

EXECUTIVE SUMMARY

Land application of sewage biosolids has been widely practiced in North America (including Ontario) and Europe for many decades. Over the years, regulations and procedures have been developed to manage the application, and protect human and animal health and the environment. A considerable amount of scientific study has been undertaken to support the development of the regulations, and to confirm the effectiveness of the application procedures. However, the public still has concerns that land application may be unsafe because it involves human and industrial waste.

Although diverse, public concern about the detrimental health and environmental effects of sewage biosolids land application has tended to coalesce around the following main issues:

1. Surface and groundwater pollution,
2. Fate and effects of pathogens,
3. Fate and effects of heavy metals and
4. Fate and effects of organic contaminants.

In the last few years, there has been an increase in the number of large Ontario jurisdictions moving towards biosolids beneficial use. This has raised public awareness and interest in the impact of biosolids land application, making it even more critical to ensure that the safety of biosolids beneficial use is scientifically confirmed.

Project Undertaking and Objectives

This study is part of an ongoing effort by the Ontario government and municipalities to update and improve land application regulations and procedures.

The Water Environment Association of Ontario (WEAO) undertook this project in conjunction with the partners representing various municipalities, Environment Canada, Ontario Ministry of the Environment (MOE) and Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA).

The objectives of the project were:

1. Review, assess, and summarize information assembled from literature and consultation with credible non-government organizations, farming associations, experts and regulatory agencies (Stakeholders) regarding the fate and significance of contaminants in sewage biosolids after they are applied to agricultural lands.
2. Use the information to divide specific contaminants in sewage biosolids into two groups:

Group I – Contaminants which have sufficient credible scientific information to assure the public that the current agricultural land application program/guidelines are adequate to protect the well beings of soils, crops, animals, human health, ground and surface water qualities.

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Group II – Contaminants which do not have sufficient credible scientific information to assure the public that the current agricultural land application program/guidelines are adequate to protect the well beings of soils, crops, animals, human health, ground and surface water qualities.

3. Recommend a long-term study program that would allow sewage biosolids generators, the federal and provincial government agencies to complete the information gaps and identify actions that would be necessary to mitigate any adverse effects that may be caused by the presence of specific contaminants in sewage biosolids. The studies should be prioritized based on needs and consensus reached between Stakeholders.
4. Provide comprehensive Terms of Reference for the top 3 studies identified in the long-term study program.
5. Disseminate the study findings and recommendations to the Stakeholders and municipalities through report(s) and workshop(s). The information package should also include a well-organized bibliography (by topic/issue and where the reference materials can be obtained/ordered) and one copy of an appendix containing all the reference materials reviewed by this study.

Information was solicited from a broad range of sewage biosolids stakeholder and expert groups, concerning current and emerging issues and research/regulatory programs relating to the agricultural land application of sewage biosolids. Information gathering focused on the fate of metals, organic contaminants, pathogens, and other contaminants in land-applied biosolids and on their significance for soil, crops, surface and groundwater quality, and human and animal health.

For survey purposes, the stakeholders were subdivided into two groups:

- Group 1 - Stakeholders located in Ontario
- Group 2 – Regulators and Experts located outside Ontario

Separate questionnaires were prepared and submitted to the groups.

Contaminants Of Concern

From the stakeholders, Technical Steering Committee, and consultants' input, the following list of contaminants was developed:

- Heavy Metals including Regulated and Unregulated
- Pathogens
- Trace Organics, including Volatile Organic Contaminants (VOCs), Polychlorinated Biphenyls (PCBs), Polynuclear Aromatic Hydrocarbons (PAHs), Pesticides, etc.
- Linear Alkylbenzene Sulphonate (LAS) Surfactants
- Endocrine Disrupter Compounds (EDCs) including Alkylphenol Surfactants (APs), Estrogenic Hormones
- Dioxins and Furans (PCDD/Fs)
- Pharmaceuticals

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- Radionuclides
- Nutrients including Nitrogen and Phosphorus

Literature Review

Literature reviews were conducted for all of the above specified contaminants of concern. The abstracts of recent publications (1995 to the present) were entered into an ACCESS database for ease of access.

The literature review included the following:

1. Heavy Metals In Sewage Biosolids Applied To Agricultural Land

The review of literature data on the fate and effects of heavy metals in sewage biosolids applied to agricultural land led to the following findings and conclusions:

- Sewage biosolids are products of wastewater treatment and depending upon sewer use controls, they can contain variable amounts of whatever heavy metals are used, domestically and industrially, in the sewerage district. However, biosolids quality has improved dramatically over the years due to industrial pretreatment programs, household hazardous waste education and changes in water supply management.
- Large amounts of research have focused on a few heavy metals considered to be the most hazardous and guidelines/regulations for land application of sewage biosolids have been developed to limit loadings of these constituents to agricultural land. Agronomic rates are more restrictive than the metals loading rate.
- There is much less Canadian than US and international research on the effects of heavy metals in land applied sewage biosolids. However, Canadian and in particular, Ontario recommended practices are among the most conservative in the world. Considering the absence of detrimental effects in studies with high metal concentrations and application rates, it is concluded that the recommended land application practices in Ontario present no significant risk to humans and the environment.
- The regulated metals can be considered Group I contaminants for which current Ontario guidelines are adequate to protect the well being of soils, crops, animals, humans and ground and surface water qualities.
- The following unregulated metals and compounds in biosolids were considered: aluminum, antimony, asbestos, barium, beryllium, boron, cyanide, fluoride, manganese, silver, thallium and tin. Based on very limited information, it was concluded that loadings of unregulated metals in land applied sewage biosolids are unlikely to exceed Ontario MOEE "Effects Based Limits" developed for contaminated site cleanup of soil for agricultural

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use, however, a few of them, e.g., silver, antimony, may exceed the Ontario MOEE “Background Limits”. Thus, the unregulated heavy metals are Group II contaminants requiring further research.

2. Pathogens In Sewage Biosolids Applied To Agricultural Land

Human health impacts of pathogens in land applied sewage biosolids have been comprehensively and frequently reviewed.

The Washington University concluded in its 1997 literature review study (Gaus et. al. 1997) that:

- in most cases, pathogens are retained in the upper 5 to 15 cm of soil and parasites are generally strained out at the soil surface because they are larger and heavier than bacteria and viruses;
- very few bacteria have been detected in ground water from biosolids-amended sites;
- even through surface water runoff has been found to contain some indicator bacteria, bacterial contamination of surface water seems unlikely, as the survival time of enteric bacteria and viruses in soil is relatively short.

The US EPA Health Effects Research Laboratory concluded in its 1985 literature review study (Kowal, 1985) that spray application of biosolids did not represent a health threat for individuals more than 100 m downwind of the application site. Organisms transported in aerosols are much more susceptible to inactivation than in soil due to solar radiation, desiccation and high temperature.

The Ohio University conducted a three-year epidemiological study between 1978 and 1982 (US EPA, 1985). The study evaluated the health risks of land application of people living in farms that received biosolids application and another group of 130 people living in farms that did not receive biosolids application. The study team comprised of infectious disease specialists, toxicologists and epidemiologists. The study concluded that there were no significant health risks to people and their domestic animals when biosolids were applied at the rate of 4 to 10 dry tonnes/ha/year. Ontario guidelines limit biosolids application to 8 dry tonnes/ha/5 years.

Pike and Carrington reported in 1986 (Pike and Carrington, 1986) that surveillance of human and animal disease in the United Kingdom showed that properly managed land application of stabilized sewage biosolids prevents infection from sewage biosolids-born pathogens following land application.

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In spite of similar conclusions reached by different experts in human health studies, some public still are skeptical or not convinced of the evidence that sewage biosolids can be safely utilized on agricultural land. They fear that biosolids application may be a major cause of surface water and private well contamination and aerial disease transmission. These concerns were expressed by some stakeholders at the WEAO Biosolids Stakeholder Workshop held in December 1999 and in recent newspaper articles and television programs. The concerns arise from a variety of issues including: the recent E.coli contamination of the Walkerton Ontario water supply; evidence that microbial contamination of the tile drainage water may occur rapidly following animal manure application; and perceived inadequate monitoring and control of sewage biosolids application.

Public acceptance is crucial to the success of land application of sewage biosolids programs. It is recommended that a task force involved medical experts, farmers, public representatives and biosolids generators and regulators be formed to explore pathogen issues and build consensus to resolve the issues.

3. Organic compounds in sewage biosolids applied to agricultural land

The World Health Organization (WHO) Working Group on the Risk to Health of Chemicals in Sewage Sludge Applied to Land has concluded that ‘the total human intake of identified organic pollutants from sludge application to land is minor and is unlikely to cause adverse health effects’.

However, during the Stakeholder Workshop a particular concern was raised re: some organic compounds namely, dioxins and furans, endocrine disruptors (mainly alkylphenol ethoxylates), and surfactants (mainly linear alkylbenzene sulphonates). Based on the concerns raised at the Stakeholder Workshop, Sections 10, 11 and 12 of this report provided a literature review of these organic compounds, and summary of the findings is provided below.

4. Surfactants In Sewage Biosolids Applied To Agricultural Land

Surfactants and their degradation products are not regulated by either the Ontario “Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land” or the US EPA Regulation 503 “Standards for the Use or Disposal of Sewage Sludge”. Some European jurisdictions have introduced limits for linear alkylbenzene sulphonates in land-applied biosolids but no justification for these numbers was identified.

The literature review revealed that high concentrations (e.g., thousands of mg/kg dry wt.) of linear alkylbenzene sulphonates or their degradation products can occur particularly in anaerobically stabilized biosolids. However, these compounds degrade rapidly (within a few days or weeks) under aerobic soil conditions and do not present a significant health or environmental hazard.

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Based on the above finding, it was concluded that linear alkylbenzene sulphonate surfactants fall into the Group I category, not requiring further study. However, the authors are not aware of linear alkylbenzene sulphonate data for Ontario soils and suggest that some be obtained.

5. Endocrine Disruptors In Sewage Biosolids Applied To Agricultural Land

Alkylphenols and their degradation products are not regulated by either the Ontario “Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land” (MOEE and OMAFRA 1968) or the US EPA Regulation 503 “Standards for the Use or Disposal of Sewage Sludge”. However, Switzerland banned the use of nonylphenol ethoxylates in fabric detergents in 1986 and some other European jurisdictions have introduced limits for nonylphenol concentrations in land applied biosolids. No basis was provided for the setting of these particular limits.

The literature review indicated that:

- Alkylphenols and alkylphenol ethoxylates do not persist in soils for extended periods and, in fact, are readily broken down by the microbial populations in the soil.
- The initial concentrations of alkylphenols and alkylphenol ethoxylates occurring immediately after sewage biosolids application should not impact crop growth, or present any leaching potential because the uptake of alkylphenols by plants is minimal. Additionally, no leaching occurs into the groundwater and there is no transfer via the food chain to animals.
- Endocrine Disruptors such as alkylphenols and alkylphenol ethoxylates are therefore considered as Group I contaminants, for which no further study is recommended, at this time.
- Estrogenic hormones that are considered endocrine disrupting compounds cannot presently be analyzed in sewage biosolids. Therefore, these compounds are considered Group II contaminants for which further study is needed.

6. Dioxins And Furans In Sewage Biosolids Applied To Agricultural Land

There are few Canadian guidelines or regulations for dioxins in soils. The CCME (Canadian Council of Ministers of the Environment) interim assessment criterion and interim remediation criterion for total TEQ concentration in soil are both 10 ng/kg dry weight. The “Guideline for Use at Contaminated Sites in Ontario” reports a background TEQ concentration in soil of 7 ng/kg dry weight and an effects based guideline of 10 ng/kg dry weight for clean-up of land for agricultural use.

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There are currently no guidelines in Ontario to regulate the concentrations of dioxins and furans in sewage biosolids for application on agricultural land. The literature review of available information indicated that dioxins and furans concentrations in sewage biosolids are extremely low. At the maximum application rate of 8 dry tonnes/ha/5 years, and assuming there is no biodegradation of dioxins and furans in soil, biosolids containing median concentrations of dioxins and furans can be applied repeatedly to the same field 66 times or 330 years before the "Background Based" soil concentration limit would be reached (Ref. Table 9.6). Thus, they are Group I contaminants for which no further study is necessary, at this time.

7. Pharmaceuticals In Sewage Biosolids Applied To Agricultural Land

There is very little information on pharmaceutical concentrations in sewage biosolids or on the environmental behaviour and ecotoxicology of these biologically active substances.

Due to the lack of data, pharmaceuticals are considered Group II compounds which need further information.

8. Radionuclides In Sewage Biosolids Applied To Agricultural Land

Whereas heavy metals and other potentially toxic elements such as arsenic and selenium in sewage biosolids have received considerable attention over the years, radionuclides are seldom mentioned and there is no provision for them in present land application guidelines/regulations. A search of international literature from 1995 to the present identified a small number of reports (none Canadian) on radionuclides in sewage biosolids.

Since long-lived radionuclides are excluded from Ontario sewer systems and medically used radionuclides are short-lived, it is concluded that radionuclides are Group I contaminants for which no further study is necessary, at this time.

9. Nitrogen And Phosphorus In Sewage Biosolids Applied To Land

Literature findings revealed that currently in Ontario, estimates of potential plant available N (PAN) following biosolids application to land are based on extensive experience of animal manure use, limited experience of biosolids use, knowledge of biosolids and soil properties, and an incomplete understanding of the effects of various biosolids management techniques and environmental conditions. Although imperfect, these estimates are probably adequate for biosolids use according to the present guidelines which call for a maximum addition of 135 kg/ha of plant available N to land in biosolids during a 5-year period. This practice severely limits N buildup in the soil and avoids potential environmental

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problems associated with more frequent applications and larger N loadings. Similarly, present Ontario practice limits biosolids P buildup in soil, facilitating efficient use of the P fertilizer value and avoiding potential environmental problems associated with more frequent applications and larger P loadings.

Based on the literature review it was concluded that available biosolids N and P information is adequate in relation to present land application practice. However, it is recommended that adoption of a more sophisticated site-specific approach to biosolids N management such as that currently being developed for the U.S.A. should be considered prior to recommending increased biosolids applications to land in Ontario.

Group I And Group II Contaminants

Based on the findings of the literature review which were discussed at the Technical Steering Committee meeting and endorsed by the Technical Steering Committee members, Table ES-1 allocates the contaminants of concern to Group I (no additional studies recommended), or Group II (additional studies required).

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**TABLE ES-1
Group I and Group II Contaminants**

CONTAMINANT OF CONCERN	GROUP I	GROUP II	GROUP II COMMENTS
Heavy Metals – Regulated and Unregulated	Regulated	Unregulated	Data required for unregulated heavy metals in Ontario biosolids
Pathogens		X	Data required to address potential risks of pathogens in biosolids for water quality and human health.
Trace Organics - Volatile Organic Contaminants (VOCs), Polychlorinated Biphenyls (PCB's), Polynuclear Aromatic Hydrocarbons (PAHs), Pesticides	X		
Linear Alkylbenzene Sulphonate (LAS) Surfactants	X		
Endocrine Disruptors (EDCs) - Alkylphenol Surfactants (APs), Estrogenic Hormones	Alkylphenols	Estrogenic Hormones	Analytical methods development required for estrogenic hormones
Dioxins and Furans (PCDD/Fs)	X		
Pharmaceuticals		X	Analytical methods development required. Data required for pharmaceuticals in Ontario biosolids
Radionuclides	X		
Nutrients - Nitrogen and Phosphorous	X		

As seen in Table ES-1, four groups of contaminants have been allocated into the Group II category. Of these contaminants, hormones that are considered endocrine disrupting compounds and pharmaceuticals cannot presently be analyzed in sewage biosolids.

Recommended Additional Study For Group II Contaminants Of Concern

Based on the findings and conclusions from the various report sections, Table ES-2 provides a summary of the recommended studies for the Group II contaminants of concern. The allocation of contaminants to Group II and recommended studies were discussed at the Technical Steering Committee meeting and endorsed by the committee members.

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TABLE ES-2
Summary of Recommended Studies

GROUP II CONTAMINANT OF CONCERN	RECOMMENDED STUDIES	COMMENTS
Unregulated Heavy Metals	Conduct a survey of unregulated heavy metal concentrations in Ontario sewage Biosolids and agricultural soils	
Pathogens		Form a task force with representatives from the wastewater treatment and medical communities, and the public to explore and build consensus on such issues as the principles that should be used to define risks and acceptable risks, develop and monitor studies that would confirm/recommend improvements to current application program.
Hormones and Pharmaceuticals	<p>Develop analytical methods for measuring pharmaceutical and estrogenic hormones in sewage biosolids.</p> <p>Conduct a survey of pharmaceuticals in Ontario sewage biosolids.</p>	Research in progress at the Agriculture and Agri-Food Canada Research Centre, London, ON to determine concentrations and fate of estrogenic hormones in land applied animal manure should be supported

Terms Of Reference For The Identified Group II Contaminants

In order of priority, pathogens, unregulated metals and pharmaceuticals and hormones in land applied sewage biosolids were identified for the Three High Priority Studies. The research recommendations are as follows:

1. Pathogens

Form a task force involving medical experts, farmers, public representatives and biosolids generators and regulators to explore pathogen issues and build consensus to resolve the issues. Some of the tasks can include, but are not limited to:

- monitoring information/tools being generated by recent Water Environment Research Foundation (WERF) and National Academy of Science (NAS) studies aiming at assessing the health impacts that may be attributable to sewage biosolids land application program;

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- using the US study information and experience as reference to determine how Ontario should define risks and acceptable risks associated with sewage biosolids land application;
 - developing and monitoring studies that are necessary to measure and assess risks;
 - developing and monitoring studies to confirm and/or improve current biosolids; management and application practices and/or guidelines for public health and environment protection;
 - developing and monitoring studies to increase public confidence and acceptance of the biosolids application program;
 - disseminating information to stakeholders including the media and general public.
2. Unregulated Metals
- A survey should be conducted to obtain a representative database of information for unregulated metals in Ontario sewage biosolids and agricultural soil.
3. Pharmaceuticals and Estrogenic Hormones
- Develop analytical methods for measuring pharmaceutical compounds and estrogenic hormones in sewage biosolids.
 - A survey should be conducted to obtain a representative database of information for pharmaceutical compounds and estrogenic hormones in Ontario sewage biosolids.

Also, research in progress at the Agriculture and Agri-Food Canada Research Centre, London, ON to determine concentrations and fate of estrogenic hormones in land applied animal manure should be supported. (Terms of reference for this activity are not presented in this document).

This report was prepared by R.V. Anderson Associates Limited, M.D. Webber Environmental Consultant and SENES Consultants Limited, for the account of Water Environment Association of Ontario. The material in it reflects our best judgment in light of the information available to them at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. We accept no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.