Storm and Wastewater

Biosolids Management Programs

This document is the sixth in a series of best practices that deal with buried linear infrastructure as well as end of pipe treatment and management issues. For titles of other best practices in this and other series, please refer to *www.infraguide.ca.*

National Guide to Sustainable Municipal Infrastructure

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Federation of Canadian Municipalities

Canada

Biosolids Management Programs

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InfraGuide – Innovations and Best Practices

Why Canada Needs InfraGuide

Canadian municipalities spend $12 to $15 billion annually on infrastructure but it never seems to be enough. Existing infrastructure is ageing while demand grows for more and better roads, and improved water and sewer systems responding both to higher standards of safety, health and environmental protection as well as population growth. The solution is to change the way we plan, design and manage infrastructure. Only by doing so can municipalities meet new demands within a fiscally responsible and environmentally sustainable framework, while preserving our quality of life.

This is what the National Guide to Sustainable Municipal Infrastructure (InfraGuide) seeks to accomplish.

In 2001, the federal government, through its Infrastructure Canada Program (IC) and the National Research Council (NRC), joined forces with the Federation of Canadian Municipalities (FCM) to create the National Guide to Sustainable Municipal Infrastructure (InfraGuide). InfraGuide is both a new, national network of people and a growing collection of published best practice documents for use by decision makers and technical personnel in the public and private sectors. Based on Canadian experience and research, the reports set out the best practices to support sustainable municipal infrastructure decisions and actions in six key areas: 1) municipal roads and sidewalks 2) potable water 3) storm and wastewater 4) decision making and investment planning 5) environmental protocols and 6) transit. The best practices are available on-line and in hard copy.

A Knowledge Network of Excellence

InfraGuide´s creation is made possible through $12.5 million from Infrastructure Canada, in-kind contributions from various facets of the industry, technical resources, the collaborative effort of municipal practitioners, researchers and other experts, and a host of volunteers throughout the country. By gathering and synthesizing the best Canadian experience and knowledge, InfraGuide helps municipalities get the maximum return on every dollar they spend on infrastructure—while being mindful of the social and environmental implications of their decisions.

Volunteer technical committees and working groups—with the assistance of consultants and other stakeholders—are responsible for the research and publication of the best practices. This is a system of shared knowledge, shared responsibility and shared benefits. We urge you to become a part of the InfraGuide Network of Excellence. Whether you are a municipal plant operator, a planner or a municipal councillor, your input is critical to the quality of our work.

Please join us.

Contact InfraGuide toll-free at **1-866-330-3350** or visit our Web site at ***www.infraguide.ca*** for more information. We look forward to working with you.

The InfraGuide Best Practices Focus

Storm and Wastewater

Ageing buried infrastructure, diminishing financial resources, stricter legislation for effluents, increasing public awareness of environmental impacts due to wastewater and contaminated stormwater are challenges that municipalities have to deal with. Events such as water contamination in Walkerton and North Battleford, as well as the recent CEPA classification of ammonia, road salt and chlorinated organics as toxic substances, have raised the bar for municipalities. Storm and wastewater best practices deal with buried linear infrastructure as well as end of pipe treatment and management issues. Examples include ways to control and reduce inflow and infiltration; how to secure relevant and consistent data sets; how to inspect and assess condition and performance of collections systems; treatment plant optimization; and management of biosolids.

Decision Making and Investment Planning

Elected officials and senior municipal administrators need a framework for articulating the value of infrastructure planning and maintenance, while balancing social, environmental and economic factors. Decision-making and investment planning best practices transform complex and technical material into non-technical principles and guidelines for decision making, and facilitate the realization of adequate funding over the life cycle of the infrastructure. Examples include protocols for determining costs and benefits associated with desired levels of service; and strategic benchmarks, indicators or reference points for investment policy and planning decisions.

Environmental Protocols

Environmental protocols focus on the interaction of natural systems and their effects on human quality of life in relation to municipal infrastructure delivery. Environmental elements and systems include land (including flora), water, air (including noise and light) and soil. Example practices include how to factor in environmental considerations in establishing the desired level of municipal infrastructure service; and definition of local environmental conditions, challenges and opportunities with respect to municipal infrastructure.

Potable Water

Potable water best practices address various approaches to enhance a municipality's or water utility's ability to manage drinking water delivery in a way that ensures public health and safety at best value and on a sustainable basis. Issues such as water accountability, water use and loss, deterioration and inspection of distribution systems, renewal planning and technologies for rehabilitation of potable water systems and water quality in the distribution systems are examined.

Transit

Urbanization places pressure on an eroding, ageing infrastructure, and raises concerns about declining air and water quality. Transit systems contribute to reducing traffic gridlock and improving road safety. Transit best practices address the need to improve supply, influence demand and make operational improvements with the least environmental impact, while meeting social and business needs.

Municipal Roads and Sidewalks

Sound decision making and preventive maintenance are essential to managing municipal pavement infrastructure cost effectively. Municipal roads and sidewalks best practices address two priorities: front-end planning and decision making to identify and manage pavement infrastructures as a component of the infrastructure system; and a preventive approach to slow the deterioration of existing roadways. Example topics include timely preventative maintenance of municipal roads; construction and rehabilitation of utility boxes; and progressive improvement of asphalt and concrete pavement repair practices.

TABLE OF CONTENTS

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EXECUTIVE SUMMARY

Municipal wastewater treatment plants generate liquid and solid discharges that have to be managed in an environmentally conscious way. In the past, attention focused on the liquid effluents discharged to watercourses. Ample legislation and effective facilities and operating procedures have evolved in this regard. In the case of solids management, the same level of attention has only started to appear in recent years. From the Canadian scan of biosolids practices, it was noted that 22 percent of responders indicated there were no specific compliance criteria applicable to biosolids programs in their jurisdictions.

In developing this best practice, we recognize 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.

Regulations regarding biosolids recycling in Canada have been developed over the past 30 years or so. As a result of the growing concerns of the public, biosolids programs are under much greater scrutiny, and several provinces have recently undertaken a review of their current legislation and practices. Thus with the changes in public perception and revised regulations, municipal governments will have to review their current biosolids practices which could lead to improved biosolids management. This best practice may help to chart the directions that may have to be taken and the initiatives that will have to be started.

Identifying and adopting best practices in a biosolids management program must be a high priority for municipal governments that operate wastewater treatment plants and generate residual solids. By implementing best practices, 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.

Biosolids management programs will vary from municipality to municipality depending on size, regulations, public perception, and social, economic, and political factors. This best practice identifies 13 elements that could be part of a biosolids program. Depending on the size and circumstances, some elements may be less applicable (e.g., source control in a small rural community without industries, separate sludge storage facilities for lagoon systems). It is important, however, that elements are not deleted merely because of size. For instance, the issue of public acceptance is important irrespective of size, but the extent of the communication strategy can be tailored.

As a precursor to implementing any best practice, a municipality should identify which of the elements outlined below are relevant. Following this, the procedures that are in place should be compared to the ones described in this best practice, to produce a statement of the variances. Finally, a plan of action can be developed to eliminate the variances and bring the program into closer agreement with the best practice.

As part of a continuous improvement approach, reviews of the program should be undertaken at regular intervals to determine how the program is performing and what improvements are needed. This best practice recommends that the program be reviewed every five years (as a minimum), with a fresh planning exercise every 15 years or when major

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.

regulatory or other changes occur that may have a significant impact on the program. Biosolids management programs must be protective of the environment and public health, sustainable, cost effective, reliable, and must have some degree of flexibility and diversity to assure their success, even under changing and unforeseen circumstances. Generally, biosolids management programs may be divided into the following key elements.

This best practice also provides a framework for undertaking the planning of the biosolids program, giving advice on technologies and end uses, and on methods for involving the public in the planning exercise.

Program element	Description
Regulatory framework	Thorough knowledge and understanding of applicable laws and regulations, including certificates of approval or permits that govern operations. Regulations and relevant documents must be readily available.
Source control	Generally accomplished through the enactment and active enforcement of a sewer use by-law, and can directly impact biosolids quality.
Solids stabilization	Stabilization is the basis for biosolids end quality affecting volume reduction, pathogen reduction, vector attraction reduction, reduction of odour potential.
Thickening	Increasing solids concentration prior to stabilization processes will positively impact downstream operations by reducing capacity requirements.
Dewatering	Like thickening, dewatering reduces the volume of material to be handled.
Storage	An important consideration in respect to flexibility. Storage for a biosolids program should not be merely considered for the final product, but for the key unit processes that make up the program such as upstream of dewatering or thickening processes, prior to further processing or haulage.
Transportation	Key considerations for transportation are program costs, safety, and public acceptance.
Biosolids Management	For the purpose of this Guide, beneficial use means the use of the nutrient value or the soil conditioning characteristics of the biosolids, such as application on agricultural land, use in silviculture, sale as fertilizer, and use in horticulture.
Odour control	Odours can be a key contributor to lowering the public's acceptance of the biosolids management program. Reduction of odour potential at all stages of the biosolids management system is therefore essential.
Contingency planning	The contingency plan should address the following as a minimum: inclement weather, changes in biosolids quality, equipment or process failure, transportation breakdowns, spills.
Quality management programs	Program should be carried out using the principles of a quality management system with continuous improvement as a core principle.
Program delivery options	Elements of a biosolids management program can be implemented using alternate project delivery methods.
Public participation / communications	Strong public participation/communications program should be an integral part of any biosolids program.

1. General

1.1 Introduction

Wastewater is collected and transported to treatment plants, which process and yield a solid product as well as a liquid one. For close to a century now, municipal managers, as well as engineers and scientists have focused their attention on the liquid stream, emphasizing the liquid treatment aspect of these plants. Solids on the other hand, have been looked upon as a consequence of this process, a by-product at best. In more recent years, greater appreciation of the process has developed and solids are now recognized as the second product.

Solids obtained from wastewater treatment facilities are called biosolids if they are treated according to certain criteria (i.e., if they are stabilized, and rendered acceptable for beneficial use). This best practice has been created after a scan of current Canadian municipal practices, which was conducted in January 2003, and is aimed at providing the reader with an understanding of different techniques and technologies used for biosolids management. It suggests state-of-the-art methodologies for planning, designing, constructing, managing, assessing, maintaining, and rehabilitating works, while considering local economic, environmental, and social factors. A bibliography of more focused material is added for further reference for those with deeper interest.

1.2 Scope

This best practice deals primarily with beneficial reuse of biosolids by various methods. It describes leading methodologies and technologies used in the development, implementation, and operation of biosolids management programs. In addition, it discusses elements of a biosolids management program that is applicable to beneficial reuse. The intent is to assist municipal governments in developing and/or improving their biosolids management programs. It is one of several best practices developed by the *National Guide to Sustainable Municipal Infrastructure*.

Solids stabilization processes produce biosolids and this best practice has considered the stabilization process as the starting point for biosolids management programs. However, two exceptions have been recognized: the source control programs and the thickening process prior to stabilization. The former is designed to control the characteristics of the wastewater generated by a municipality, whilst the latter impacts the hydraulic loading on the stabilization process. This best practice discusses these elements as well as the elements downstream.

This best practice does not address the impact of supernatant/filtrate/centrate return from digestion and dewatering processes on the liquid treatment train. Biosolids are one of the two end products of a wastewater treatment facility. For details regarding supernatant, the reader is referred to the best practices for wastewater treatment plant optimization and wastewater source control.

1.3 General Health and Safety Issues

In general, biosolids production and management are governed by environmental legislation that has been developed to protect public health and the environment.

Biosolids management programs must be developed, implemented, and maintained with due regard for the health and safety of workers, the public, animals, crops, and the environment, particularly when considering options for biosolids end use.

This best practice suggests state-of-the-art methodologies for planning, designing, constructing, managing, assessing, maintaining, and rehabilitating works, while considering local economic, environmental, and social factors.

1. http://www.nrtee-trnee.ca/eng/overview/overview_e.htm (Last accessed September 25, 2003)

1.4 Glossary

Aerobic digestion — The degradation of organic matter in sludge brought about through the action of micro-organisms in the presence of oxygen for purposes of stabilization, volume reduction, and pathogen reduction.

Agricultural land — Land on which food, feed, or fibre crops are grown. This includes range land and/or land used as pasture. In this document, this term also covers silviculture, lands.

Alkaline stabilization — A process in which sufficient alkaline material is added to sludge to produce highly alkaline biosolids. Lime stabilization is a form of alkaline stabilization.

Anaerobic digestion — The degradation of organic matter in sludge brought about through the action of micro-organisms in the absence of oxygen for purposes of stabilization, and pathogen reduction. The process is carried out in a tank or other vessel called a digester.

Beneficial use — For the purpose of this Guide, taking advantage of the nutrient content and soil conditioning properties of a biosolids product to supply some or all of the fertilizer needs of an agronomic crop or for stabilizing vegetative cover (in land reclamation, silviculture, landfill cover, or similar ventures); or using the biosolids product as a fuel source.

Biosolids — A primarily organic product produced by wastewater treatment processes that can be beneficially used. They are the treated solid or semi-solid residues generated during the treatment of domestic sewage in a wastewater treatment facility. (Such facilities may also receive an industrial component.) Biosolids must meet the regulations of the jurisdiction in which they are produced or applied. Requirements may include pollutant concentration, pathogen reduction, and vector attraction reduction criteria.

Biosolids application rate — The amount of biosolids on a dry weight basis that can be applied to a land application site, usually defined in dry tonnes/hectare. There are usually restrictions on the frequency of application depending on jurisdictional regulations.

Biosolids cake — Biosolids dewatered to a solids concentration normally greater than 15 percent. Most biosolids cake is in the range of 22 to 35 percent solids concentration. (See also cake and sludge cake.)

Buffer — An area of land that designates a zone of separation between possible conflicting land uses.

Cake — In this publication, cake refers to biosolids cake.

Composting — The controlled biological oxidation and decomposition of organic matter, including sludge and biosolids at controlled time and temperature conditions specified in the criteria used in that jurisdiction.

Dewatered biosolids — See Biosolids cake.

Domestic sewage — Waste and wastewater from humans or household operations.

Dry tonnes — The measurement of the weight in metric tonnes of the dry solids in sludge or biosolids (i.e., the mass of solids without water, 1 tonne = 1000 kg).

Heat drying — Dewatered cake is dried by direct or indirect contact with a heat source, and the moisture content is reduced to 10 percent or lower.

Heat treatment — Liquid sludge is heated to temperatures of 80°C or above for 30 minutes.

Incineration — Combustion at high temperatures (820 –1200 °C) in the presence of oxygen, where organic material is converted into heat energy, flue gas and slag.

2. The terms implications and outcomes are used interchangeably in this best practice.

Land application — The placement of biosolids at a predetermined rate and in accordance with relevant site management policies and regulations (see biosolids application rate) to support vegetative growth either on the surface or in the subsurface.

Land application site — An area of land covered by a single permit or certificate of approval on which biosolids are applied to condition the soil or fertilize crops.

Lime stabilization — See alkaline stabilization.

Mesophilic — Related to micro-organisms that grow and live optimally at moderate temperatures in the range of 10-45ºC (typically between 20-37ºC) which are commonly associated with an indoor environment.

Moisture content — The quantity of water present in soil, biosolids, or residual solids, usually expressed as a percentage of wet weight.

Nutrient — Any substance that is required for plant growth. The term generally refers to nitrogen, phosphorus, and potassium in agriculture, but can also apply to other essential and trace elements.

Pasteurization — Sludge is heated to 70°C or higher for 30 minutes or longer to destroy pathogens.

Pathogens — Organisms such as bacteria, protozoa, viruses, and parasites which can cause disease in humans and animals.

Pre-treatment — Treatment of industrial wastewater to remove certain concentrations of some pollutants from the wastewater before discharge to a communal wastewater treatment plant in compliance with local sewer-use by-law requirements.

Residual Solids — See sludge.

Sludge — Unstablized organic solids sometimes referred to as residual solids.

Sludge Cake — Sludge, dewatered to a solids concentration greater than 22 percent.

Soil amendment — Anything that is added to the soil (i.e., lime, gypsum, inorganic fertilizers and organic material, including biosolids) to improve its physical or chemical condition for plant growth.

Soil conditioner — Any material applied to improve aggregation and stability of structural soil aggregates.

Solids concentration — Usually quoted in percentage, it is the percentage by weight of dry solid material in sludge or biosolids (one percent solids = 10,000 mg dry solids/kg of slurry).

Thermophilic — Related to 'heat loving' micro-organisms which grow best at temperatures above 40ºC (typically between 45-60ºC) that will kill ordinary micro-organisms. These are found naturally in hot locations such as hot springs, thermal vents at the ocean bottom, etc.

Vector attraction — The characteristic of residual solids or biosolids that attracts rodents, flies, mosquitoes, or other organisms capable of transporting infectious agents, such as pathogens.

Volatile solids — Materials, generally organic, which can be driven off from a sample by heating, usually to 550°C. The non-volatile inorganic solids remain as ash.

Definitions have been adapted from the following references:

1. *California Water Environment Association (CWEA) Manual of Good Practice — Agricultural Land Application of Biosolids (1998).*
2. *Use and Disposal of Municipal Wastewater Sludge, EPA 625/10-84-003.*

2. Rationale

2.1 Biosolids Management

Municipal wastewater treatment plants generate liquid and solid discharges that have to be disposed of in an environmentally conscious way. In the past, the focus of attention has been on liquid effluents that were discharged to watercourses. Abundant legislation and effective facilities and operating procedures have evolved in this regard. In the case of solids management, increasing attention has only started to become apparent in recent years. From the scan of biosolids practices in Canada in January 2003, it was evident that in some jurisdictions, legislation does not exist or is not as definitive as it should be. While over 90 percent of respondents noted some form of regulatory framework that governed their program, 22 percent of them indicated there were no specific compliance criteria.

Over the last 30 or more years, the primary method of reuse has been application on agricultural land. Regulations in Canada have been developed over the past 20 years or so. Currently, there is growing public concern regarding the safety of biosolids management practices. This has brought biosolids programs under much greater scrutiny, resulting in several provinces undertaking reviews of the current legislation and practices.

2.2 Anticipated Benefits from Applying Best Practices

Identifying and adopting best practices in the various elements of the biosolids management program should be a high priority for municipalities that operate wastewater treatment plants and generate residual solids. By implementing best practices, municipalities will improve their chances of realizing the benefits outlined in the following sections.

2.2.1 Compliance with Regulatory Requirements

Biosolids management programs should contain monitoring and continuous improvement components that measure compliance with legislative and other local public issues and expectations over time.
It is crucial that properly trained operators are available for running biosolids programs to ensure that the regulations are being followed and the public safety is protected. Where possible operators should be certified. Using this best practice will improve program compliance.

2.2.2 Improved Biosolids Quality

Best practices are designed to produce a final biosolids product for beneficial use that is higher in solids content and lower in pathogens, metals, odour production potential, and other substances that could adversely affect the safety/acceptability of the biosolids product or restrict its usage. These will include nutrients and other elements that will enhance soil properties. By improving the quality of biosolids, there will be greater acceptance of the product and more potential for beneficial use and possibly to establish revenue from the sale of the product; pellets and compost are examples of where this may be applicable.

2.2.3 Improved Odour Management

Odour concerns, which are part of every biosolids management program, are of paramount importance. Odour generation and control are issues in many elements of a biosolids management program. Odour management must therefore be considered a key parameter when selecting best practice options in elements such as stabilization, thickening, and dewatering, further processing storage, transportation, and end use.

By continuously improving biosolids quality and meeting or exceeding regulatory requirements, improved public acceptance will follow.

2.2.4 Improvements in Safety

Safety is a key consideration within biosolids management programs, with respect to the public who may be affected during the transportation, storage, and final intended use of the biosolids product and with respect to the safety of workers who are involved in handling and treating biosolids at the processing facility, and the final destination. This best practice will improve safety by achieving a higher quality product (see 2.2.2), by developing and implementing procedures for handling biosolids, and by upgrading worker education and training programs.

2.2.5 Wider Public Acceptance

Improved public acceptance is one of the most important outcomes to best practice initiatives in municipal operations. As indicated above, adoption of best practices within the elements of a biosolids management program will result in improvements with respect to regulatory compliance, higher biosolids quality, odour reductions, and improvements with respect to safety concerns and local public expectations. These improvements, coupled with a proactive public communication program, are expected to result in wider public acceptance of a municipal biosolids management program.

In addition to having serious concerns with respect to odours, safety, and potential health and environmental impacts associated with a biosolids management program the public is also concerned whether municipalities and their contractors are complying with all the regulatory site management requirements when applying the biosolids to agricultural land. These concerns and fears must be alleviated to build public trust and confidence in municipal biosolids management programs. Demonstrating that best practices are being implemented within the biosolids management program, along with the municipal government's willingness to respond to public comments and make information about its program readily available to the public, can improve the public acceptance of the program.

2.2.6 Improved Cost Effectiveness

Improved cost effectiveness can be realized in any biosolids management program by implementing best practices. By continuously improving biosolids quality and meeting or exceeding regulatory requirements, improved public acceptance will follow. This can result in greater demand for the final product. Adoption of practices such as thickening or dewatering of solids before processing or dewatering before transport can positively impact program costs.

2.2.7 Sustainability

Sustainable development is defined as development that meets the needs of the present, without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). In this regard, the actions we take today must be protective of our natural resources and the environment. In the context of municipal infrastructure management, sustainability includes financial resources as well as social development.

Any well-managed program should be sustainable over the long term. The practices within the program should permit the program to carry on for the foreseeable future, without adverse impacts. The adoption of best practices will allow the program to be sustained economically, while improving and enhancing the quality of life, and protecting human health and the environment, including land, surface water and ground water, air, animals, and crops.

2.3 Biosolids Quality Categories

There are different levels to which biosolids can be processed. The U.S. Environmental Protection Agency (EPA), in its Part 503 Rule, has defined several categories: the most commonly referenced ones being Class A, Class B, and Exceptional Quality (EQ). In Canada, the *Fertilizer Act* is the only national regulation that makes reference to biosolids, since biosolids as with all environmental legislation is under provincial jurisdiction. Regulations in some provinces refer to the EPA definitions, while others have developed their own terminology and definitions.

For the purpose of this best practice, it was decided to refer to three basic qualities of biosolids: Category 1, Category 2, and Category 3. These quality levels are defined in Table 2–1, with references to some provincial guidelines/regulations where appropriate. This is to assist the users of this best practice to understand the levels of quality, as they develop or modify their biosolids management programs, and select processes and end uses that are desirable or applicable to their particular case.

Category 1 is a high-quality biosolids product equated with the definition of exceptional quality (EQ) in the EPA Rule and Class A compost in the British Columbia Organic Matter Recycling Regulation. BC Class A compost has more restrictive standards that EPA EQ pollutant requirements. The product is nearly pathogen free (same as Category 2 or EPA Class A). The primary difference between categories 1 and 2 is the reduced content of pollutants (e.g., heavy metals) in Category 1. Category 1 biosolids would typically have unrestricted use and can be retailed in some jurisdictions in Canada.

Category 2 is equivalent to the EPA Class A (similar to British Columbia), and is near pathogen free (less than 1000 MPN per gram). The pollutant concentrations in Category 2 are the same as Category 3 (thus higher than Category 1), which places restrictions on its use.

Category 3 is equivalent to EPA Class B (similar to British Columbia). The biosolids in this category contain less than two million MPN fecal coliforms per gram of total solids, dry weight. Pollutant concentrations are the same as Category 2 but because of the higher pathogen content, Category 3 biosolids typically have the most restrictions in regard to end use including site management restrictions.

Vector attraction reduction (VAR) refers to the reduction of the attractiveness of biosolids to vectors such as flies, mosquitoes, fleas, rodents, and birds. This reduces the potential for transmitting disease. VAR requirements apply to all categories.

Table 2–1
Comparison of different biosolids quality categories used in this report

Table 2–1: Comparison of different biosolids quality categories used in this report

Parameter	Category 1	Category 2	Category 3
1. Terminology			
US EPA Alberta British Columbia Ontario Quebec	Exceptional Quality EQ) (No Classification) Class A Compost (No Classification) C1, P1	Class A Class A C2, P2	Class B Class B C3, P3
Pathogen Reduction Requirements	Less than 1000 MPN fecal coliforms per gram of total solids, dry weight or Density of *Salmonella* less than 3 MPN per 4 grams of total solids, dry weight	Less than 1000 MPN fecal coliforms per gram of total solids, dry weight or Density of *Salmonella* less than 3 MPN per 4 grams of total solids, dry weight	Less than 2 Million MPN fecal coliforms per gram of total solids, dry weight
In addition to meeting the pathogen reduction requirements above, the biosolids must be treated by one of the following processes below.			
Acceptable Processes (For details see US EPA Part 503)			
	Composting In vessel Windrow Heat drying Heat treatment of liquid biosolids Thermophilic Aerobic Digestion: Pasteurization Heat and High pH: Other processes that meet specific time-temperature relationships	Composting In vessel Windrow Heat drying Heat treatment Thermophilic Aerobic Digestion Pasteurization Heat and High pH Other processes that meet specific time-temperature relationships	Aerobic digestion Anaerobic digestion Composting Lime stabilization Air drying

Example of Pollutant Limits (mg per kg total solids, dry weight)						
	BC Class A compost	US EPA	*Fertilizer Act of Canada*	US EPA	BC Class B Biosolids	US EPA
Arsenic	13	41	75	75	75	75
Cadmium	3	39	20	85	20	85
Chromium	100	1,200	–	3,000	1,060	3,000
Copper	400	1,500	–	4,300	2,200	4,300
Lead	150	300	500	840	500	840
Mercury	2	17	5	57	15	57
Molybdenum	5	(under review)	20	75	(under review)	75
Nickel	62	420	180	420	180	420
Selenium	2	36	14	100	14	100
Zinc	500	2,800	1,850	7,500	1,850	7,500

3. Work Description

3.1 General

Biosolids management programs will vary from municipality to municipality depending on size, regulations, public perception, social, economic, and political factors. Generally, biosolids management programs may be divided into the following key elements:

- regulatory framework;
- source control;
- thickening;
- solids stabilization;
- dewatering;
- storage;
- transportation;
- biosolids management;
- odour control;
- contingency planning;
- quality management programs;
- program delivery options (e.g., use of contractors); and
- public participation/communications programs.

Depending on the size and circumstances, some elements may be less applicable (e.g., source control in a small rural community without industries). It is important, however, that elements are not deleted merely because of size. For instance, the issue of public acceptance is important irrespective of size, but the extent of the communication strategy can be tailored.

As a precursor to implementing any best practice, a municipality should identify which of the elements outlined above are relevant. Following this, the procedures that are in place should be compared to the best practice, to produce a statement of the variances. Finally, a plan of action can be developed to eliminate the variances and bring the program into closer agreement with the best practice. As part of a continuous improvement approach, reviews of the program should be undertaken at regular intervals to determine how the program is performing and what improvements are needed.

The following sub-sections discuss methodologies and technologies that may be part of a biosolids management program and provide a summary of the components of a best practice for each key element.

3.2 Defining a Biosolids Management Program

3.2.1 Overview

In the 2003 Survey of Canadian Municipalities, 72 percent of the 105 respondents indicated they had a biosolids management program. It was not determined if these municipalities had undertaken a formal planning exercise to select the components of a program that would best fit the needs of the municipality. Over 50 percent of municipalities responding to the survey indicated that they would be undertaking a planning study in the near future to develop a biosolids management program.

A biosolids management planning study should not just be a process to evaluate available technologies and select the one with the best life cycle costs. The study must review and assess the available technologies and consider how best to arrange the different components to provide an overall system that addresses the protection of the environment and public health, public concerns, reliability, flexibility, regulatory compliance, and cost.

Figure 3–1, page 22, illustrates a generic flow chart for a biosolids management program. It is unlikely that any program will be as extensive with the same number of options and degrees of flexibility. The figure does however illustrate the positioning of the different elements outlined above and their interrelationships, providing a roadmap of what options may be considered and where flexibility may be provided.

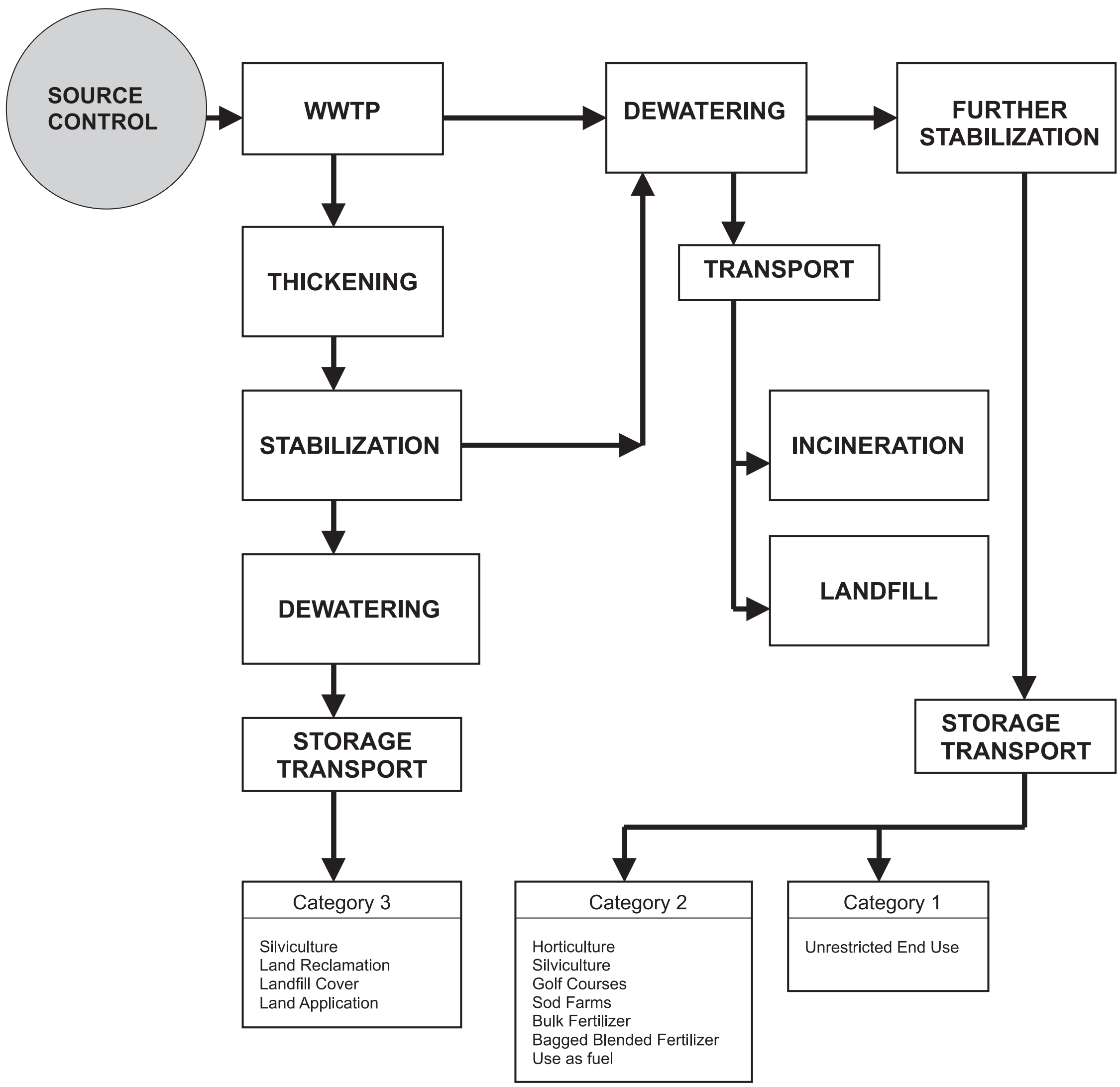
Figure 3–1
Generic flow chart for a biosolids management program

3.2.2 Planning Process

At the start of the planning process, the objectives of the plan should be identified. These may include the following:

- selecting the most appropriate mix of technologies and management options with reasonable costs;
- ensuring that the program will comply with regulatory requirements;
- addressing the liabilities, risks, and limitations of the options selected;
- incorporating flexibility and reliability;
- providing contingency measures that will provide "buffer" in the event of changes, failures, inclement weather, political or market factors
- developing a plan that can be updated to meet future needs of anticipated regulatory changes;

Figure 3–1: Generic flow chart for a biosolids management program



Notes:
- If product quality fails the requirement criteria at any level, it can be disposed at landfill sites as a contingency, when dewatered.
- Liquid recycling is not shown.
- Dewatering may not be a preferable option for small WWTPs producing Category 3 Biosolids.

- developing a strong business management system that includes staff training, data recording and reporting to Senior Management, city council and public; and
- maintaining an outreach and communication program with stakeholders.

The planning process should comprise the following steps.

- Identify and involve stakeholders and develop communication plan.
- Identify a long list of solids treatment processes and management options.
- Establish and apply screening criteria to produce a short list of options.
- Establish evaluation criteria and weighting factors for ranking short-listed options.
- Apply evaluation criteria and determine preferred options.
- Develop a biosolids management strategy.
- Research legislative and local policies requirements.

3.2.3 Screening Long-Listed Options

Screening criteria are generally pass/fail. A single fail mark against any one of the criteria will remove that particular option from further consideration (see Appendix A: Example of Screening Matrix).

Screening criteria can be selected from those presented in Table 3–1.

The screening process will quickly eliminate unsuitable and undesirable options, allowing more focus on the more likely alternatives. Options may be discarded for a variety of reasons that may include incompatibility with the existing treatment process, unsuitability for local conditions (e.g., alkaline stabilization in areas where native soils are predominantly alkaline). With the remaining options (i.e., those that now form the short list), proceed to a more detailed evaluation.

3.2.4 Detailed Evaluation

The first step in the detailed evaluation exercise should be to establish the criteria to be used and the relative weighting of each criterion, according to the importance attached to it. These weightings will be used to create a ranking of short-listed options. Some communities involve a stakeholder advisory group in establishing weightings.

Possible evaluation criteria are presented in Table 3–2.

Table 3–1: Possible Screening Criteria

Compatibility with existing site conditions and processes	Health and safety (public and operator/worker)
Proven technology	Diversity of end uses
Regulatory compliance	Potential for odours
Public acceptability	Political support
Environmental impacts	Applicability to local situation
Cost effectiveness	

Table 3–2
Possible Evaluation Criteria

Table 3–2: Possible Evaluation Criteria

Social/Environmental Criteria	Operational Criteria
Public acceptance	Impact on operations staffing requirements
Potential for odours	Easy to operate
Public perception of end product	Easy to maintain
Public health and safety	No major retraining requirements
Operator/worker safety	Reliability
Protection of the environment (compliance with legislative requirements)	
Technical Criteria	**Economic and Implementation Criteria**
Proven technology	Capital costs
Design complexities	Operation and maintenance costs
Applicability to local situation	Potential for innovative delivery partnership
Land requirements	Suitability for alternate delivery methods
Impact on plant processes	Product marketability (diversity of end use)
Storage constraints	
Impacts of water plant residuals	
Impacts on plant expansion	
Ability to cope with adverse conditions	

Weightings may be in any range — one to five, one to ten. The main consideration is that the range allows enough “width” between criteria considered extremely important and those that are less important.

A matrix of options and criteria can then be created (see Appendix A for an example of a detailed evaluation matrix). Each option is then scored against each of the criteria and the score multiplied by the weighting to give a weighted score. The summation of the weighted scores for the options then produces a ranking of the short-listed options.

Both capital and operating costs should be over the agreed time frame. They may be considered separately or combined as a life cycle cost.

3.2.5 Development of Strategies

It should be noted that the screening process is usually carried out on individual technologies and end use as opposed to systems.

Once the preferred technology and management options have been identified, different strategies can be developed that incorporate the various elements of the program (see Figure 2–1) including, for example, a pre-stabilization process (thickening), stabilization, further processing, transport, storage, and distribution.

It is recommended that diversity in the biosolids processes be developed (e.g., composting for a portion and land application of cake for the balance). The strategies should also consider capacity and redundancy.

For instance, if one option becomes unavailable for whatever reason, then does the other have enough capacity? If not, then there will have to be a contingency process in place. In several municipalities, landfill is identified as the final contingency measure.

The final selected strategy should be reviewed against the objectives identified at the start of the process. Any special staff training requirements should be clearly defined, and costs and staff time taken into account.

Finally, an implementation plan and schedule should be developed which would include a definition of project requirements, estimated capital costs, estimated operating costs, timing, contract operations and resources. Consideration should also be given to procurement methods such as design-build, design-build-operate, design-build-own-operate. Include in the biosolids management plan a public communications strategy and be sure to estimate all costs associated with it.

3.2.6 Tips for Successful Planning

Proper planning needs to be done carefully and will consume resources (staff time and money). However, it will help to assure that the program can achieve its objectives while minimizing risk and maximizing public acceptance. The following tips will help to deliver a successful program.

- Implement an effective public participation program as part of the planning and continue with a communication strategy as part of the program.
- Visit facilities with operating examples of equipment, processes, or end uses that are being considered as options.
- Sufficient diversity should be built into the program to ensure the program's success does not hinge on a single product or management method.
- Provide sufficient resources, staff, and finances for the planning process.

Flexibility must be provided not only to cope with changing conditions (such as equipment failure, inclement weather, significant changes in biosolids quality), but also to allow for operational flexibility. Strategically located storage is a prime example of this. This may include storage ahead of thickening or dewatering equipment to allow for optimizing feed rates to equipment, or storage to accommodate long weekends or storage to balance peaks.

3.3 Regulatory Framework

The framework of applicable laws, regulations, and guidelines in the municipal, provincial, or federal jurisdiction is an important consideration in the development and implementation of a biosolids management program. While the promulgation of a regulatory framework is not part of the biosolids management program, a thorough working knowledge of the legislation and guidelines pertaining to biosolids management should be resident within the management staff of the biosolids management program.

Legislation may vary between provinces; however, it is likely that the prevailing legislation and guidelines will pertain to most aspects of the biosolids management program including:

- environmental assessment as part of the planning process;
- monitoring and reporting requirements;
- storage requirements;
- transportation requirements;
- emission criteria;
- design, construction, and operation of biosolids processing and end-use facilities;
- biosolids quality criteria;
- land application rates and site management procedures;
- requirements for documentation;
- contingency planning;
- staff training; and
- quality assurance.

Include in the biosolids management plan a public communications strategy and be sure to estimate all costs associated with it.

Municipal governments that have and enforce source control as part of their wastewater management strategy will be perceived as proactive when the public considers biosolids quality and the potential effect on public health and the environment.

The key element of good practice in regard to compliance is a thorough knowledge and understanding of applicable laws and regulations, including certificates of approval or permits that govern the biosolids program. Resources will be required to obtain and update a library of the applicable legislation and guidelines. In addition, investments, both financial and in terms of management time, will be required to provide for and maintain the training of management and staff.

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. Likewise should there be no applicable guideline, then the owner should consider basing its operations on one of the regulations from a neighbouring jurisdiction.

3.4 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 the biosolids management is crucial, because it directly affects the quality of the final biosolids product in relation to substances, such as heavy metals, priority organic compounds (such as furans and dioxins), and radionuclides. The proper management of the biosolids is vital for the establishment of a sustainable biosolids program over the long term. In the 2003 Survey of Canadian Municipalities ranging in size from less than 1000 to over 1 million, 80 percent reported industrial wastewater dischargers. The most common types of industry were dairy processing, meat processing, other food processing, brewing and beverage, metal finishing, chemical manufacturing, and plastics manufacturing.

Source control programs will also greatly assist in how the public perceives the biosolids program. Municipal governments that have and enforce source control as part of their wastewater management strategy will be perceived as proactive when the public considers biosolids quality and the potential effect on public health and the environment.

Source control is generally accomplished through the enactment, and active enforcement of a sewer use by-law, which establishes the characteristics of wastewaters, which may be discharged to the municipal sanitary sewer or to the wastewater treatment plant facility. Enforcement of the by-law can lead to the need for dischargers to install wastewater pre-treatment systems.

In addition to the sewer use by-law, a program of pollution prevention (or P2) can be initiated within the industrial sector of the municipality. Pollution prevention is aimed at avoiding the creation of wastes at the source by using various methods including material substitution, process modifications, product reformulation, and waste reduction.

Household hazardous waste programs are also helpful in controlling the characteristics of wastewater and the quality of the biosolids. In addition, the public perceives these programs in a positive way.

According to the *National Guide to Sustainable Municipal Infrastructure,* the elements of a best practice for source control program are:

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

3.5 Solids Stabilization

Solids stabilization is a key element of a biosolids management program. Several important benefits may be realized through a properly designed and operated solids stabilization process including volume reduction, pathogen reduction, vector attraction reduction, reduction of odour potential, and production of a uniform biosolids product which meets the requirements for the selected management method.

The EPA has categorized biosolids into two classes: A and B, depending on the type of stabilization process used and the quality of the resulting biosolids product.

For a more complete comparison of the three categories, please refer to Table 2–1.

From Table 3–3, it can be seen that there are two possible stabilization elements. The first is a process that significantly reduces pathogens, and the second reduces pathogens further. The first would result in a Category 3 biosolids and the second in a Category 2 product. To produce Category 1 biosolids, specific pollutants, particularly metals, must meet lower concentration levels.

Several biosolids stabilization processes are in use.

Some stabilization processes may be combined to improve the characteristics of the stabilized product. For example, composting may be applied to either raw (undigested primary solids) or digested solids to achieve the pathogen reductions necessary to have the product meet the pathogen limits for Category 1 or 2. However, digestion before composting provides advantages in terms of reduced odour potential and higher product quality.

When selecting and designing the biosolids stabilization process, it is essential to know the intended management method of the biosolids product in advance. Some processes can produce a marketable product or a material suitable for a variety of beneficial uses, while others may only produce a material that has restrictions on use. Generally speaking, Type 2 processes are more expensive both in capital and operating costs. (Refer to appendixes B and C for additional information on stabilization processes and comparisons.)

Stabilization processes in general need to be sized comfortably, to enable facilities to cope with variations in loadings and system conditions.

Table 3–3: Possible Stabilization Processes

Type 1 Processes to Reduce Pathogens Significantly to Produce Category 3 Biosolids	Type 2 Processes to Further Reduce Pathogens to Produce Category 1 or 2 Biosolids
Anaerobic digestion	Heat drying
Aerobic digestion	Heat treatment
Alkaline stabilization	Thermophilic digestion
Air drying	Alkaline stabilization and heat
Composting at 40°C for 5 days in vessel or outs ide (with one 4-hour period at 55°C)	Composting at 55°C for 3 days in vessel or 15 days outside
	Pasteurization

3.6 Thickening

Thickening and dewatering are important elements of a biosolids management program. Solids thickening reduces the volume before further processing steps. Increased solids concentration before digestion can optimize digester capacity, which could also have a positive effect on volatile solids destruction. However, it should be noted that thickening will produce a concentrated supernatant (or centrate if thickening centrifuges are used), which flows back to the wastewater treatment process and can have a significant impact on its performance.

As in the case of solids stabilization, it is important to determine the end use of the final biosolids product before selecting the thickening technologies, since the choice of technologies can have an impact on downstream processes and, therefore, the final product characteristics.

As part of the thickening process, the addition of polymer is usually required. The choice of conditioning agent, whether it is a polymer or a metal salt, may impact the characteristics of the final product.

Thickening technologies include:

- gravity thickening;
- dissolved air flotation (DAF);
- centrifugation;
- gravity belt thickening (GBT); and
- rotary drum thickening.

3.7 Dewatering

Dewatering is an important process, because it removes a significant quantity of water from the solids and thus greatly reduces volumes for downstream handling and treatment. As is the case with thickening, the expected solids concentration following dewatering may vary with waste activated sludge (WAS) being more difficult to dewater. Dewatering will produce 15 to 40 percent total solids concentrations.

Dewatering processes include:

- belt filter presses;
- centrifuge;
- rotary press;
- recessed plate filter press; and
- other (drying beds, cyclones, screens).

Dewatering of biosolids is usually enhanced by adding conditioning agents such as polymer, which is the most common conditioning process before mechanical dewatering.

3.8 Storage

3.8.1 Overview

Storage for a biosolids program should not be considered merely for the final product but for key unit processes that make up the program. These may include:

- storage upstream of dewatering or thickening processes to provide flexibility or a facility to blend solids streams before further processing;
- storage of biosolids cake or liquid biosolids before haulage;
- permanent bulk storage of biosolids product liquid, cake, or pellets; and
- temporary storage in case of emergency conditions.

In addition to operational flexibility and contingency planning, storage may result in a thickened product, which could reduce further handling and processing costs. Siting of biosolids storage facilities should consider buffer zones and future land use plans.

3.8.2 Regulations and Design Considerations

Some jurisdictions require a minimum amount of solids storage to allow for winter restrictions on some end uses such as agricultural land application. Sizing of the facility will have an environmental assessment component and the storage facility will have to operate in a manner that avoids both public nuisances and impacts on the environment. Storage can take many forms: lagoons, covered or open tanks, or silos. The design should take into account solids volume, solids concentration, potential for odour and facilities for control, stability of the material being stored, and material handling. Facilities should be designed to prevent runoff from the site, and landscaped to screen operations from public view.

3.8.3 Odour Management

Odour generation and management are major concerns at storage sites in proximity to the general public. Improper management of the site and the material being stored can have severe consequences, the most drastic of which is closure of the site.

Consideration must be given both to the potential increase in odours that may result from storage and the containment or mitigation of these odours. The following factors are identified in the National Biosolids Partnership (NBP, 2001) *Manual of Good Practice for Biosolids* as factors that contribute to odour generation:

- the type of conditioning agent;
- high solids centrifuges;
- length of storage period;
- inadequate drainage;
- storage of incompletely stabilized biosolids;
- changes in pH especially for lime stabilized product;
- inadequate housekeeping; and
- rewetting of dried product.

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. However, for lagoons this may be impractical. Options include the use of straw on cake storage lagoons, using flexible membrane covers, or providing larger buffer zones.

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.

3.9 Biosolids Transportation

Transportation of the biosolids is part of many biosolids management programs and is important, particularly from the standpoint of public acceptance of the program. If trucks are dirty or odorous, or if there are spills of material, complaints from the public will result and that could jeopardize the biosolids management program. In addition, the transportation component of the program may be the most costly on a life cycle basis. The key elements of control are public perception, safety, and program costs.

Generally, biosolids are transported in trucks, although in some cases transportation may be accomplished using pipelines, rail cars, or barges. Biosolids may be transported in liquid form, usually less than 10 percent solids, or in dewatered form, usually more than 15 percent solids.

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. For transporting dewatered biosolids, dump trucks, tractor-trailers, and roll-off containers are typically used. These containers 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.

Improper management of the site and the material being stored can have severe consequences, the most drastic of which is closure of the site.

Biosolids can be put to good use by applying on agricultural land, use in silviculture, sale as fertilizer, and use in horticulture.

Costs of owning and operating a fleet of trucks or leasing and operating trucks should be compared to contracting out the transportation requirements. Whichever method is chosen, there should be sufficient flexibility to deal with the unforeseen circumstances – breakdowns, inclement weather, driver sickness, accidents, vacations, labour disputes, and the reliability of the route. Note that in some jurisdictions haulers must be licensed.

Use of trucking 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.

3.10 Biosolids Use/Management

Biosolids can be put to good use by applying on agricultural land, use in silviculture, sale as fertilizer, and use in horticulture. In this context, beneficial use means the use of the nutrient value or the soil conditioning characteristics of the biosolids. Use of biosolids in land reclamation projects, in landfill cover and as a fuel are both forms of beneficial use since some benefits are derived from these methodologies.

Disposal of biosolids means the material is essentially wasted without taking advantage of its nutrient value. Incineration and landfill may be considered as a disposal method, although incineration is generally accompanied by energy recovery in the form of heat. In the case of landfills, there are some landfills, which operate, in a bio-reactive mode, generating methane that can be used for power generation. In this case, careful attention must be paid to leachate capture, handling, and treatment.

Beneficial use of biosolids may, from the public's perspective, be preferable over non-beneficial methods. However, the choice of biosolids end use will depend on many factors specific to the municipality including community size (quantity of biosolids), quality of the biosolids, availability and distance from markets, availability of options, public acceptance of the beneficial use option, and costs.

3.11 Odour Control

Reduction of odour potential at all stages of the biosolids management system is an important consideration since odours are a major source of complaints from the public. Odours can be a key contributor to lowering the public's acceptance of the biosolids management program.

Odour concerns generally arise in the following areas of the biosolids management program: the biosolids processing facility, bulk storage, transportation, and the end use facility. The choice of processes and technologies, and the operation of these facilities will have a significant impact on the associated odour potential. In addition, steps may be taken to reduce the generation of odours, to reduce the emission of odorous compounds to the air, and to reduce odours by treating the odorous gases prior to discharge to the atmosphere.

The use of centrifuges and rotary presses for thickening and dewatering instead of alternative technologies can reduce the generation of odour locally, because they are enclosed. However, recent experience has provided an indication that anaerobically digested biosolids dewatered using high solids centrifuges could be more odorous, and therefore more offensive, during downstream processing and handling. In addition, the choice of conditioning agents (such as polymers) to assist in solids thickening and dewatering can impact odour generation.

For drying, enclosed drying systems will result in less odor emissions than open drying systems.

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.

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.

3.12 Contingency Planning/Emergency Response

A contingency plan and emergency response procedures are an integral part of a well-managed biosolids management program. The development and implementation of these plans and procedures is very important for increasing the public acceptance of the biosolids management program since this type of exercise will 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:

- 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.

No municipality whether large or small, should be without a contingency plan and emergency response procedures for the biosolids management plan. 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.

3.13 Quality Management Programs

The development and implementation of a biosolids management program should be carried out using the principles of a quality management system. All facets of the biosolids management program should be captured within the quality management system. This element of the program, in conjunction with the public participation/communications program, is extremely important in raising the comfort level of the public thereby increasing public acceptance of the biosolids management program.

All facets of the biosolids management program should be captured within the 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. This approach may be brought to bear on each element of the biosolids management program. In each instance, the following steps occur.

1. The element is **planned** (desired results identified and activities planned).
2. Activities are **implemented** to achieve the intended results.
3. Results are **checked** to see if results are achieved.
4. **Action** is taken, based on the verification of the outcome, to improve the program where possible.

Thus, a process of continuous improvement is built into the quality management system.

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.

Whichever delivery method is used, a combination of quality and cost should be used in the selection process.

Another key component of quality management is monitoring and record keeping. Process control parameters need to be monitored as well as product quality parameters. Parameters to be monitored include pH, temperature, chemical usage, solids concentrations, pathogens, concentrations of metals, nutrients, hazardous substances, flow rates, tonnages, volumes, land application rates, and fuel usage, spillage during transportation/application, complaints, etc.

The NBP (National Biosolids Partnership) in the United States has developed an environmental management system (EMS) for biosolids. The program is based on the principle of quality management mentioned above, and its process structure combines the structures of ISO 9001 "Product Quality Management" and ISO 14001 "Environmental Quality Management," plus a mandatory requirement for public consultation and communication. The EMS comprises 17 management elements in five broad areas that must be considered. (These documents may be downloaded from the NBP's Web site <*www.biosolids.policy.net*>.

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. Some of the analytical work can be done by the municipality, but more complex analysis will have to be done by an independent laboratory.

3.14 Program Delivery Options

3.14.1 Available Options

The discussion of the various elements of the biosolids management program presented earlier has been from the standpoint of a program developed and implemented by the municipality. However, there have been numerous cases where biosolids management programs have been successfully delivered by alternate means.

3.14.2 Delivery Guidelines

The following guidelines are recommended when considering alternative project delivery (APD) methods.

- There must be a clear understanding of the reasons for adopting an APD approach. Is it to save money or time?
- Clearly define any particular design, operation, or maintenance requirements in the bid documents, including performance criteria and the methods of testing for these, compliance monitoring protocols, and any specific equipment preferences the owner has.
- Clearly define the risks and responsibilities.
- Whichever delivery method is used, a combination of quality and cost should be used in the selection process. It is strongly recommended that bidders be pre-qualified.
- APD methods are significantly different from traditional project delivery. The risks are different, and careful consideration is necessary when selecting and implementing an APD method. For any APD, especially ones that have a design-build portion, the owner should consider hiring a professional advisor to assist in the development of bid documents, evaluation of bids, design review, and administration of the contract.

3.15 Public Participation/ Communications Program

The public has become more interested and concerned in environmental issues and how these issues can impact their health. Thus, a strong public participation/communications program should be an integral part of any biosolids management program from its conception. It is important that the communications plan 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 while the biosolids management program is being developed. 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.

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.

Stakeholder groups for a biosolids management program with a land application program component could include, but not be limited to:

- residents, businesses, and institutions in the receiving municipalities as well as those affected by transportation;
- residents, businesses, and institutions in the proximity of the biosolids generating facility;
- farmers and farming associations;
- end product users/consumers;
- elected officials, rural and urban;
- generating wastewater treatment plant staff;
- other municipal staff including health officer;
- haulers/contractors;
- biosolids management companies;
- media;
- regulators;
- activist groups;
- schools; and
- taxpayers.

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.

3.15 Public Participation/ Communications Programs

The expected benefits of implementing and maintaining a strong public participation/communications program are to gain wide acceptance of the biosolids management program from the stakeholders, to increase the uptake of biosolids, and to promote the municipal government's environmental protection programs. While there will be costs incurred during the public participation process and for the maintenance of the communications program, these costs should be weighed against the costs of overcoming public opposition. Lack of public acceptance can lead to failure of the preferred biosolids management program, resulting in a potentially significant increase in overall cost.

During the early planning stage of the process, it is important to develop a mission statement for the program, identify communications plan and objectives, identify potential stakeholders, meet with the potential stakeholders, and identify the issues and concerns of each group relating to the proposed biosolids management program. From these initial meetings, the stakeholders who will continue being involved in the public participation process and some of the key issues/concerns can be identified.

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. Each information vehicle is useful at different stages of the public participation/communications process. It is likely that a successful program will make use of several of the methods of distributing information.

4. Applications and Limitations

4.1 Applications

This best practice provides guidance in planning, developing, and implementing a biosolids management program. For more specific information on particular elements of the program, the reader is directed to references.

For municipalities without a formal biosolids program, this best practice provides a template for planning a biosolids program that contains all the elements or only those that are relevant to the municipality. In municipalities where there is an existing biosolids management program or some elements of a program, this best practice may be used to add elements to the existing program or to improve existing elements. It is recommended that the program be reviewed every five years and a full planning exercise done every 15 years or when regulations or other impacting factors change, whichever comes earlier.

4.2 Limitations

There are some issues, which may limit the ability of some municipalities from applying some of the elements and technologies described in Section 3. These issues include:

- municipality population;
- municipality location;
- existing wastewater treatment system;
- existing biosolids management system;
- public opinion/political resistance;
- financial resources; and
- staff resources.

Smaller municipalities will be limited primarily by a lack of financial and staff resources. This challenge can be overcome by forming support groups with neighbouring municipalities who have the same needs. Also, the choice of biosolids processing and management options may be limited due to the characteristics of the existing wastewater treatment and biosolids handling systems. For similar reasons, remote municipalities will have a limited ability to apply many of the processing and end-use options described in this report.

Negative public opinion and political resistance may present significant limitations to a biosolids management program, particularly when the biosolids management program involves transporting biosolids from one municipality to another. The NIMBY (not-in-my-backyard) and NIMTOO (not-in-my-term-of-office) syndrome may arise and present a significant challenge.

The absence of legislative requirements relating to biosolids management may serve as a disincentive to implementing best practices, particularly if municipal governments are already severely limited in financial or human resources.

As society develops more and more products for consumption or use, and the public becomes better educated, there are more questions raised by the public on the potential impacts of various contaminants that can be found or expected in biosolids, for example, the question on the presence of pharmaceuticals, hormones, antibiotics, and other industrial chemicals such as surfactants in biosolids. In addition to supporting ongoing research led by government agencies, universities and professional associations, municipal governments must remain cognizant of such issues in the industry. Supporting research does not have to be limited to providing financial resources to the researchers, it can include providing in-kind supports as well as advocating the need for research to the provincial/federal government.

As society develops more and more products for consumption or use, and the public becomes better educated, there are more questions raised by the public on the potential impacts of various contaminants that can be found or expected in biosolids.

Biosolids program management needs proper attention and, depending on the size of the municipality and the complexity of the program, it may be necessary to devote full time resources including a dedicated program manager. Failure to assign sufficient, properly qualified resources will have a negative impact on the program's success.

Under most legislation, the municipality is considered the "generator" of the biosolids and contracting out part or all the services associated with the program may still not alleviate risks and liabilities that accompany the final use of the product. This is especially complex when it comes to impacts on third parties (e.g., the neighbours of a farmer who uses biosolids). The municipality's best defence is to ensure that the quality of its program and its product are always maintained, as well as to maintain a constant and transparent dialogue with its contractors, regulators and public stakeholders.

This best practice does not provide technical details about each element of the biosolids management program. The reader is referred to the specific references provided in the text for more detail on any element of the program.

4.3 Expected Outcomes

By applying the practices described in this best practice, with due regard to local circumstances, it is expected that municipalities plan, develop, implement, and maintain a viable, sustainable biosolids management program that meets or exceeds the requirements in applicable legislation and guidelines, and can receive a high level of public acceptance. In so doing, the municipality may be expected to realize the following benefits:

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

Appendix A:

Screening and Evaluation

A. Screening and Evaluation

Table A–1
Example of Screening Exercise

Table A–1: Example of Screening Exercise (please note that the indicated scores of methods and technologies are given for this specific example)

Scoring: 1 – Acceptable 0 – Fail

Reference No.	Description	Public acceptance	Health and safety – public	Health and safety – operator/worker	Proven successful performance	Potential for odours	Political support	Regulatory compliance	Applicability to local situation	Total
Biosolids Treatment Technology Alternatives										
1	Mesophilic Anaerobic igestion	1	1	1	1	1	1	1	1	8
2	Thermophilic Anaerobic Digestion	1	1	1	1	1	1	1	0	Fail
3	Staged Mesophilic Digestion	1	1	1	1	1	1	1	1	8
4	Staged Thermophilic Digestion	1	1	1	1	1	1	1	0	Fail
5	Temperature Phased Anaerobic Digestion (TPAD)	1	1	1	1	1	1	1	0	Fail
6	Aerobic Digestion	1	1	1	1	1	1	1	0	Fail
7	Autothermal Thermophilic Aerobic Digestion (ATAD)	1	1	1	1	1	1	1	0	Fail
8	Dual Digestion	1	1	1	1	1	1	1	1	8
9	Alkaline Stabilization	1	1	1	1	1	1	1	1	8
10	Alkaline Stabilization – N-Viro	1	1	1	1	1	1	1	1	8
11	Heat Drying	1	1	1	1	1	1	1	1	8
12	Irradiation	0	1	0	0	1	0	1	1	Fail
13	Pyrolysis (Fuel from Sludge)	1	1	1	0	1	1	1	1	Fail
14	In-Vessel Lime Pasteurization	1	1	1	1	1	1	1	1	8
15	Composting – open	1	1	1	1	1	1	1	1	8
16	Composting – in-vessel	1	1	1	1	1	1	1	1	8
17	Long Term Lagooning	0	1	1	1	0	0	1	0	Fail
18	Seasonal Air Drying	0	1	1	1	0	0	0	0	Fail
Management Options										
1	Land Application	1	1	1	1	1	1	1	1	8
2	Horticulture	1	1	1	1	1	1	1	1	8
3	Parks	1	1	1	1	1	1	1	1	8
4	Silviculture	1	1	1	1	1	1	1	0	Fail
5	Incineration	1	1	1	1	1	1	1	1	8
6	Landfill Cover Amendment	1	1	1	1	1	1	1	1	8
7	Landfill (monofilling of biosolids)	1	1	1	1	1	1	1	1	8
8	Co-disposal with Municipal Solid Waste	1	1	1	1	1	1	1	1	8
9	Land Reclamation	1	1	1	1	1	1	1	1	8
10	Land Farming	1	1	1	1	1	1	1	1	8

A. Screening and Evaluation

Table A–2
Example of a Typical Evaluation Matrix

Table A–2: Example of a Typical Evaluation Matrix

		Health and Safety		Feasibility		Public Acceptance		Proven Successful Performance		Ease of Operation		Ability to Cope with Adverse Conditions		Product Diversity		Storage Constraints		NPV Unit cost/tonne		Timing		Design Complexities		TOTAL
	Weighting		*10*		*9*		*9*		*8*		*7*		*6*		*5*		*5*		*4*		*3*		*3*	
Ref.	**Description**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	**Raw**	**Wgt'd**	
Biosolids Treatment Technology Alternatives																								
1	Mesophilic Digestion																							
2	TPAD																							
3	Heat Drying																							
4	Composting – Open																							
5	Composting In-vessel																							
End Use/Disposal Options																								
1	Land Application																							
2	Horticulture/Parks																							
3	Landfill Cover																							
4	Monofill/Land Farm																							
5	Co-disposal w/MSW																							
6	Land Reclamation																							

Note: The raw scores are those assigned to the particular evaluation criteria for the technology following 'agreed upon' ranking (e.g. 0-5, 0-10, etc). The weighted (Wgt'd) score is the product of the raw score and the "weighting" that has been adapted for the evaluation criteria.

Table A–3: Possible Evaluation Criteria

Criteria	Description
Capital Cost	Relative assessment of capital cost as compared to other alternatives
Operating Cost	Relative assessment of operating costs as compared to other alternatives
Net Present Value	Is a way of comparing the value of money now (cost of investment) with the value of money in the future after taking inflation and return into account
Reliability	Ability to meet treatment objectives
Flexibility	Ability to continue to meet treatment objectives under changing operational and weather conditions: adaptability to changing treatment requirements/objectives
Expandability	How easily can the process be expanded to handle future conditions
Compatibility	With other management processes and practices
Operability/Simplicity	How easy is it to operate; how much operational staff time is required; ease of automation
Maintainability	How easy to maintain; amount of maintenance required; maintenance staff level of technical capability required
Constructability	How easy to construct; impact on other treatment processes during construction
Operational Safety	How safe is it to operate; any special safety training required; any safety implications to surrounding area and neighbors or to community in general
Land Requirements	How much land is required; any special land considerations such as location restrictions, impact of future land use, etc.
Process Experience	Amount of full-scale application experience; confidence that the process will meet the project's requirements
Product Marketability	How marketable is the final product for beneficial reuse
Neighbour Issues	Potential impacts on neighbours due to volume or effects of traffic, potential odours, potential noise pollution, visual impacts, etc.
Public Acceptance	How acceptable any alternative product will be to the public/community in general
Environmental Issues	How any alternative affects air, soil, surface water and groundwater quality

Note: This is a comprehensive list of criteria; use only those necessary for each individual analysis.
Source: Marten (2002).

Table A–3
Possible Evaluation Criteria

Appendix B:
Technology and End-Use Alternatives

Technology and End-Use Alternatives

The following are the basic descriptions of various technologies and end uses. Appendix C contains a summary of these technologies with key advantages and disadvantages.

Technology Alternatives

Mesophilic Anaerobic Digestion
Mesophilic anaerobic digestion is the natural breakdown of organic matter by bacteria in the absence of air and in a digester whose temperature is controlled at 35°C to 38°C. Sludge is continuously or intermittently introduced into the reactor while biosolids, lower in organic and pathogenic content, are also withdrawn continuously or intermittently. Detention time of the sludge usually occurs for 15 to 30 days.

The sludge is biologically degraded in the digester through three stages: hydrolysis, acidogenesis, and methanogenesis. During this last stage, methane gas, a beneficial by-product, is generated and can be converted into heat and/or energy. The treated biosolids can also be dried or dewatered and then used as a nutrient-rich soil conditioner for land application. Mesophilic anaerobic digestion produces a Class B product as defined by EPA 503.

Thermophilic Anaerobic Digestion

Thermophilic anaerobic digestion is the anaerobic digestion of sludge at an induced temperature range between 49°C and 57°C. At this higher temperature range, (thermophilic) digestion occurs much faster than mesophilic digestion as biochemical reaction rates increase with temperature, doubling with every 10°C rise in temperature (Metcalf and Eddy, 2003). The residence time is typically 12 to 14 days.

Besides the advantage of increased biochemical reaction rates, and consequent lower HRT and tankage volume, thermophilic digestion also increases the sludge-processing capability, improves sludge dewatering, and increases bacterial destruction. However, the disadvantages of thermophilic digestion includes higher energy requirements to maintain the temperature necessary for heating, poor quality of supernatant which contains larger quantities of dissolved solids, increased odour potential, and less process stability.

Thermophilic digestion can produce a Class A product but not consistently. For consistent Class A pathogen reduction, a two-stage process is required to minimize the potential for short circuiting that can occur in a single mixed vessel.

Dual Digestion (two-stage aerobic-anaerobic)

Dual digestion consists of two stages, the first is an aerobic reactor followed by an anaerobic reactor. The aerobic reactor is fed with oxygen instead of air, thus producing an exothermic bioreactor. The sludge is naturally heated by the oxidation of the volatile solids, and no additional heat is required when the sludge is directed into the anaerobic reactor, which operates at mesophilic temperatures.

Dual digestion requires smaller anaerobic digesters and eliminates the need for an external heat source. However, the disadvantages of dual digestion include odour problems in the aerobic stage, foaming in the aerobic and anaerobic stages, and the temperature of sludge entering anaerobic reactor must be closely monitored.

Staged Mesophilic

Staged mesophilic is a multistage anaerobic digestion process at mesophilic temperatures. Both stages are heated and mixed, providing a sufficient SRT in the first reactor for methane production. The staged mesophilic digestion generates lower offensive odours and the biosolids produced seem to be slightly easier to dewater.

Staged Thermophilic

Staged thermophilic digestion is a multistage anaerobic digestion at thermophilic temperatures. Unlike staged mesophilic digestion, all reactors in the staged thermophilic anaerobic digestion operate as methane reactors (to eliminate short-circuiting). The flow from reactors is continuous flow, not batch flow.

Temperature Phased Anaerobic Digestion (TPAD)

Temperature phased anaerobic digestion (TPAD) is a two-staged reactor system, patented by Iowa State University. The first reactor operates at thermophilic temperatures and the second reactor operates in the mesophilic temperature. By using this two-staged system, the shortfalls of the individual technologies when operated alone are eliminated while the advantages of both systems are realized.

The thermophilic anaerobic digestion alone can achieve higher volatile solids and pathogen destruction, with little foaming, but the process offers poor process stability and can produce offensive odours and poor dewaterability. Mesophilic anaerobic digestion alone on the other hand, cannot produce Class A solids without advanced digestion, is less effective with volatile solids reduction, and foaming occurs often.

Heat Drying

Heat drying is mechanical drying partially using the heat of wet sludge. This generates a dried biosolid product such as pellets. Solids concentration of the dried product can be 90 to 95 percent. Mechanical processes that have been used for drying sludge include flash dryers, spray dryers, rotary dryers, multiple-hearth dryers, fluid-bed dryers, and multiple-effect evaporation. Burners and autonomous recycling can also be used.

Composting

Composting is a process used to put organic material through a biological degradation process to generate a stable end product. Temperatures of 50°C to 70°C are reached as a consequence of bacteriologic activities during this process. Three types of micro-organisms are mainly responsible for the degradation of the organic material: bacteria, actinomycetes, and fungi. The process is very reliable depending on operating conditions.

Historically, biosolids have been directly applied to agricultural land as a soil amendment on a seasonal basis and/or delivered to private operators for use as compost feedstock. Composting is a preferred method of recycling biosolids, because the finished product quality is high, finished material handling risks are low, seasonal storage logistics are reduced, and a marketing value can be realized. Storage and handling of digested or lime-stabilized and otherwise uncomposted biosolids involves odour problems.

In-Vessel Composting

In-vessel composting is composting within an enclosed container or vessel. The benefits of this are easier process and odour control, faster throughput, lower labour costs, and smaller land area requirements. In-vessel composting is typically a plug flow or dynamic (agitated bed) system. The initial carbon to nitrogen (C:N) ratio should be from 25:1 to 35:1 by weight. Mixing and turning of the material is carried out on a regular basis to prevent drying, caking, and air channelling. The composting time normally lasts for 10 to 21 days followed by a 12 to 16-week unaerated curing period.

Open Composting

Compost is naturally heated and under this pasteurizing effect enteric pathogenic organisms are destroyed. Most composting operations will consist of the following steps:

- mixing dewatered sludge with an amendment and /or bulking agent (usually wood chips, straw, or sawdust);
- aerating the compost pile either by the addition of air or by mechanical turning, or both;
- recovery of the bulking agent (if practical);
- further curing and storage; and
- final end use.

The open composting consists of a mixture of biosolids, bulking agents, and finished compost to achieve solids content of 40 to 50 percent, which improves the structural integrity of the mixture. The main objection to open composting is the offensive odours usually generated. Precipitation also creates difficulties with the operation by slowing down the degradation process of organics due to excessive moisture and evaporative cooling.

Generally, there are two types of open composting: aerated static pile and windrow composts. Aerated static pile is a mixture of dewatered sludge and bulking agent, which has been placed over exhaust piping or a grid of aeration pipes. The material is usually left to compost for 21 to 28 days and then is typically cured for another 30 days. A layer of screened compost is usually placed on top of the compost for insulation. Aerated static piles are not mixed.

Windrow composting consists of long parallel piles called windrows, which are turned/mixed periodically during the compost period. During this turning operation, odours are generated. Compost time ranges from three to four weeks up to several months before the compost is cured. Curing time depends on the stability required for the end use of the compost.

Pyrolysis

Pyrolysis is the splitting of organic substances into gaseous, liquid, and solid fractions in an oxygen-free atmosphere. The resulting components of this process are a gas stream (primarily hydrogen, methane, carbon monoxide, and various other gases depending on the material pyrolyzed), a tar and/or oil stream (liquid at room temperature containing chemicals, such as acetic acid, acetone, and methanol), and a solid stream (a char consisting of almost pure carbon plus inert material that may have entered the process).

Management Options

Land Application (Agricultural)

Biosolids applied to agricultural land, at the recommended loading rates, can be of great benefit to the land. Biosolids act as a soil conditioner to transport nutrients, increase water retention, and improve soil fibre.

Sunlight, soil micro-organisms, and dryness are factors that continue to treat biosolids once applied. However, biosolids can only be applied when the weather and soil conditions permit. Biosolids cannot be applied in wet weather or when the soil is waterlogged, due to the risk of runoffs which will contaminate nearby surface waters, and due to limitations of the spreading equipment.

Horticulture/Parks

Biosolids have been used to enhance the growth of sod or topsoil in the past. Biosolids intended for this use are in the dried (e.g., pellets) or composted form and must have a higher degree of pathogen kill.

Application of composted biosolids to parkland has been implemented in Ontario in the past. End users in pursuit of this beneficial product are the golf course/driving range facilities, landscaping industries, and sod farms.

Landfill Cover Amendment

In this strategy, biosolids are used for landfill cover. A layer of biosolids is applied over the municipal solid waste to reduce odours, prevent unwanted animals and minimize litter. The addition of biosolids to landfill cover will enhance vegetative growth and sustain it for longer than if biosolids are not used.

This method of biosolids disposal management has gained popularity but requires highly stabilized biosolids due to potential leachate problems.

Landfill (monofilling of biosolids)

Monofilling of biosolids is depositing biosolids in a landfill, usually in trenches. The recommended solids content of biosolids for narrow trenches is 15 to 30 percent so solids can be spread evenly. Wide trenches, greater than three metres wide, are required for biosolids with solids content of 30 percent or more.

Co-Disposal with Municipal Solid Waste

This management method involves spreading biosolids in a layer, which is then immediately blended into the municipal solid waste. This has become the most prevalent landfilling method of biosolids management in Canada. However, this method eliminates the beneficial use of biosolids and must be carefully controlled.

Land Reclamation

Land reclamation is the restoration of infertile or deserted land by establishing a vegetative cover. Land reclamation projects using biosolids have been very successful, including places such as strip-mined areas, mine refuse piles, sand and gravel pits, hazardous waste sites, closed landfills, urban renewal areas, areas disturbed by construction activities, arid lands, and dredge spoil sites.

Biosolids have been especially beneficial in reclamation projects, because of the conditioning properties of biosolids. In some mine reclamations, biosolids were used after conventional methods had failed to establish sufficient vegetative cover.

Appendix C:
Comparison of Technologies and End-Uses

Table C–1: Treatment Technologies Comparisons

Technology	Possible End Uses	Advantages	Disadvantages/Concerns
Mesophilic Anaerobic Digestion	Land application	Established treatment process Energy recovery Reduces total solids mass Yields solid residue Class B product for soil conditioning Conforms to existing facilities and staff familiarity	Medium construction and operating costs Process susceptible to upset Does not produce Class A product without pasteurization or advanced digestion Requires digester gas safety equipment
Thermophilic Anaerobic Digestion (and other related advanced digestion processes)	Land application	Enhances dewaterability Improved energy recovery Reduces total solids mass Leads to pathogen free product for Class A product provided other criteria met	Structural capacity of existing digesters – high construction cost for reinforcement or new tanks Higher NH_3 recycle Requires moderate additional heat input Odour potential
Dual Digestion (aerobic followed by anaerobic)	Land application	Some energy recovery Rapid start-up Can lead to Class A product Compatible with oxygen-activated sludge sewage treatment process	Odour control required Oxygen required for thermophilic aerobic conditions Possible sensitivity to toxins Large plant experience limited Batch mode required to produce Class A sludge Other potential unknowns
Staged Mesophilic	Land application	Solids easier to dewater Reduced odours compared to single stage Energy recovery Class B product	Both digesters to be mixed and heated Operations more complex and expensive than present Minimal improvement in volatile solids reduction (odour potential)
Staged Thermophilic	Land application	Class A product potential Improved solids reduction over single stage	Structural capacity of existing digesters – high construction cost for reinforcement or new tanks Higher NH_3 recycle Requires moderate additional heat input Odour potential
Temperature Phased Anaerobic Digestion (TPAD – thermophilic followed by mesophilic)	Land application	Operates well with wide variety of retention times 15% to 20% improvement over single stage digestion in volatile suspended solids (VSS) destruction Can produce Class A	Patented process Structural capacity of existing digesters – high construction cost for reinforcement or new tanks More complex design and operation Low SRTs could raise volatile acid levels affecting final product quality
Autothermal Aerobic Digestion (ATAD)	Land application	Small footprint Can lead to Class A product	Production of excess foam and unacceptable odours

C. Comparison of Technologies and End-Uses

Table C–1
Treatment Technologies Comparisons

Table C–1: Treatment Technologies Comparisons *Continued*

Technology	Possible End Uses	Advantages	Disadvantages/Concerns
Heat Drying	Agriculture Horticulture Land application	Class A, pathogen-free product Greatly reduces solids mass Can be stored if kept dry Can be used as a component in fertilizer Little odour associated with final product Easier to apply Usually good markets for product	High construction cost High operation and maintenance costs No legislative experience with this product as a fertilizer Volatile solids not reduced Must be stored and distributed dry Potential safety concerns (fire) May require significant odour control at processing facility
Composting – Open	Agriculture Horticulture Home gardens Land reclamation Bulk and packaged products	Class A product if operated properly Low construction costs Product is marketable Can be used in combination with other municipal solid waste (MSW) organic waste resource recovery options static pile and windrow options	High operation and maintenance costs Processing is weather-dependent unless covered/heated Processing odour concerns Significant land requirements Potential for pathogen regrowth if temperatures not maintained or achieved
Composting In-vessel	Agriculture Horticulture Home gardens Land reclamation Bulk and packaged products	Class A product if operated properly High quality end product Decreased land requirements and odour problems compared to open composting	High construction cost High O&M costs Limited process flexibility Odour control required but is manageable Few proven working examples available
Pyrolisis – Gasification	Fuel production – gas or oil Aggregate amendments from ash	Marketable end products Potentially no residues for disposal Year round operation – no seasonal impacts Products fit in non-agricultural use. There are not nutrients (EPA or other classification not available)	Few proven operating plants Could involve significant design complexities and costs Operators unfamiliar with process If used on raw sludge, ancillary process systems will become obsolete Need to balance loss of methane-generated heat with heat potential of fuel product.

Table C–2: End Use Options Comparisons

End Uses	Products	Advantages	Disadvantages/Concerns
Land application on agricultural land	Liquid digested biosolids Dewatered cake Dried biosolids Composted biosolids	Beneficial use Good for farmers (approx $100 to $150 savings per acre)	Cost of transporting Public concerns Requires pathogen-free material for some uses
Agriculture Horticulture – parks, sod farms, nurseries commercial/residential gardens	Dried biosolids Composted biosolids	Beneficial use If pellets or compost used, can generate revenue as fertilizer/soil amendment Can be marketed/sold/delivered in bulk or packaged blended with other soil amendments e.g. bark, wood chips, peat	Legislative controls may not be in place Production costs Requires pathogen-free material for some uses Marketing stigma if biosoloids only
Landfill Cover – daily, intermediate, final, and buffer areas	Dewatered cake Partially dried biosolids	Beneficial use Improved vegetative restoration of site	Processing still required Cost of transporting Other materials could be available at lower cost
Landfill	Dewatered cake Partially dried biosolids	Less public issues Low cost alternative Short custody time	Not re-use Consumes landfill space Operational difficulties
Co-disposal in landfill (with municipal solid waste)	Dewatered cake Partially dried biosolids	Reduced operational difficulties Potential for improved landfill gas generation and recovery	Not re-use Consumes landfill space
Land Reclamation	Dewatered cake Dried biosolids Composted biosolids	Beneficial use Recovers/improves otherwise unusable/unsightly land	Transportation Public concerns

Appendix D:
Useful Website Addresses

The Web site addresses for each province's guidelines are listed below.

British Columbia
<http://wlapwww.gov.bc.ca/epd/epdpa/mpp/omrreg.html#guidance>

Saskatchewan
<http://www.se.gov.sk.ca/environment/protection/land/guidelanddisposal.htm>

New Brunswick
<http://www.gnb.ca/0009/index-e.asp>

Nova Scotia
<http://www.gov.ns.ca/enla/>

Ontario
<http://www.ene.gov.on.ca/envision/land/nutrient_management.htm>

Quebec
<http://www.bnq.qc.ca>
<http://www.menv.gouv.qc.ca/matieres/mat_res-en/fertilisantes/index.htm>
<http://www.menv.gouv.qc.ca/matieres/mat_res/fertilisantes/index.htm>

Alberta
<http://www3.gov.ab.ca/env/info/infocentre/PubDtl.cfm?id=1616>

Prince Edward Island
<http://www.gov.pe.ca/af/agweb/library/documents/manureguide/index.php3>

Newfoundland and Labrador
<http://public.gov.nf.ca/agric/>

Manitoba
<http://www.gov.mb.ca/agriculture/soilwater/index.html#manure>

D. Useful Website Addresses

Other useful websites are listed below.

The Canadian Water and Wastewater Association
<https://www.cwwa.ca/e_index.htm>

Water Environment Research Foundation
<https://www.werf.org/>

Water Environment Federation
<https://www.wef.org/>

Water Environment Assoication of Ontario
<https://www.weao.org/>

National Biosolids Partnership, USA
<https://www.biosolids.policy.net/>

European Union Commission on Environment
<https://europa.eu.int/comm/environment/waste/sludge/index.htm>

Northeastern Biosolids and Residual Association, USA
<https://www.nebiosolids.org/>

CAST, a non-profit organization sponsored by the National Academy of Sciences, National Research Council, USA
<https://www.cast-science.org/cast/src/cast_top.htm>

Agriculture, Agri-Food Canada
<https://res2.agr.ca/initiatives/manurenet/manurenet_en.html>

Northwest Biosolids Association
<https://www.nwbiosolids.org>

Canadian Food Inspection Agency
<https://www.inspection.gc.ca/english/toce.shtml>

Agriculture and Agri-Food Canada
<https://www.agr.gc.ca/index_e.phtml>

Ontario Ministry of Environment (MOE)
<https://www.ene.gov.on.ca>

Ontario Ministry of Agriculture and Food (OMAF)
<https://www.omafra.gov.on.ca>

Ontario Government
<https://192.75.156.68:81\>

City of Ottawa
<https://ottawa.ca/index_en.html>

US EPA, Office of Water
<https://www.epa.gov/waterscience/biosolids>

Kansas Department of Agriculture
<https://www.accesskansas.org/kda/Nutrientmanagement/nutrient-mainpage.htm>

State of Ohio
<https://www.epa.state.oh.us/dsw/rules/final_sludge.html>

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