140
Portugal							
Soil ph<5.5	1	50	50	1	30	50	150
5.5<soil<7	3	200	100	1.5	75	300	300
Soil ph>7	4	300	200	2	110	450	450
Poland							
Light soil	1	50	25	0.8	20	40	80
Medium soil	2	75	50	1.2	35	60	120
Heavy soil	3	100	75	1.5	50	80	180
Romania	3	100	100	1	50	50	300
Slovakia	1	60	50	0.5	50	70	150
Slovenia	1	100	60	0.8	50	85	200
Spain							
Soil ph<7	1	100	50	1	30	50	150
Soil ph>7	3	150	210	1.5	112	300	450
Sweden	0.4	60	40	0.3	30	40	100
UK(1)	3	400 (5)	135	1	75	300 (3)	20
USA (2)	20	1450	775	9	230	190	1500

(1) For soil of pH $\geq$5.0, except Cu and Ni are for pH range 6.0 – 7.0; above pH 7.0 Zn = 300 mg kg^{-1} ds (DoE, 1996);
(2) Approximate values calculated from the cumulative pollutant loading rates from Final Part 503 Rule (US, EPA 1993);
(3) Reduction to 200 mg kg^{-1} proposed as a precautionary measure;
(4) EC (1990) – proposed but not adopted;
(5) Provisional value (DoE,1989).
(6) Regulatory limits as presented in the German 1992 Sewage Sludge Ordinance (BMU, 2002)
(7) Proposed new German limits (BMU, 2007)
(8) Chromium VI
(9) For ph<6
(10) In soils where 5<ph<6 it is permitted to use lime-sterilised sludge

Other elements only restricted in some countries or regions:

	Arsenic	Molybdenum	Cobalt
Steiermark		10	50
Belgium (Flanders)	22		
Hungary	15	7	30

Table A7. Maximum level of heavy metals (mg per kg of dry substance) in sewage sludge used for agricultural purposes.

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Directive 86/278/EEC	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Austria							
Lower Austria	2	50	300	2	25	100	1500
Upper Austria	10	500	500	10	100	400	2000
Burgenland	10	500	500	10	100	500	2000
Voralberg	4	300	500	4	100	150	1800
Steiermark	10	500	500	10	100	500	2000
Carinthia	2.5	100	300	2.5	80	150	1800
Belgium (Flanders)	6	250	375	5	100	300	900
Belgium (Walloon)	10	500	600	10	100	500	2000
Bulgaria	30	500	1600	16	350	800	3000
Cyprus	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Czech republic	5	200	500	4	100	200	2500
Denmark	0.8	100	1000	0.8	30	120	4000
Estonia	15	1200	800	16	400	900	2900
Finland	3	300	600	2	100	150	1500
France	20	1000	1000	10	200	800	3000
Germany (1)	10	900	800	8	200	900	2500
Germany (2)	2	80	(600)	1.4	60	100	(1500)
Greece	20-40	500	1000-1750	16-25	300-400	750-1200	2500-4000
Hungary	10	1000/1(3)	1000	10	200	750	2500
Ireland	20		1000	16	300	750	2500
Italy	20		1000	10	300	750	2500
Latvia	20	2000	1000	16	300	750	2500
Lithuania	-	-	-	-	-	-	-
Luxembourg	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000
Malta	5	800	800	5	200	500	2000
Netherlands	1.25	75	75	0.75	30	100	300
Poland	10	500	800	5	100	500	2500
Portugal	20	1000	1000	16	300	750	2500
Romania	10	500	500	5	100	300	2000
Slovakia	10	1000	1000	10	300	750	2500
Slovenia	0.5	40	30	0.2	30	40	100
Spain	20	1000	1000	16	300	750	2500
Spain	40	1750	1750	25	400	1200	4000
Sweden	2	100	600	2.5	50	100	800
United Kingdom	PTE regulated through limits in soil						

(1) Regulatory limits as presented in the German 1992 Sewage Sludge Ordinance (BMU, 2002)
(2) Proposed new limits (BMU, 2007)
(3) Chromium VI

Other elements only restricted in some countries or regions:

	Arsenic	Molybdenum	Cobalt
Lower Austria			10
Steiermark	20	20	100
Belgium (Flanders)	150		
Denmark	25		
Netherlands	15		
Czech republic	30		
Hungary	75	20	50
Slovakia	20		

Table A8. Standards for maximum concentrations of pathogens in sewage sludge

	Salmonella	Other pathogens
Denmark a)	No occurrence	Faecal streptococci:< 100/g
France	8 MPN/10 g DM	Enterovirus: 3 MPCN/10 g of DM Helminths eggs: 3/10 g of DM
Finland (539/2006)	Not detected in 25 g	Escherichia coli <1000 cfu
Italy	1000 MPN/g DM	
Luxembourg		Enterobacteria: 100/g no eggs of worm likely to be contagious
Poland	Sludge cannot be used in agriculture if it contains salmonella	

a) applies to advanced treated sludge only
b) tbc – need to be checked

Table A9. Standards for Maximum Concentrations of Organic Contaminants in Sewage Sludge (mg/kg DS except PCDD/F: ng TEQ/kg DS)

	Absorbable organic halides (AOX)	Bis(2-ethylhexyl) phthalate (DEHP)	Linear Alkylbenzene Sulfonate (LAS)	Nonylphenol/ Nonylphenol ethoxylate (NP/NPE)	Polycyclic aromatic hydrocarbon (PAH)	Polychlorinated biphenyls (PCB)	Dioxins/Furans (PCDD/F)	others
Directive 86/278/EEC	-	-	-	-	-	-	-	
EC (2000)a)	500	100	2600	50	6b	0.8c	100	
EC (2003)a)			5000	450	6b	0.8c	100	
Austria								
Lower Austria	500	-	-	-	-	0.2 d)	100	
Upper Austria	500					0.2 d)	100	
Vorarlberg	-					0.2 d)	100	
Carinthia	500				6	1	50	
Denmark (2002)		50	1300	10	3b			
France					Fluoranthene: 4 Benzo(b)fluoranthene: 2.5 Benzo(a)pyrene: 1.5	0.8c)		
Germany (BMU 2002)	500					0.2 e)	100	
Germany (BMU 2007) f)	400				Benzo(a)pyrene: 1	0.1 e)	30	MBT+OBT:0.6 Tonalid: 15 Glalaxolide:10
Sweden	-	-	-	50	3b)	0.4c)	-	
Czech Republic	500					0.6		

a proposed but withdrawn
b sum of 9 congeners: acenapthene, fluorene, phenanthrene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-c,d)pyrene
c sum of 7 congeners: PCB 28, 52, 101, 118, 138, 153, 180
d sum of 6 congeners:PCB28,52,101,138,153,180
e Per congener
f Proposed new limits in Germany (BMU 2007)

Appendix B. Detailed Descriptions of Class A Biosolids Processes

B.1 Alkaline Stabilization

B.1.1 Process Description

Alkaline stabilization is a reliable and well-established method for stabilizing biosolids. In the process, an alkaline material such as lime is added to biosolids to raise the pH to greater than 12.0 standard units in order to reduce pathogens. Lime as either hydrated lime ($Ca(OH)_2$; also known as calcium hydroxide or slaked lime) or quicklime (CaO)) is the most common alkaline compound. Other alkaline compounds that have been used including cement kiln dust, lime kiln dust, Portland cement or fly ash (WEF, 1995). The proper and thorough mixing of biosolids and the alkaline source has been considered as crucial in the development of a superior product. When lime is used, it may be added in either liquid or dry form. In dry lime alkaline stabilization, biosolids are dewatered prior to mixing with lime. This mixture is then typically dried and cured with the process producing a soil consistency like product (WEF, 1995). In liquid form, a lime slurry may be added to stabilize and thicken the biosolids prior to land application (e.g. subsurface injection). In addition, a lime slurry may be added to stabilize and condition the biosolids prior to dewatering. Under this condition, other conditioners such as aluminum or iron salts would typically be added to enhance dewatering. This method has been used primarily with vacuum filters and recessed plate filter presses.

When quicklime (CaO) is used, it reacts with water in an exothermic reaction that can achieve temperatures in excess of 700^{o}C. This process not only pasteurizes the material but can produce a soil like material. Besides the reliance of an exothermic reaction, additional heat needed to produce the finished dry material may be supplied in a vessel such as a drum or rotary dryer. Moisture reduction may also be achieved by air drying in windrows. If drying is applied, the final product may have a solids content of 50% to 60% or greater (WEF, 1995).
Advanced alkaline stabilization methods involve the use of additional chemicals other than lime, high chemical addition rates and supplemental drying. These additions or modifications are designed to increase the stability of the product, decrease the odour potential and further reduce pathogens. Modifications to the process can include the addition of "possolanic" materials to the process which on their own do not have any cementitious value; however, they can react with calcium hydroxide at normal temperatures to form compounds that have cementitous properties.

Proprietary systems such as those provided by the suppliers listed below employ some or all of the advanced stabilization methods indicated in the previous paragraphs:

- N-Viro Systems Canada (www.nviro.com)
- Lystek International (www.lystek.com)
- RDP Technologies, Inc. (www.rdptech.com)
- Synagro Technologies Inc (www.synagro.com)
- Bioset Inc (Veolia Water/US Filter)

B.1.2 Alkaline Stabilization Facilities in Canada

A summary of existing proposed and test case alkaline stabilization facilities in Canada is presented in **Table B1**. Each of the facilities is described separately.

Table B1. Existing and Proposed Alkaline Stabilization Facilities In Canada

Facility Location	Supplier	Commission Date
Leamington, Ontario	N-Viro Systems	January 1996
Sarnia, Ontario	N-Viro Systems	March 2001
Stellarton, Nova Scotia	RDP Technologies	March 2005
Region of Niagara, Ontario	N-Viro	Fall 2005
Halifax Regional Municipality, Nova Scotia	N-Viro	2006
Summerside, Prince Edward Island	N-Viro	2008
Guelph, Ontario	Lystek International	2002

B1.2.1 Town of Leamington (Ontario)

The Town on Leamington uses alkaline stabilization to treat waste activated sludge produced at the municipal wastewater treatment facility and to treat the biosolids produced at a local Heinz Food facility. The system is summarized below in **Table B2**.

Table B2. Alkaline Stabilization in Leamington

Type of System	N-Viro
System Commission Date	January 1996
Solids Treated	Activated Sludge
Current Operating Status	2200 dry tonnes biosolids / year

The Leamington N-Viro system is owned and operated by the Town of Leamington. The Town uses N-Viro Canada as a source of expertise should the system fail or need improving. A 15-year contract with Leamington stipulates that N-Viro arrange for the supply of the alkaline material and that they arrange for sale of the final product. The product is registered as a soil amendment under the Federal Fertilizer Act and currently all of the product is sold to a local fertilizer distributor that sells it as a soil amendment (Lyddiatt, 2005).

Public reaction to the soil amendment has been largely confined to its production. Prior to installing an odour control system (biofilter), odour complaints were received by neighbouring homes (Lyddiatt, 2005). Since alkaline addition to soil is practiced in the Leamington area, there has been good reception from the agricultural community for a product that can provide the same effective lime addition rate in addition to providing nutrients.

The estimated cost for the facility was $2.2 million. This price did not include the odour control system that was installed later at a cost of approximately $0.4 million. Operating costs are reported to be in the range of $400 to $450 per dry tonne of sludge processed. This includes production costs such as labour, electricity, raw materials for the N-Viro system and royalty payments. Revenue generated by the sale of the product is retained by N-Viro.

Discussion with the City of Leamington (Woods, 2011) indicated that odour complaints are still received when removing material from the storage barn and from trucks leaving the site. Trucks must load within the barn and, if odours occur, the loading/trucking must stop. The primary odour is said to be ammonia. Dustiness can also be an issue. At present there is storage for a 3-month period. N-Viro would like to expand to 6-month storage, but the city is not prepared to fund it. If a central processing site for several communities in the area, also including Toronto, progressed beyond the discussion stage, there is belief that Leamington may agree to the expansion.

B1.2.2 City of Sarnia (Ontario)

The City of Sarnia uses alkaline stabilization to treat biosolids and primary sludge. Anaerobic digesters that originally treated the solids were decommissioned and now act as storage for the feed to the stabilization system. The system is summarized in **Table B3**.

Table B3. Alkaline Stabilization in Sarnia

Type of System	N-Viro
System Commission Date	March 2001
Solids Treated	Activated sludge and primary sludge
System Capacity	4380 dry tonnes solids / year
Current Operating Status	Near capacity

The Sarnia N-Viro system is operated by the City of Sarnia. N-Viro arranges for the sale of the final product and the purchase of chemicals required for the system. All of the N-Viro product is sold to a fertilizer distributor which sells the soil amendment to farmers. Since Sarnia has very little industrial input into its wastewater treatment system, metals are not an issue in its biosolids (Jacobs, 2005).

Concerns raised by the public regarding the N-Viro product include the potential survival of pathogens during the treatment process and the potential for hazardous compounds being present in the alkaline source (cement kiln dust). Discussions with concerned citizens have alleviated the pathogen fears. To alleviate the fears of using cement kiln dust, the contract between the City and N-Viro stipulates that ash from incinerators handling hazardous waste can not be used. In addition, the alkaline source is analyzed for various compounds (Jacobs, 2005).

The estimated cost for the facility was approximately $6 million. The estimated operating and maintenance cost is $500,000 per year which includes revenue from the sale of the N-Viro product. Revenue from the sale of the product is shared between the City and N-Viro, although not on an equal basis and is sold at approximately $7.50 per tonne (N-Viro, 2005, Dobson, 2004 and Jacobs, 2005). Based on the operating cost of $500,000 per year and the processing of approximately 4,400 dry tonnes of solids per year, the normalized operating cost is $114 per dry tonne.

At present, Sarnia is planning to review their biosolids management plan (Prouse, 2011). The N-Viro system is aging and operational and maintenance costs are escalating. There is insufficient storage and it appears that disposal of the product is challenging. The window of time for agricultural application of the product is narrow – about 2 weeks in spring and 2 weeks in fall. The facility does not have protected storage capacity for the remaining 11 months. Product must be stored outside in the weather. Wind-blown dust raised from the outside piles is reportedly a concern.

B1.2.3 Town of Stellarton (Nova Scotia)

The East River Pollution Abatement System (ERPAS) of the Pictou County District Planning Commission commissioned (March 2005) an alkaline stabilization system supplied by RDP Technologies. The facility is owned and operated by ERPAS and a tender was issued to solicit proposals regarding the disposal of the final product. In Nova Scotia, the product is classified as exceptional quality and, therefore, no restrictions will be placed on its disposal. The plant is expected to treat 3500 wet tonnes per year of municipal solids (Mackinnon, 2005).

Attempts to update ERPAS information with plant staff for this current review were unsuccessful.

B1.2.4 Region of Niagara (Ontario)

The Region of Niagara has approved a 10-year service contact for N-Viro Systems to process approximately 50% of its 9,800 dry tonnes of solids produced each year. N-Viro is responsible for the processing and ultimate disposal of the product. The cost is anticipated to be in the neighbourhood of $450 per dry tonne. If all of the Region's solids are processed at the facility, the cost is expected to be reduced to approximately $350 per dry tonne. The final product will be used for agricultural purposes (Wallin, 2005).

B1.2.5 Summerside (PEI)

When first proposed for Summerside, PEI (about 2005-2006), the N-Viro processing facility was to have a capacity of 1,200 dry tonnes per year. One year of adoption of the N-Viro biosolids treatment process in 2008, Summerside has eliminated the need to send any processed biosolids to landfill. The N-Viro facility there now produces more than 3700 tonnes per year of the NVSA product, all of which is marketed and distributed by the firm AgroMart to agricultural clients (Gaudet, 2011). The NVSA product there is well-received by agricultural users, with no adverse issues expressed at all. Because of an initial strong ammonia odour, Gaudet (2011) recommends dealing with agricultural clients rather than municipal applications or private retail sales for landscaping, gardening and other domestic uses.

B1.2.6 City of Guelph (Ontario)

The City of Guelph has been the demonstration site for the Lystek stabilization process, a relatively new process. The Lystek system was first batch-tested at the Guelph Wastewater facility in October 2002. The study estimated the cost to process biosolids ranged from $120 to $145 per dry tonne. Guelph has now adopted the Lystek process and has abandoned their former composting process. The City intends to continue with the process for biosolids management (Walsh, 2011).

B1.3 Impact of Feed Source on Alkaline Stabilization Process

The feed source for alkaline stabilization may be primary sludge, waste activated sludge (WAS) or digested sludge. WEF (1995) reports that the lime dose requirement for each of these sources is different based on a mass of lime per mass of solids. **Table B4** summarizes an example provided by WEF (1995) where the lime dose maintains a minimum pH of 12 for 30 minutes. The lowest lime dose was required by primary sludge and the highest lime dose was required by WAS; WAS required two and one half times the amount of lime relative to primary sludge.

Table B4. Lime Addition Requirements

Type of Sludge	Solids Concentration (%)	Average Lime Dose (kg $Ca(OH)_2$ per kg dry solids)
Primary	4.3	0.12
Waste Activated Sludge	1.3	0.30
Anaerobically digested $^{\alpha}$	5.5	0.19
α: Includes waste activated sludge		

Although differences in the lime dose requirement reported in **Table B4** can be partially attributed to dilute waste streams (dilute streams have more water for which the pH must be raised), WEF (1995) reports that lime requirements for solids in the range of 0.5% to 4.5% are more closely related to the total mass of solids than to volume. This would suggest that primary sludge is the preferred source for alkaline stabilization. The higher lime cost for treating primary sludge can be offset by the reduced cost requirement of not providing secondary treatment. It should be noted, however, solids reduction also occurs through the activated sludge and anaerobic digestion processes that will reduce the mass of solids that need to be treated in the alkaline stabilization mode. These processes may ultimately reduce the amount of lime required for alkaline stabilization.

In addition to cost, the final product characteristics must be considered when determining the appropriate feed source for an alkaline stabilization technology. If the feed source has a low solids content and desired final product is more granular in nature (50 to 60% solids), excess lime will need to be added to increase the solids content or the feed stream may be dewatered prior to adding lime. A drying step may also be included to ensure the product meets its required solids content.

B1.4 Storage Requirements

If the alkaline stabilized product is compliant with the Fertilizer Act, the most likely source of disposal for such a large volume is through a fertilizer distributor; similar to what is done in Leamington and Sarnia. Depending on the terms of the contract, it is possible that the fertilizer distributor may be able to store the product.

Fertilizers for agricultural use are typically applied during the spring and fall. Since land application of the product is not permitted during the winter and there is the potential of a spring or fall where fertilizers were not applied due to wet weather, storage requirements for the product were estimated to be 10 months (November to following September).

B2 Composting

B2.1 Process Description

Composting is a biological process in which organic material undergoes biological degradation to a stable end product called humus. Composting has received increased attention as an option for enhanced stabilization and utilization of biosolids. This technology can be applied for stabilization of dewatered sludge (between 14% and 30% solids), supplied in undigested, digested or chemically stabilized forms. The self-heating aerobic process attains temperatures in the pasteurization range of 50^o to 70^oC. This results in the inactivation of pathogens and the production of well-stabilized compost that can be stored indefinitely and has minimal odour (WEF, 1995). Drying during the composting process can produce solids concentrations of 50% to 55%. The high quality biosolids product can be used beneficially as a soil conditioner or organic fertilizer supplement for the horticultural and agricultural industry and/or as a biofuel for its energy value.

Three separate stages of microbial activity occur during the composting process:

1. Initial mesophilic stage, during which temperatures within the pile increase from ambient to about 40^oC,
2. Thermophilic stage, caused by the heat generated through conversion of organic matter to carbon dioxide and water vapour, where temperatures can range from 40^o to 70^oC, and
3. Cooling stage associated with reduced microbial activity as composting approaches completion (i.e., curing).

Composting under aerobic conditions, depending on the system design, involves the following steps:

1. Mixing of dewatered sludge with a bulking agent or amendment to ensure an adequate mixture porosity for proper aeration, structural integrity, acceptable mixture density, reduced bulk moisture content and to provide supplemental carbon to adjust the energy balance and carbon-to-nitrogen ratio,
2. Aeration and/or agitation of the mixture to promote the aerobic microbiological decomposition reactions (i.e., active composting),
3. Curing of the compost to complete the stabilization process.

In addition to providing the required oxygen substrate for organics degradation, aeration and agitation facilitate the removal of exhaust gases, water vapour, and heat. The rate of aeration may be used to control process temperature and the rate of drying.

Product curing, which follows active composting, may be preceded or followed by screening. The overall detention time for composting and curing is typically between 50 to 80 days (WEF, 1995). If feasible, the bulking agent is recovered by screening for reuse (Metcalf & Eddy, 1991). An area for temporary storage of the final stabilized product is usually provided at the site. Composting is enhanced and controlled by many factors:

- Proper blend with bulking agent, temperature, moisture, oxygen, and carbon to nitrogen ration (25:1 to 35:1)
- Dewatered cake of 14 to 30% solids; increased to 38 to 45% with bulking agent, e.g. wood chips and saw dust
- Aeration required
- Thermophilic temperature, 55 to 60°C
- Maintain sufficient moisture to minimize dust
- Insufficiently cured/matured compost will reheat and generate odours when stored and rewetted
- Drying required especially if screening used >55% and <75% or fire may occur.

The mass of compost product is typically about one half of the mass of wet dewatered sludge that is added to the process (WEF & ASCE, 1992). However, there is little change in the volume, as the product is less dense than the wet sludge.

B2.2 Benefits of Composting

Composting is a cost-effective alternative for the production of well-stabilized, essentially pathogen-free biosolids for a number of potential beneficial uses. Maintenance of a minimum temperature of 55°C for at least three days can achieve virtually complete inactivation of pathogens in aerated static pile systems (WEF & ASCE, 1992). Some fungi however (e.g., *Aspergillus fumigatus*) are able to survive the composting process because they are thermo-tolerant organisms.

Composting is a versatile sludge processing technology that, depending on process design, can treat dewatered undigested and/or digested sludge and potentially produce a Class A biosolids product. This could defer or eliminate the need for future digester upgrades and expansions in the City and can represent a flexible option as part of a diversified biosolids management program. Additional volatile solids destruction and degradation of persistent organic substances in digested biosolids may be possible.

The biosolids compost product can be considered for use as a soil conditioner and a low-grade fertilizer. It could be available for use by the City or marketed to various industrial, commercial, and residential users. With increasing concerns over odours and pathogens in liquid and dewatered biosolids and the need for alternative utilization routes, there will likely continue to be a general increasing trend in the use of composting for municipal WWTF sludge stabilization.

B2.3 Process Alternatives

B2.3.1 Process Descriptions

Aerated Static Pile
In the aerated static pile process, the mixture of dewatered cake and coarse bulking agent is placed over a porous bed (i.e., a grid of closed and perforated piping). Air is supplied to each pile by a dedicated blower and piping, and is drawn downward or forced upward through the mixture. The bulking agent may be partially recovered by screening and reused in the process. The pile is covered with an insulating blanket of wood chips or screened compost. The active composting period is 21 to 28 days. A cure stage of 30 days or more is required.
Small applications can consist of a number of individual piles whereas larger applications can involve a continuous pile that is divided into sections representing the contribution of each day. New facilities are typically covered and some are fully enclosed for reduced odour and health risk concerns and for improved process control.

Windrow
Windrows consist of long narrow parallel piles of the mixture through which aeration is achieved by natural convection and diffusion. In the aerated windrow process, supplemental forced aeration through underlying air channels is used. The windrow is remixed periodically by a turning mechanism to facilitate air movement and moisture release. Newer windrow operations are covered or enclosed systems. The active composting period is 21 to 28 days; curing is more.

In-Vessel Systems
In-vessel systems for active composting are enclosed and mechanized processes, comprising a reactor(s) and conveyors that offer an increased degree of process and odour control. The systems are compact and can be highly automated, including PLC-based automatic control systems. The control of environmental conditions such as air flow, temperature, and oxygen concentration permits shorter composting times. The in-vessel processes are generally more

costly to construct than aerated static piles and windrows.

The mixture of dewatered sludge, amendment, and recycled compost is fed into one end of a tunnel, silo, or channel of the in-vessel process and moves continuously towards the discharge end. Air supplied by blowers is forced through this mixture which may be periodically agitated, depending on the process design.
The three general in-vessel reactor designs include:

- Vertical plug-flow,
- Horizontal plug-flow (i.e., tunnel reactor), and
- Agitated bin reactors.

The plug-flow systems involve periodic feeding (e.g., daily) and discharge of "finished" compost from the opposite end. Unlike the plug-flow designs, the dynamic agitated bed process uses mechanical mixing during processing. Depending on the particular process or system supplier, the detention time in the reactor can vary between 10 to 21 days for active composting. Curing is 30 to 60 days longer. Compared with static pile and windrow composting, in-vessel processes can produce a more consistent product, require less space, and provide an enhanced degree of odour containment and control. Modular system designs can facilitate future expansion.

B2.3.2 Advantages and Disadvantages

In general, composting technology has the following advantages:

- Composted biosolids can be physically handled easier than other biosolids products,
- Composting processes have the potential to produce a Class A biosolids product; the US EPA's 40 CFR Part 503 Rule requires the composting process to maintain a temperature of at least 55^{o}C for a minimum of three days to destroy pathogens and qualify as Class A.

A disadvantage of composting is the increased amount of solids to be managed (i.e., through the addition of bulking agent and reduced density of product).
The relative advantages and disadvantages of the alternative processes are summarized in **Table B5**. Advantages of each type system depend to some extent on the material to be composted and site conditions.

B2.3.3 Technical Considerations

Process variables that can affect composting operations and performance include temperature, bed porosity, moisture content, ratio of organics to nutrients, pH, aeration levels, and detention time (WEF & ASCE, 1992). Parameters that can be monitored and used to control in-vessel composting processes include:

- Mixture temperature
- Blower static pressure
- Relative humidity of the fresh air supply

Table B5. Advantages and Disadvantages of Composting Process Alternatives

Process	Advantages	Disadvantages
Aerated Static Pile	• Flexibility and adaptability to various bulking agents • Flexibility to accommodate varying feed conditions and loadings (i.e., since working volumes are not fixed) • Simple mechanical equipment	• Labour intensive • Large land area required • Odour potential • Exposure of operators to composting piles • Potentially dusty working environment
Windrow	• Flexibility and adaptability to various bulking agents • Flexibility to accommodate varying feed conditions and loadings (i.e., since working volumes are not fixed) • Simple mechanical equipment • Low capital cost • Process optimization possible through forced aeration and periodic turning	• Very large land area required (i.e., to accommodate dedicated turning machine) • Labour intensive • Odour potential • Exposure of operators to composting piles • Dusty working environment • Long composting period
In-Vessel [Vertical Plug-Flow]	• Completely enclosed reactors improves odour and dust control capability and reduces ambient influences • Shorter composting times and relatively small systems and land area requirement • Lower labour requirement • Operators not exposed to composting material • Enhanced process control • Enhanced product consistency • Public acceptance of in-vessel process facilities may be better	• Higher capital cost • Outfeed device can pose as a bottleneck • Potential difficulties in maintaining uniform aerobic conditions throughout reactor • Relatively maintenance intensive • Limited flexibility in accommodating changing influent conditions • Types of suitable bulking agent limited and dependent on materials handling equipment • Increased mechanical complexity
In-Vessel [Horizontal Plug-Flow]	• Completely enclosed reactors improve process, dust and odour control capability • Shorter composting times and relatively small systems and land area requirement • Lower labour requirement • Operators not exposed to composting material • Enhanced process control and product consistency	• Higher capital cost • Fixed volume reactor(s) limits flexibility • Limited ability to accommodate varying influent conditions • Relatively maintenance intensive • Types of suitable bulking agent dependent on the materials handling equipment used
In-Vessel [Agitated Bin]	• Medium system sizes • Lower labour requirement • Compost mixing capabilities • Enhanced aeration and uniformity of compost mixtures with mixing • Flexibility to accommodate various bulking agents due to mixing • Enhanced process control and product consistency	• Higher capital cost • Fixed-volume reactor(s) limits flexibility • Less compact than other in-vessel systems; relatively large land area required • Potentially dusty working environment • Operators exposed to composting piles • Relatively maintenance intensive (i.e., equipment maintenance)

- Relative humidity of process headspace
- Volume of fresh air
- Blower speed
- Oxygen concentration in process headspace

A number of factors can influence selection of the most appropriate composting process for a given application. These can include (Metcalf & Eddy, 1991; WEF, 1995):

- Characteristics of the sludge supply (e.g., solids content, degree of stabilization, if any, and loading rates).
- Type of equipment and chemicals used in upstream sludge dewatering and the consistency of the resultant cake.
- Land availability.

.Dewatered sludge cake of 20 to 25% solids can be mixed with bulking agent or amendment to produce the desired solids content of the feed supply. The uniformity of the mixture with respect to porosity is critical in static pile systems and less so in windrow and agitated bed systems.

The minimum solids content of the supply mixture should be about 40% for static pile and windrow systems, while in-vessel systems may function with lower solids content of 35% Sludge supply that is stabilized by aerobic or anaerobic digestion prior to composting can significantly reduce the size of the composting facility due to the reduced organic solids content. Composting of stabilized sludge offers the flexibility for direct application of the dewatered biosolids to agricultural land without composting, in the event that the composting system is overloaded or out of service (e.g., for maintenance).
Other considerations include:

- In addition to enhanced volatile solids destruction, composting can potentially achieve additional biological degradation of persistent organic substances in digested biosolids.
- Storing of dewatered sludge supply in a building minimizes the generation and release of odour from the composting facility and ensures that the sludge does not freeze during the wintertime.
- Composting of undigested sludge results in higher reaction rates, oxygen demand, heat generation, and odour potential.
- Material being composted should be regularly mixed or turned, depending on the compost process, to prevent drying, caking, and air channeling (Metcalf & Eddy, 1991).
- Process temperature should be kept at between 55 to 65^{o}C for a defined period of time until pathogen control requirements are met (i.e., for the generation of Class A biosolids). For the first few days, temperature should be maintained at optimum levels of between 50 and 55^{o}C to promote maximum rates of organics degradation and stabilization.
- New composting facilities typically include odour control systems for the containment and treatment of exhausts. Odour control system can include biofilters, wet scrubbers,

and/or thermal oxidation for the removal of ammonia and other odour compounds (WEF, 1995).

- The energy value of composted biosolids is modest but acceptable for use as an alternative fuel supplement for certain industrial applications (e.g., for cement production).
- Depending on process design, it may be possible to co-compost municipal WWTF waste sludge with other organic solid wastes. The latter solid wastes require pre-sorting and pulverizing prior to mixing with sludge. The potential to combine with the City's solid waste composting program should be investigated.
- Site considerations include land availability, access, proximity to the WWTFs, proximity to end users of the finished product, climatic conditions, and availability of buffer zone.
- The market for compost varies regionally based on local conditions such as land use, availability of competing soil amendment and fertilizer products, guidelines for biosolids compost, and public acceptance of biosolids products (Spinosa and Vesilind, 2001). There are currently limited developed end uses and markets for compost product in Canada.

Metals content of the composted biosolids affects the usability of the product and must be considered during design to ensure a market for the final product.

Nova Scotia and Canadian Council of Ministers of the Environment (CCME) compost guidelines exist, specifying maximum concentration limits of selected metals for Class A and Class B compost. This can influence biosolids utilization options.

As indicated above, many factors must be considered in the design of a composting system for each specific application. Additional details on process design considerations can be found in other available literature sources (Haug, 1980; Metcalf & Eddy, 1991; WEF & ASCE, 1992; WEF, 1995).

B2.3.4 Municipal Considerations

Prior to closing the City of Guelph's Eastview landfill, the compost was used as a cover material. The process was started up in 1995 and is used to compost dewatered, anaerobically digested sludge. Owing to exceedance of the Ontario Compost Guidelines with respect to certain metals concentrations, the compost product from the Guelph plant was hauled for use at landfill sites (e.g., as landfill cover). The compost quality meets Agriculture and Agri-Food Canada's (AAFC) fertilizer criteria; however, since the material is composted it must meet Provincial compost standards. The City of Guelph has thus abandoned the process. The City of Guelph now used the Lystek Process, discussed later in the chapter.

Other Ontario cities, including Kingston and Sault Ste. Marie, have examined the option of biosolids composting; however, in both cases, the biosolids stream exceeds metal criteria concentrations and the compost could not provide for unrestricted use.

In other regions where the metal content of the overall compost stream is considered, co-composting can result in acceptable compost which can be used for parks, flower beds, topsoil and sale to the public (Castro-Wunsch, 2003). In Medicine Hat, Alberta, the use of composting was motivated by new regulatory restrictions, which made it economically unfeasible to place biosolids in the landfill (Fisher, 2003).

One of the biggest compost issues noted in the literature was the potential for objectionable odours. This impacts both the workers and neighbours of the facility. The odour issues have been resolved by ensuring the compost remains aerobic and that proper compost operating procedures are observed (Robson, 2003; Cavers, 2003; Fisher, 2003).

In addition to odours, the potential for unwanted material such as plastics can degrade the quality of the compost and reduce the public acceptance for the use of the compost (Cavers, 2003).

B3 Thermal Drying

B3.1 Process Description

Thermal drying is the process of evaporating water from sludge or digested biosolids by the addition of heat. Complete drying typically results in a product with 5 to 10% moisture content, corresponding to a 30-fold volume reduction. The moisture content of thermally dried biosolids is the lowest of the process alternatives considered. Heat is one of the most effective pathogen destructors. Thermal drying is capable of biosolids disinfection. The product can be used on acid or alkaline soils. Fuel is needed to provide the drying, but the product itself can become a fuel if an end-user is identified. As well as being used as a fertilizer or soil conditioner, the dried biosolids (termed pellets or granules) can be used as a biofuel. The quality of the granules produced, drying system used and local economic factors are likely to determine the end use of the dried biosolids.

During drying, biosolids undergo several structural changes as the moisture content decreases. The most critical stage is called the plastic stage when the moisture content is between 40 to 60% Dry Solids (DS). In this stage, the dried product becomes sticky and difficult to manipulate. The power input required to move the product through this phase to higher concentrations is high. It is essential to minimize dust production or accumulation during the drying process due to the increased probability of fire or explosions, which have occurred in this process in the past. Dust collection systems are used to capture the product dust.
The main benefits of drying sludge thermally can be summarized as follows:

1. Increased pathogen destruction is achieved,
2. Storage of dried sludge requires less volume and is easier to handle,
3. Transportation costs are reduced,
4. Sludge drying increases the number of final disposal or utilization options
5. The final product can be marketed more easily as a fertilizer or soil conditioner, and
6. Dried sludge has a higher fuel value and can be incinerated or thermally converted.

B3.2 Process Alternatives

Dryers are classified on the basis of:

- The predominant method of transferring heat to the biosolids (convection, conduction, radiation or a combination of these),
- Whether drying and pelletization occurs in one or two steps, and
- Whether the biosolids are partially (<90% DS) or completely (>90% DS) dried.

The following provides a description of the three categories of heat dryers classified by the method of transferring heat to the biosolids (convection, conduction, or radiation).

B3.2.1 Direct (Convection) Dryer Process Alternatives

In convection dryers, the wet sludge is in direct contact with the heat transfer medium, which is usually a hot gas. Direct (convection) dryers include:

- Flash dryers
- Rotary drum dryers
- Fluid bed dryers
- Cold air dryers
- Belt dryers
- Solar dryers

A brief description of the most prevalent direct dryer designs follows.

Rotary dryers consist of a horizontal cylindrical steel drum, rotating at 5 to 25 rpm. The wet sludge/biosolids are mixed with an amount of dry product at the feed point. Flue gases from a burner flow co-currently and in direct contact with the biosolids. The mixture of biosolids and hot gases is conveyed to the discharge end of the drier where the dry product is separated from the gas and vapour mixture. The temperature of the hot gas at the inlet of the drum is typically between 450 to 500°C and the temperature of the product is approximately 100 to 140°C. The oxygen content at the dryer outlet is between 15-17%. The flue gas and vapour mixture is sent to a condenser and the flue gases and non-condensables are treated in an odour control unit.

There are three main disadvantages with these types of dryers: the high oxygen content in the drum which presents fire and explosion risks, the large volume of gas that needs to be treated in an odour control unit and the high energy losses from the large stack required. To address these disadvantages, some manufacturers implement air/vapour recirculation systems with heat exchangers.

Rotary dryers have found successful application in municipal biosolids facilities. The product is easy to handle, store and market as a fertilizer or soil conditioner.

Fluid bed dryers: In fluidized bed systems, the biosolids are fluidized when brought into contact with hot gases flowing upward. These are vertically mounted systems, and in the most recent designs, the hot gases are recirculated in a closed loop. Wet biosolids are mixed with dry product, enter at the top of the chamber and sink to the bottom. As the product dries, its density decreases and as a result, the drier product occupies the upper part of the chamber. The dried product is discharged through an overflow, and the gases are directed to a cyclone separator and an odour control unit. The cyclone captures the dust created by the constant attrition of the particles caused by fluidization.

Fluidized bed dryers tend to be sensitive to variations in sludge composition because of its effect on the fluidization process. The heat exchangers incorporated in the chamber suffer from abrasion. The system is considered to have high power requirements. Although the process is an efficient drying method, it is seldom used for drying municipal WWTF residual solids (WEF, 1995).

B3.2.2 Indirect (Conduction) Dryer Process Alternatives

In conduction dryers, a solid retaining wall separates the wet sludge/biosolids from the heat transfer medium, which is usually steam or another hot fluid. Indirect (conduction) dryers include:

- Paddle dryers
- Hollow-flight dryers
- Disk dryer
- Thin-film dryers
- Multiple-effect evaporation dryers

A brief description of the most common indirect dryer systems employed for municipal biosolids follows.

Thin film dryers: This is an example of a drying system that dries biosolids through the plastic phase without dry product recirculation. It is a horizontal system in which biosolids are introduced into a fixed shell containing a spinning shaft. The material is spread onto the wall where it forms a thin film on a jacket heated by steam or thermal oil. Blades mounted on the shaft scrape the product and force it across the dryer to the discharge end.
The main disadvantages of this type of drying system is the large amount of mechanical wear exerted by the dried product when it above 80% DS.

Disc dryers are composed of heated hollow discs set one after the other in parallel along a rotor. The discs and rotor are enclosed in a fixed shell. Biosolids fill the shell and submerge the discs and rotor. Scrapers attached to the encasing shell extend inward until just above the rotor shaft.

The discs are equipped with large paddles, which control the residence time of the product. Disc dryers can be used for partial or complete drying. If used for complete drying, dried biosolids are mixed with wet feed before entering the dryer. This configuration is subject to heavy mechanical wear.

Paddle dryers have a similar configuration to disc dryers. Hollow wedge-shaped, self-cleaning blades take the place of the discs and casing. The rotor speed is low and the residence time is high. Paddle dryers are subject to similar wear problems as disc dryers when used for complete drying.

B3.2.3 Radiation Dryer Process Alternatives

In radiation dryers, infrared lamps, electric resistance elements or gas-heated incandescent refractories supply the energy required to heat the wet biosolids and evaporate moisture. For municipal sludge/biosolids applications, infrared drying is usually associated with combustion, where applicable.

B3.2.4 Pelletization of Dried Sludge

Pelletization of dried sludge can be desirable, especially if the dry product is to be used as a fertilizer or soil supplement. Pelletization may be accomplished in one step with drying or it may follow as a separate step. In the former case, dewatered sludge is first sent through a pelletizer where it is transformed into a pellet. This procedure gives cohesion to the sludge and creates a large external surface area that accelerates the drying process.

An example of a single step dryer/pelletizer is the SEGHO multi-tray hard pelletizer Pearl Process by Seghers. This is an indirect vertical dryer with a number of heated trays constructed one above the other inside a cylindrical shell. The sludge/biosolids dry as they contact the heated trays. Recycled pellets are coated with a thin layer of incoming wet material and introduced to the dryer at the top. As they move from the top to the bottom trays they dry out and are finally transported to a separation hopper where they are sorted for size. Pellets are recycled 5 to 7 times, growing in size with each pass through the dryer, until they reach the desired diameter at which stage they are separated from the recycling stream and sent to the storage facility.

Pelletization is provided for the following reasons:

- Storage of dried sludge/biosolids pellets reduces the risk of fire and glowing, which is higher for dried sludge dust.
- Handling of dried sludge pellets is easier and poses less nuisance to the environment and the personnel in contact with it.

B3.3 Technical Considerations

For each of the three dryer categories described above, there are specific technical and design considerations. However, the following apply to all types of dryers and play the most important role in the dryer selection and sizing.

- The desired moisture content of the wet and dried sludge/biosolids will affect dryer selection.
- The amount of flexibility required in the design to accommodate varying sludge/biosolids characteristics.
- Mechanical dewatering is a requirement prior to drying.
- Continuous or batch drying operations affect dryer size.
- Storage requirements for wet and dried sludge/biosolids are an important consideration.
- Condensate from air recycle streams must be considered.
- Dust may be a hazard if the dried biosolids are stored in large volumes where heat can build.
- Energy sources for the dryer may be natural gas or fuel oil; because of the large amounts of energy required, recovery of heat from the exhaust gases should be considered. In addition future energy costs should be considered.
- Pelletization of the dried biosolids may improve their marketability.
- Safety requirements, especially prevention of risk of fire or explosion.
- Consideration must be given to odour control especially if unstabilized sludge/biosolids are dried (if rewetted odours will be emitted).

B3.4 Advantages and Disadvantages

Table B6 presents an overview of the most significant advantages and disadvantages of the various heat-drying processes employed at municipal wastewater treatment works.

B3.5 Thermal Drying / Pelletization Facilities In Canada

A summary of selected thermal drying facilities in Canada is presented below in **Table B7**. All of the facilities identified use or have used the pelletization technology.

Table B6. Advantages and Disadvantages of Heat Drying Processes

Process	Advantages	Disadvantages
Direct Dryers	Dried product has low dust content Direct drying is a good choice if the end product will be used as a fertilizer or soil amendment If a dry solids content above 90% is required, direct dryers are more thermally efficient. Reduced seasonal storage compared to other options	Large volume of gas that needs to be treated in an odour control unit High power requirements Less thermally efficient than indirect dryers when incomplete biosolids drying is required Fire/explosion controls are necessary
Indirect Dryers	Low quantities of non-condensable gases Smaller size odour control units required Allow operation under a vacuum or closely controlled atmosphere More thermally efficient if partial drying is required (65-85% DS) Reduced seasonal storage compared to other options	Although lower dust is produced during the drying process, the dried product has higher amounts of dust than with direct dryers Often requires further granulation of the dried product to make it marketable Debris, such as plastic, hair, can be problematic Fire/explosion controls are necessary

Table B7. Thermal Drying Facilities In Canada

Facility Location	Commission Date
City of Windsor	1999
City of Toronto	1999
Smiths Falls	1992
City of Montreal	1998
Communite Urbaine De L'Outauais	1992

B3.5.1 City of Windsor (Ontario)

The City of Windsor has contracted a private company (Prism Berlie Windsor Ltd – American Water) to manage the solids produced at the City's two wastewater treatment facilities (Little River and Lou Romano). Prism Berlie has the choice of either landfilling the solids or processing them at its pelletization facility. The rate paid to Prism Berlie is higher if the solids are processed by pelletization. The biosolids were landfilled when an explosion and fire at the pelletization facility in 2002 halted biosolids processing. Since restarting, the pellets are land applied in Lambton County (Guidelin, 2011). Actions were taken to install a monitoring system to control O_2 content in the pelletizer to avoid fire.

The Prism Berlie facility was constructed in 1999 and is expected to process the approximately 10,300 dry tonnes of solids per year produced by the Windsor wastewater treatment facilities (Windsor, 2005).

The City indicates (Guidelin, 2011) that extra attention is needed in design and construction for handling the high solids feed to the pelletizer as pumping, augering and bin storage are difficult when solids exceed about 31% in the cake. Excess capacity is required to sustain operations. Pellet consistency is good in winter, but not as good in summer when the pellets are larger and 'fluffier'.

B3.5.2 City of Toronto (Ontario)

In June of 1999, Toronto city staff recommended that the construction of a pelletization facility at the Ashbridges Bay Treatment Plant be awarded to R.V. Anderson Associates (Program Manager) and USF Canada (technology supplier) for a total price of approximately $23 million (Toronto, 1999). It was estimated that the project would take 20 months.

The Ashbridges Bay Plant produced approximately 53,000 dry tonnes per year of solids and, historically, 12,000 dry tonnes per year was land applied (Toronto, 2005). The pelletization facility was anticipated to eventually treat 50% of the solids generated. In August 2003, a fire destroyed the pelletization facility before it was fully turned over to the City of Toronto. The fire was reported to be most likely caused by an oil leak from the tubes that were used to heat and ultimately dry the biosolids.

The pelletizer is currently operating but is not handling all of the biosolids from Ashbridges Bay; it manages about 40% of biosolids production. Confidential sources suggest that the process is complex and unreliable. After the initial fire at least one other small fire has occurred. Precise control of the dewatered cake feeding the pelletizer is required at 26% solids. One major problem has been with 'hair' plugging processing screens. Pellets may ignite is storage is improper. Nitrogen is used in the process on standby for fire suppression.

The pellet product is marketed as fertilizer with a label, but indication is that some product is used as a fuel in the US. A portion of dewatered biosolids (~10%) is land applied as cake, but odours are an issue. The remainder of cake is landfilled.

B3.5.3 Town of Smiths Falls (Ontario)

The Smiths Falls WPCP produces Make-Gro Fertilizer 3-3-0 Heat Processed Sewage Sludge (http://www.smithsfalls.ca/wastewater-treatment-plant.cfm). The pellets are a by-product of the wastewater sludge generated at this facility. The pellets are recognized as a fertilizer product by the Canadian Food Inspection Agency and regulated under the Federal Fertilizer Act. The marketed fertilizer pellets are used for agriculture (excluding crops for human consumption), horticulture, siliviculture and energy production purposes.

The Town of Smiths Falls owns and operates the pelletization facility, which is located at its wastewater treatment facility. The facility was built in 1992 (Swiss Berlie) at a cost of approximately $7 million and processes the co-thickened waste activated sludge and primary sludge. In 2004, the facility processed 510 dry tonnes of solids and had operating and maintenance cost of approximately $200,000 per year or $392/ dry tonne of solids generated (Joynt, 2005).

During the period April 2003 to October 2004, the pelletization facility was shut down since it was more economical to pay for sludge disposal at the Ottawa wastewater treatment facility. When the 2005 rates were released, the Town determined it was economical to operate the facility rather than have the sludge treated in Ottawa (Joynt, 2005).

The demand for the pelletized product exceeds the supply. Since the product is designated a fertilizer, it has unrestricted use. The Town sells the product to local farmers at the rate of $2/ tonne (Joynt, 2005).

B3.5.4 City of Montreal (Quebec)

The City of Montreal operates a physical/chemical (primary) treatment wastewater treatment facility, which during 2008 treated an average dry weather flow of 31.09 m^3/s. Dewatered solids have historically been directed to four on-site multiple hearth incinerators at the rate of approximately 285,974 tonnes in 2008 with 33% cake solids content. In 1998, a pelletization system was installed to divert approximately 10,000 dry tonnes of solids per year from the incinerators. The system is owned and operated by the City.

B3.5.5 Communité Urbaine De L'Outaouais

The Communite Urbainé De L'Outaoais (formerly the City of Gatineau) owns and operates a Berlie pelletizer system that processes approximately 3,200 dry tonnes per year of anaerobically treated biosolids produced at the wastewater treatment facility. The City has a contract with a firm (GSI Environmental) to manage the disposal of the pelletized product (Boisvert, 2005). GSI Environmental mixes the product with other material (e.g. compost) for land application in Quebec.

The pelletizer system began operation in 1992 and has had numerous operational issues including one fire. Modifications have improved the system reliability and plant staff are now satisfied with its operation. Gas for the drying units is produced in the anaerobic digesters.

Appendix C. Full List of Biosolids-Related Questions posed by HRM Council

The following is a full list of questions posed by HRM Council during their discussion on biosolids. Some of these questions pertained to issues of HRM policy or procedure, and were not included in the terms of reference for the Request for Proposals (RFP) for the biosolids review. These questions of policy and procedure are indicated by *italic font*. Some of the other questions were either combined or separated in the RFP, and some were edited for clarity.

It was agreed with HRM staff that those questions relating to HRM policy or procedure will be addressed by HRM staff in a future report to Council at the time when the review study is presented to them.

1. Is the product from N Viro currently being used on farms in and around HRM?

2. How are pollutants removed from the product to obtain a Class A soil (items such as Drano, household cleaners, pharmaceuticals etc.).

3. Is there a difference between Sewage Sludge and biosolids?

4. Could any of the pathogens/microbes be "reactivated" once introduced to heat/ water?

5. Research done by Guelph University showed three pollutants found in the control test section, what were the three pollutants? Were those pollutants found in the grapes grown in that soil?

6. What is the onus on HRM re: the signed contract with N Viro if HRM decide they do not wish to use the product. How much will it cost HRM not to use the product in HRM? Is it HRM's responsibility to help N VIRO if HRM chooses not to use the product in HRM?

7. A thorough review of our existing policy re: N VIRO product and potential uses of the product.

Is the N-Viro Soil Amendment product suitable for use on athletic fields?

8. Have CO2 emissions been tested for

9. Once a Class A Bio Solid, is the product in anyway considered "sludge"?

10. How does Class B Bio Solid compare to commercial fertilizer? Are there any standards for fertilizer?

11. Include information on the condition of the land in Nova Scotia in regard to it having been "overused" and some information on a "balance" between the Class A product we have and fertilizer. Crops need fertilizer**.**

12. Pharmaceuticals that are passed through feces, how are they destroyed?

13. What would HRM do with the sewage sludge if it were not used for Bio Solids, and include economic answers in the report in regard to options for the sewage sludge.

14. What are the heavy metals/pharmaceuticals that could be found in the product and what are the concerns associated with those materials.

15. If the product is continued to be used, how will testing be carried out? What are the environmental impacts of the biosolids/biofuels?

16. How much bio solid is HRM dealing with in terms of excess?

17. How long has N Viro been in operation and how much sewage sludge is trucked out each year? Even though the product is not used on food crops, cows may ingest it and the results show up in the milk that children drink. [What are the implications for milk consumers, particularly children?]

18. Include [all] the CCME report that came out in December as part of the research for this report re: risk assessment.

19. Include information on the "germinal contact" (dermal?) [and dust inhalation from the N-Viro Soil Amendment product, commercial fertilizer and animal manure] such as baseball players diving into the dust on a playing field etc. - they get skin infections. Some people have become sick from the dust blowing off the trucks carrying the material.

20. Does HRM have liability insurance, as a third party, in regard to the N Viro contract in case something happens in future regarding this product?

21. Have information on animal manure issues as well in context with the report as fertilizers must be discussed in full context.

What is the experience regarding acceptance of biosolids products for land application in other jurisdictions (Moncton, New Brunswick was especially mentioned as having a positive experience)?

22. What is the fact/fiction re: Switzerland/Sweden etc. who are now banning the use of Biosolids?

23. Is it fact/fiction that Class A sewage sludge is a potential killer?

24. How often is the product tested for quality control monitoring/assurance? Issues such as Listeria/E-coli outbreaks, are they possibilities? What opportunities could create a gap in quality assurance? How safe is the "additive"?

25. What is the reason for there being no public education on the use of this product prior to the Dunbrack Street incident?

26. Is pH level testing done?

Appendix D. Annotated Bibliography

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Pepper, I.L. 2003. Biosolids Safe for Land Application, UA Researchers Find. Accessed at http://uanews.org/cgi-bin/WebObjects/UANews.woa/wa/goPDF?ArticleID=7784	Samples of biosolids from across the U.S., and bioaerosols from application equipment called "slingers" in the U.S. Southwest were analyzed for concentrations of the bacterium *S. aureus*. No detectable levels of *S. aureus* were observed in 23 samples of either Class A or B biosolids (including aerobic and anaerobic digestion, lime stabilization, heat-dry pelleting and/or composting) or 27 samples of bioaerosols.
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Quanrud, D., Zerzghi, H., Leung, C., Gerba, C. and Pepper, I. 2011. Fate of Endocrine Disruptors Following Long-Term Land Application of Class B Biosolids and Risks to Public Health. Proceedings Water Environment Specialty Conference on Residual and Biosolids (CD-ROM), Sacramento, CA. May 21-25.	The fate of estrogenic activity, nonylphenol, and PBDEs in soil was determined following 20 years of land application of Class B biosolids at a site in southern Arizona. Estrogenic activity and nonylphenol do not accumulate in soils at all, but PDEs do in top layers only, but at concentrations less than 100 ug/kg (ppb).
Ralph, J., "Regional Niagara Organic Diversion Strategy", Presented at the Canadian Organic Recycling Conference, September 2002.	Conference paper discussing composting of the Region of Niagara's municipal solid waste
Robson, L., "The City of Penticton's Composting Experience", Presented at the 2nd Canadian Organic Recycling Conference, Penticton, BC, April 24 and 25, 2003.	Conference paper discussing the positive composting experience of Penticton, BC
Schafer, P.L., Farrell, J.B. (2000) "Turn Up the Heat" Water Environment and Technology. Vol 12, No. 11, November 2000.	Periodical article used as technical reference for temperature-phased anaerobic digestion for Class A biosolids.
Shimp, G.F., Rowan, J.M., Long, D.W., Santha, H. (2002) "Class A' Digestion: Retooling an Old Process to Fulfill a New Objective." 75th Annual Technical Exhibition and Conference. Water Environment Federation Technical Conference Proceedings. Water Environment Federation. September 2002.	Conference paper used as technical reference for temperature-phased anaerobic digestion for Class A biosolids.
Shore, LS and Shemesh, M. 2003. Naturally produced steroid hormones and their release into the environment. *Pure Appl. Chem.*, **75(11–12)**: 1859–1871.	Technical paper used to document concentrations of estrogenic hormones in livestock manures
Singh, A., Patel, J., Mosher, F., Ward, O., Key, W., "Demonstration of an Advanced Biosolids Treatment Process for the Production of High Solids Concentration and Low Pathogen Product for Beneficial Reuse." Lystek International Incorporated. [Online: www.lystek.com/images/ProspForum2004Timing-Oct1-04.pdf]	Lystek alkaline stabilization website article describing the process
Singh, A., 2011.	Personal Communication indicates that Lystek is now in three municipalities in Ontario
Smith, J. and R.Y. Surampalli, 2007. Disinfection processes and stability refinements to biosolids treatment technologies: past, present and future. Pp 89-95 In Eds. R.J. LeBlanc, P.J. Laughton and R. Tyagi, Conference Proceedings - "*Moving Forward*, Wastewater Biosolids Sustainability: Technical, Management and Public Synergy" June 24-27, Moncton, New Brunswick, Canada.	Conference paper used to document concentrations of pathogens in municipal biosolids
Spinosa, L. and Vesilind, P.A. (2001) Sludge into Biosolids – Processing, Disposal and Utilization. First Edition. IWA Publishing, London, UK. ISBN 1 900222 08 6.	General reference text regarding all aspects of biosolids management.

Termeer, W., "Biosolids – From Feedstocks To Markets", Presented at the Canadian Organic Recycling Conference, September 2002.	General article about composting in Halifax.
Toronto (City of), City of Toronto Council Legislative Documents, from the web site www.toronto.ca and dated June 1999.	City website information concerning status of pelletization system and processing problems.
US EPA (US Environmental Protection Agency), 1993. Part 503 – Standards for the Use or Disposal of Sewage Sludge. Fed. Regist. Vol. 58, No. 32, 9387-9404.	US EPA legislative framework for land application of sewage sludge.
USEPA (United States Environmental Protection Agency), 1994. "Plain English Guide to the EPA Part 503 Biosolids Rule", EPA832-R-93-003, September.	An easy to read and understand guide for the US EPA legislative framework for land application of sewage sludge.
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US EPA (US Environmental Protection Agency), 2003. Final Action Not to Regulate Dioxins in Land-Applied Sewage Sludge. EPA-822-F-03-007, October 2003. US EPA Office of Water, Washington DC. See http://www.epa.gov/ost/biosolids/dioxinfs.html.	After five years of study including outside peer review of toxicity and exposure assessments, the US EPA determined that dioxins from land application of biosolids do not pose a significant risk to human health or the environment.
USEPA (United Stated Environmental Protection Agency), "Use of Composting for Biosolids Management" Biosolids Technology Fact Sheet. From web site www.epa.gov/owm/mtb/factsheet.htm, Printed December 16, 2005.	USEPA Fact Sheet provides general information on composting of municipal biosolids
USEPA (United States Environmental Protection Agency), 2000. "Alkaline Stabilization of Biosolids" Biosolids Technology Fact Sheet. EPA 832-F-00-052. Washington, D.C., September.	USEPA Fact Sheet provides general information on alkaline stabilization of municipal biosolids
U.S. EPA. 2009. Targeted National Sewage Sludge Survey Sampling and Analysis Technical Report. Office of Water, Report No. EPA-822-R-08-016, Washington, D.C.	Report of EPA Survey of emerging substances and metals in sludges and biosolids from 74 WWTFs in the U.S.
US EPA (US Environmental Protection Agency, 2011. Problem Formulation for Human Health Risk Assessments of Pathogens in Land-applied Biosolids. National Center for Environmental Assessment, Cincinnati, OH. EPA/600/R-08/035F.	US EPA recommended framework for formulating and conducting human health risk assessments of pathogens in land-applied biosolids.
Van Ham, M, Doerksen, G, Lee, K, Tang, K, Shoji, B and MacKinnon, D. 2005. A Regional Approach to Biosolids Management: Lehigh's Sechelt Organic Mine Reclamation Program 3rd Canadian Organic Residuals and Biosolids Management Conference", Calgary, AB June.	Paper discusses use of biosolids to reclaim an old mining site near Sechelt, BC, and the steps taken to achieve buy-in from a variety of stake-holders.

VEI (Vision Envirotech International), web site www.vei.ca/ composting_projects.htm printed October 5, 2004.	
Viau, E., Bibby, K., Paez-Rubio, T. and Peccia, J. 2011. Toward a Consensus View on the Infectious Risks Associated with Land Application of Sewage Sludge. *Environ. Sci. Technol*. Online version. Dx.doi.org/10.1021/es200566f|Environ. Sci. Technol. XXXX, XXX, 000-000.	Paper looks at risks associated with land application biosolids via different exposure routes. Traditional monitoring of *Salmonella* spp. and enteroviruses underestimates risk from other pathogens, especially norovirus. Rigorous biosolids treatment processes that reduce pathogens are more important than extending community separation distances from the application sites.
Wallin, R., President, N-Viro Systems Canada, personal conversation May 11, 2005.	
Water Environment Federation and the American Society of Civil Engineers (WEF & ASCE) (1992) Design of Municipal Wastewater Treatment Plants. Volume II. WEF Manual of Practice No. 8; ASCE Manual and Report on Engineering Practice No. 76. Library of Congress Catalog Card No. 91-30528. Book Press, Inc., Brattleboro, Vermont.	Standard reference text on design of wastewater and biosolds treatment facilities.
Water Environment Federation (WEF) (1995) Wastewater Residuals Stabilization. WEF Manual of Practice FD-9. Library of Congress Catalog No. 95-14028. Alexandria, Virginia.	Standard reference text on design and operation of biosolds treatment facilities.
WEAO (Water Environment Association of Ontario), 2001. Fate and Significance of Selected Contaminants in Sewage Biosolids Applied to Agricultural Land Through Literature Review and Consultation with Stakeholder Groups. Final report, April 2001, prepared by R.V. Anderson Associates Ltd., M.D. Webber Environmental Consultant and SENES Consultants Ltd. See http://www.weao.org/committees/biosolids/biosolids.html.	Review of literature on fate and significance of nutrients, metals, trace organics and pathogens in land-applied biosolids.
Webber, M.D. and P. Sidhwa, 2007. Land application of sewage biosolids: Are Canadian trace metal guidelines/regulations over-protective for crop production. In Conference Proceedings, *Moving Forward*, Wastewater Biosolids Sustainability: Technical, Managerial and Public Synergy. June 24-27, 2007, Moncton, New Brunswick, Canada.	Reviews of: research involving long-term and larger than recommended biosolids applications to land; information about trace metal sorption in biosolids and soils; and recent biosolids analyses all indicate that Canadian guidelines/regulations are more protective than necessary for sustainable, high quality agricultural crop production.
Windsor (City of Windsor) web site, www.citywindsor.ca, printed May 25, 2005.	
Woods, K., Supervisor at the Town of Leamington Water Pollution Control Plant, Personal conversation May 13, 2011.	Personal communication concerning status of N-Viro system in Leamington, ON.

World Health Organization, International Water Association, and NSF International 2003. Heterotrophic Plate Counts and Drinking-water Safety: The Significance of HPCs for Water Quality and Human Health. Edited by J. Bartram, J. Cotruvo, M. Exner, C. Fricker, A. Glasmacher. IWA Publishing, London. ISBN: 1 84339 025 6.	Reference document discussing the meaning and importance of the total heterotrophic plate count in drinking water treatment
Xia, K., Hundal, L.S., Kumar, K., Armbrust, K., Cox, A.E. and Granato, T.C. 2010. Triclocarban, Triclosan, Polybrominated Diphenyl Ethers and 4-Nonylphenol in Biosolids and in Soil Receiving 33-Year Biosolids Application. *Environ. Toxicol. Chem.*, **29(3)**: 597-605	Site receiving long-term applications of Metro Chicago biosolids were monitored for antimicrobials, nonylphenol and PBDEs. Triclosan, triclocarban and 4-nonylphenol underwent rapid biotransformation in the soil, while PBDEs degraded very slowly. The PBDEs, nonylphenol and triclocarban were tightly bound to the top 30 cm of soil, while triclosan showed some downward mobility.
Young, T.M., Ogunyoku, T., Giudice, B., Scow, K., Park, I. and Zhang, N. 2011. Antimicrobials and other trace organics in biosolids: Effects on soil microbial processes and potential for endocrine disruption. Proceedings Water Environment Specialty Conference on Residual and Biosolids (CD-ROM), Sacramento, CA. May 21-25.	Examined effect of increasing triclosan doses on microbial activity in soils when added in biosolids or commercial fertilizer. Increasing doses of triclosan led to reduced soil microbe activity, however for test plots receiving biosolids, the reduction in activity caused by TCS was more than offset by increases in activity resulting from the biosolids amendment. No such effect was observed when commercial chemical fertilizer was used for control sites.