Sewage Sludge Management Plan City of Iqaluit

Draft Planning Report

Prepared for:
City Hall
City of Iqaluit
P.O. Box 460
Arnaituq Arena
Building 901
Iqaluit, Nunavut, X0A 0H0

Prepared by:
Earth Tech Canada Inc.
17203-103rd Avenue,
Edmonton, Alberta, T5S 1J4
(780) 488-6800

December 13, 2005

Earth Tech Canada Inc. 3rd Floor, GoGa Cho Building, 4916 – 47 Street, P.O. Box 1259, Yellowknife, NT X1A 2N9

December 13, 2005

Refer to File: 86905.0002

L:\work\86000\86905\03-Report\Planning Report\051211 Cover Letter.doc

City of Iqaluit
P.O. Box 460
Iqaluit, Nunavut X0A 0H0
Attention: Mr. Geoff Baker
Capital Projects Officer

Dear Mr. Baker:

Re: City of Iqaluit Sewage Sludge Management Plan – Draft Planning Report

Telephone 867.873.6316
Facsimile 867.873.6407

Earth Tech Canada Inc. is pleased to submit twenty (20) copies of a Draft Planning Report for the Iqaluit Sewage Sludge Management Plan. We recommend that the copies be distributed to all of the Stakeholders that were advised of this project back in July.

The report presents comprehensive information on regulations, and technologies for sludge management, as well as a decision analysis of the technologies for their potential application to Iqaluit.

Based upon the decision analysis we have developed a shortlist of technologies, and a proposed implementation plan for the appropriate shortlisted technologies. The implementation plan is based upon an environmental planning evaluation of the community, and discussions with the landfill operating staff.

Our next step in the project will be to encourage feedback from the Stakeholders, and begin the preliminary engineering process, so that we are prepared for the sludge when the wastewater treatment plant is commissioned at the end of January. A funding application to the Federal Government should also be initiated in order to take advantage of any grants that may be available.

If you have any questions please do not hesitate to contact the undersigned at (780) 453-0910.

Sincerely,

EARTH TECH (CANADA) INC.
Per:

Ken Johnson, M.A.Sc., P.Eng.
Project Manager
Encl.

Table of Contents

Table of Contents

List of Tables

List of Figures

1 - INTRODUCTION

1.1 BACKGROUND

Since the application of modern sewage treatment technologies in the past 75 years, the municipal sewage sludge has been an inherent part of the overall waste management practices. The municipal sewage sludge was traditionally considered a waste product, and disposed of like any other waste, in a dump of some sort, or even in the ocean. The high nutrient characteristics in sewage sludge were ultimately identified, and over the past 30 years sewage sludge has been legally marketed to farmers who ploughed it into soil as a fertilizer additive. There was a dramatic increase in this practice since 1990, and this prompted governments to put in place standards to regulate the beneficial use of sewage sludge.

The United States (US) Environmental Protection Agency (EPA) Title 40, Code of Federal Regulations, "Biosolids Rule" governs the use or disposal of municipal sewage sludge or "sewage biosolids" in the United States of America. Since the implementation of this regulation in 1993, the disposal of untreated sewage sludge on agriculture lands or in landfills has been discouraged. Most municipalities in Canada have also recognized that the sewage sludge presents a treatment and disposal challenges and it needs to protect the public health and the environment.

However, in the Canadian north, the municipal sewage sludge has been virtually ignored because of the predominance of lagoon wastewater treatment systems. In a lagoon system, sewage sludge essentially becomes part of the lagoon itself as it settled to the bottom. Only when the performance of a lagoon starts to decrease substantially then the sludge removal is deemed necessary.

The application of mechanical sewage treatment systems in the Northwest Territories and Nunavut over the past 15 years (Fort Simpson in about 1990) has brought forward a demand for sewage sludge handling, and disposal. Landfilling of sewage sludge has been a "tried and true" technology with limited requirements for planning, engineering and regulation, however regulatory demands have been increasing and sludge management is a necessary part of any new sewage treatment system.

1.2 PROJECT SCOPE

In 2003, Earth Tech (Canada) Inc. was retained by the City of Iqaluit to undertake the design of improvements/upgrades to the existing non-commissioned Waste Water Treatment Plant (WWTP). The initial facility was constructed as a membrane treatment facility, however this facility was never commissioned. The facility upgrading consists of converting the membrane facility to a conventional secondary treatment facility (activated sludge).

1 - INTRODUCTION

It is the intent to upgrade the WWTP in three phases, with a first phase of construction to be completed in the spring of 2006. The first phase will provide primary treatment; the second phase will provide secondary treatment; and the third phase will provide an increase in overall capacity.

As part of the overall waste management planning, the City of Iqaluit is required to complete and implement a sludge management plan for the residual waste stream. Phase 1 of the treatment improvements will produce screenings, grit, and primary sludge.

The City of Iqaluit engaged Earth Tech (Canada) to complete a Planning Study for a Sewage Sludge Management (SSM) Plan to serve this new waste stream. The City of Iqaluit has stated that their project goals are:

1. To develop a sludge management program to deal with screenings, grit and sludge generated at the WWTP.

2. To complete preliminary design, Class D cost estimates, yearly operations, and maintenance estimate for the facility required for the management of the sewage sludge from the WWTP.

The three key elements in the development of a sewage sludge management (SSM) plan are:

1. the identification and the decision analysis of technologies (options) for SSM,

2. an evaluation of the potential siting of recommended SSM option, and

3. the consultation with the regulators and the stakeholders.

This planning report is intended to identify all of the feasible options with the intent of leaving "no stone left unturned" and these options are to be brought forward by the City for stakeholder scrutiny. The feasible options are then be systematically analysed, and presented in a manner that clearly identifies the most appropriate option for the sewage sludge management. Equally important is a site for the selected option; appropriate selection of the site may ultimately influence the success of the project. Land use issues such as regulated and non-regulated setbacks between adjacent land uses, and community planning and zoning bylaws are significant elements to consider.

The consultation with both the regulators and the public will ultimately determine the acceptance of any sewage sludge management option. This acceptance will include the land use and environmental considerations.

1.3 CITY OF IQALUIT

1.3.1 Location

Iqaluit is the largest community and the capital city of Nunavut, located in the southeast part of the Baffin Island, near the mouth of the Sylvia Grinnell River, at 63° 44′ N latitude and 68° 31′ W longitude. Iqaluit is 2275 kilometres east of Yellowknife and 2,087 kilometres north of the Ottawa   Located at the head of Frobisher Bay, this community was established in 1949 as *Frobisher Bay*, when the Hudson's Bay Company moved its post here from a site 70 kilometres southeast. It became a municipal hamlet in 1971 and a City in 2001 (the only City in Nunavut). The land area of the municipal boundary is 52.34 square kilometres.

Iqaluit's major economic activity is government of Nunavut and Government of Canada offices. Other economic activity includes social institutions, educational institutions, a hospital, stores, and tourism.

According to the "2001 Community Profiles" by Statistics Canada, the demographic information for Iqaluit was:

- Aboriginal identity population: 3,065
- Total population: 5,236

The Government of Nunavut population projection for Iqaluit is 5,606 in the year 2005 and 6,477 in the year 2010.

1.3.2 Area Geology, Terrain, Vegetation, and Climate

Iqaluit's location is above the tree line and within the continuous permafrost zone of Canada. The terrain surrounding Iqaluit is "rolling", and the region generally consists of glacially scoured igneous/metamorphic terrain. The subsoil is made up of glacial drift over granitic Precambrian bedrock. The overburden consists of silty-sand, sand, gravel and boulders which varies in depth up to 18 meters. In some locations, a thin layer of organic material is found. Iqaluit experiences 8 months of the year in which the average daily temperature is below freezing, on an average. Iqaluit has an Arctic climate with January high and low temperatures of -21.5 °C and -29.7 °C, respectively and July high and low mean temperatures 11.4 °C and 3.7 °C, respectively. The annual precipitation is made up of 19.2 cm of rainfall and 25.5 cm of snowfall for a total of 43.0 cm precipitation. The prevailing winds are northwest at 16.7 km/hr.

2 - EXISTING REGULATIONS FOR SEWAGE SLUDGE MANAGEMENT

2.1 Sewage Sludge Management (SSM) Regulations

The framework of applicable laws, regulations, guidelines and standards in the municipal, provincial, or federal jurisdiction is an important consideration in the development and implementation of a SSM plan. While the dissemination of a regulatory framework is not part of the SSM plan, a working knowledge of the legislation, and guidelines pertaining to SSM should be part of the knowledge base for the SSM plan management staff.

2.2 United States Regulations for SSM

The most important SSM Regulation in from the United Stated of America (USA) is the EPA (Title 40, Code of Federal Regulations; 40 CFR), Part 503, "Biosolids Rule" (1993). The Biosolids Rule, governs the use, and the disposal of municipal sewage sludge in the USA. The requirements of the "Standards for the Use or Disposal of Sewage Sludge" within the Biosolids Rule are based on results of a comprehensive multimedia risk assessment that began in the mid-1970's.

The "Biosolids Rule" spells out specific management practices, numerical criteria, monitoring frequencies, record keeping, and reporting requirements for three major use and disposal options, which are land application, incineration, and surface disposal. All of the protocols were intended to protect the public health and the environment. The Rule limits where and when biosolids may be applied, requires processes to kill pathogens, limits amounts of metals that can be applied to any piece of land, and restricts public access to sites with sewage sludge.

The US EPA established a Class A and a Class B identification for the sewage sludge. These classes are based upon the sewage treatment process, which will define the level of pathogenic (disease causing) organisms and the reduction in the "vector attraction potential" (disease-carrying animals and insects such as flies, rodents, and birds). These biosolids classes also dictate the application requirements of the sewage sludge, such as buffer requirements, crop harvesting restrictions, and public access to the sewage or biosolids application site.

"Class A" sludge contains low levels of metals, no detectible levels of pathogens, and do not attract vectors. There are no requirements regarding buffer zones, crop type, crop harvesting, and site access if used in small quantities by the general public. When used in bulk, Class A sludge is subject to buffer requirements, but not to crop harvesting restrictions. Technologies that can meet the US EPA Class A standards include thermal treatment methods like composting, heat drying, heat treatment, thermophilic (heat generating) aerobic digestion, and pasteurization. Class A technologies, known as PFRP (Processes that can Further Reduce Pathogens), must process the sludge for a specific length of time at a specific temperature. Class A sludge may then be distributed to public for unrestricted or limited restricted application to farms, lawns, gardens, golf courses, etc.

"Class B" sludge is treated, but can contain compliant amounts of pathogens. Class B requirements make sure that pathogens in the sludge have been reduced to levels that protect public health and the environment. This sludge is subject to buffer requirements, public access, and crop harvesting restrictions. The treatment technologies that can meet the US EPA Class B standards include anaerobic digestion, aerobic digestion, composting, air-drying, and lime stabilization. Class B technologies, known as PSRP (Processes that can Significantly Reduce Pathogens), must process the biosolids under certain operating conditions (length of time and temperature). Class B sludge may then be distributed to public for restricted application to farms, landfills, and forests.

The terms Class A and Class B sludge are standard phrases that have gained general use internationally.

2.3 Canadian Regulations for SSM

In November 2003, the Canadian Council of Ministers of the Environment (CCME), which is comprised of 14 federal, provincial and territorial member jurisdictions, agreed to pursue the development of a Canada-wide Strategy for Municipal Wastewater Effluent (MWWE), with the outcome of a harmonized (one-window) management approach for MWWE across Canada by November 2006. The MWWE Strategy will address a number of governance and technical issues resulting in a harmonized management approach.

Regarding the issue of sewage sludge, the Development Committee of the CCME will prepare a proposal to develop a strategy for environmental risk management of the municipal sewage sludge. Wherever possible, opportunities to link the Canadian Environmental Protection Act (CEPA) 1999, and the Fisheries Act with development of the Canada-wide Strategy will be undertaken.

At this time there is no regulation under the Fisheries Act applicable to the release of effluents from municipal wastewater systems, although these systems are recognized as a significant source of harmful substances in the environment.

It is envisioned that the outcome of the process will be effective environmental protection through a harmonized management regime that will be fair, consistent and predictable. <u>Currently, treated sewage sludges, for the most part, are provincially regulated in Canada.</u>

2.3.1 Alberta Regulations

In Alberta, under the "Environmental Protection and Enhancement Act" (1993) (EPEA), Alberta Environment has the responsibility for waste management facilities dedicated to handling and disposing of non-hazardous waste including municipal sewage sludge. The Code of Practice for Compost Facilities, and the General Standards for Landfills, outlines minimum requirements for the design, construction, operation, and monitoring of landfills that accept 10,000 tonnes or less per year of non-hazardous and inert waste or a compost facility accepting 20,000 tonnes or less per year of mixed organic material.

Alberta Environment only requires notification with respect to compost facilities, which process only vegetative matter and/or manure. The responsibility for reviewing applications and monitoring waste facilities is managed regionally, with approvals and registrations being authorized by the Regional Directors of the Alberta Environment. The disposal of sewage sludge by incineration is regulated under the "Guidelines for Design and Operation of Refuse Incinerators in Alberta."

2.3.2 Ontario Regulations

In Ontario, sewage sludge is regulated under Ontario's Environmental Protection Act. The 1996 "Guidelines for the Utilization of Biosolids (Sludge) and Other Wastes on Agricultural Land," were developed by the Ontario Ministry of Environment (MOE), and others, and are used by the Ontario MOE to assist them in issuing Certificates of Approval to municipalities or contractors for "organic soil conditioning site". Certificates of Approval are required for all land application sites, and include explicit management conditions that are enforceable by the Province under the Environmental Protection Act. Sludge that is sold as a fertilizer may fall under the Agriculture and Agri-food Canada (AAFC).

In the wake of the tragedy in Walkerton in May 2000, the provincial government committed itself to province-wide nutrient management standards. The 2002 "Ontario Nutrient Management Act" came into force in July 2003, and included a province-wide ban on the land application of untreated septage, to be phased in over 5 years. The Act also states a ban of sewage sludge application on snow-covered or frozen soils. The General Regulation under the Nutrient Management Act sets out specific details of the legal requirements for the handling, storage, and land application of "non-agricultural materials" (nutrient-rich materials not from animal sources) including sewage sludge. The generators of these non-agricultural materials, such as municipalities, are required to have a nutrient management strategy in place by 2008.

The management of composting with due regard to process conditions and characteristics, to prevent contamination of the environment, is controlled by the 2004 "Interim Guidelines for the Production and Use of Aerobic Compost in Ontario." This document includes discussion of generic composting technologies, major operating parameters, sampling and chemical analyses, monitoring of processes, reporting of results, and assessment of potential off-site impacts.

2.3.3 Nova Scotia Regulations

In Nova Scotia, the use/disposal of sewage sludge is regulated by the "Guidelines for Land Application and Storage of Biosolids in Nova Scotia" (2004) under the "Environment Act." These guidelines provide site selection criteria such as soil requirements, separation distances to protect public health and water quality, land slope, depth to groundwater, and land use restrictions. These guidelines also require nutrient and land management plans including sampling, record keeping, monitoring, and reporting of all the activities.

According to these guidelines, only stabilized biosolids can be applied to land. Biosolids acceptable for land application and/or storage falls into one of three categories, depending on the metal and pathogen content: EQ, Class A, or Class B. There are no restrictions for land application of EQ biosolids or biosolids, regulated by the Canadian Food Inspection Agency (CFIA) under the Canadian Fertilizer Act, and no Approval is required. However, the land application of either Class A or Class B biosolids requires an Approval, and restrictions pertaining to the use of these products will apply. For both Class A and Class B biosolids, land application is not permitted when the ground is frozen, snow covered, or saturated. The acceptable stabilization methods to the Department of Nova Scotia Environment and Labour are: composting, aerobic digestion, anaerobic digestion, alkaline/lime stabilization, heat drying, heat treatment, and pasteurization.

2.3.4 Other Provincial Regulations

The other provincial jurisdictions have similar regulations developed by environment departments to protect the environment and human health from adverse effects. The stipulations generally include acceptable methods of stabilization, suitability of the land as well as application rates, separation distances, and waiting periods between the application of the biosolids and various uses of the land. The stipulations may also include handling and follow-up requirements related to transportation, storage, and record keeping.

2.3.5 Northern Territories Regulations

All of the northern territories (Yukon, Northwest Territories, and Nunavut) have legislation in place for the regulation and enforcement of waste disposal into water. The administration of the legislation is covered by regional water boards consisting of local representatives; the water boards are supported by technical resources at either the Federal or Territorial level that "audit" the facilities for compliance with individual community water licenses. In addition to the Territorial legislation, Federal legislation such as the Fisheries Act may be applied to each and every facility. None of the territories have explicit legislation applying to the treatment or disposal of sewage sludge. Under the current water license administrative framework, sewage sludge may be considered as "solid waste", and the disposal management may be considered similar to municipal solid waste.

2.4 Summary of SSM Regulations in the Context of Iqaluit's SSM Plan

The discussion on SSM Regulations in the previous sections identifies that the existing regime for the management of sewage sludge (biosolids) in Canada includes a number of Acts, Regulations, Guidelines, and Standards administered by federal, provincial, and territorial governments. In addition, certain municipalities administer sewer use by-laws that control the disposal of specific substances at the source. In the context of Iqaluit's SSM Plan, though the SSM Legislation may vary between provinces/territories; however, it is likely that the prevailing legislation and guidelines will pertain to most aspects of the Iqaluit's SSM Plan including:

- design, construction and operation of sewage sludge processing and end-use facilities;
- sewage sludge quality criteria
- sewage sludge transportation requirements
- sewage sludge site management procedures
- environmental assessment as part of the planning process
- monitoring and reporting requirements
- contingency planning
- staff training

In order for the City of Iqaluit to properly implement any form of sludge management, an appropriate regulatory stakeholder dialogue must be implemented and maintained.

3 – STAKEHOLDER DIALOGUE

3.1 Stakeholder Dialogue Process

The stakeholder dialogue process for the Iqaluit SSM Plan is intended to be a collaborative process involving the City of Iqaluit, and all community and regulatory stakeholders, including potential users of treated sewage sludge. Including the public as a partner, in any program such as this, builds trust and contributes to the program's success. It is the intent of the process to provide all stakeholders with the information about the SSM Plan to achieve the following objectives:

- promoting public knowledge regarding the Plan benefits
- moving public from typical reactive response to an informed response about SSM
- building sense of confidence about public health and environmental protection
- earning public trust and public respect

3.2 Identification of Stakeholders

The management of sewage sludge in the City of Iqaluit has many potential stakeholders, ranging from the regulatory authorities to the public interest groups. The following stakeholders are identified after consultation with the City administration:

Regulatory Stakeholders

- Nunavut Water Board (NWB)
- Indian and Northern Affairs Canada (INAC)
- Environment Canada (EC)
- Department of Fisheries and Oceans Canada (DFO)
- Government of Nunavut, Department of Environment
- Government of Nunavut, Department of Health and Social Services
- Government of Nunavut, Department of Community and Government Services

Community Stakeholders:

- Solid Waste Management Committee
- Waste Matters Inc. (previously Iqaluit Recycling Society)
- Bill Mackenzie Humanitarian Society/ Jim Little
- Iqaluit Hunters and Trappers Association (HTA)
- Iqaluit Community Greenhouse Society
- Nunavut Volunteer Network

3.3 Dialogue Strategy Undertaken

As part of the stakeholder dialogue, from the beginning, Earth Tech will provide an information package to all the stakeholders, identified in Section 3.2. The ET information package will consist of a covering letter followed by a series of figures to introduce the nature of the waste stream from the new WWTP, and the potential "stabilization technologies" (See Figures 3.1 and 3.2).

3.4 Feedback from Stakeholders

At the time of preparing this report, no direct feedback was received by the City of Iqaluit regarding the SSM Plan. This lack of response may be due to a number of factors including:

1. lack of interest from the stakeholders based upon the general "does not concern me" position.

2. "wait and see" perspective of the stakeholders to respond at the time of the definitive information.

3. "protocol" perspective of the stakeholders, particularly the regulatory stakeholders who routinely respond to definitive reports or positions and not general information.

Iqaluit Sludge Management Planning

Outline Biosolid Streams from WWTP

Phase 1		Phase 1
Fine Screening and Grit (Future)	50 kg/day → 80 L/day	Landfill
Primary Filter	1630 kg/day → 1720 L/Day	Stabilization and Disposal

Phase 2		Phase 2
Waste Activated Sludge	3100 kg/day → 3500 L/day	Stabilization and Disposal

EarthTech
A tyco International Ltd. Company

Figure 3.1

Revised 2005 07 04

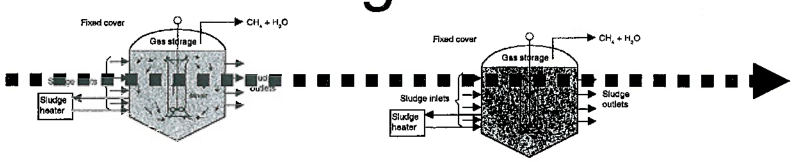
Iqaluit Sludge Management Planning

Outline "Appropriate" Stabilization Technologies

Aerobic Digestion Stabilization

Final Disposal

Anaerobic Digestion Stabilization

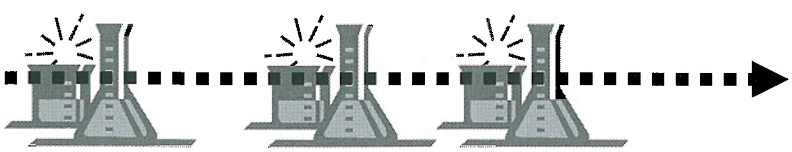


Final Disposal

Composting Stabilization

Final Disposal

Chemical Stabilization



Final Disposal

Physical Stabilization (freeze/thaw)

Final Disposal

EarthTech

A tyco International Ltd. Company

Figure 3.2

Revised 2004 07 04

4- Technology Identification

4.1 Identification of Sewage Sludge Management Technologies (SSMTs)

Conventional municipal sewage treatment uses physical, chemical, and biological processes to separate solids and biological contaminants from the municipal wastewater. The solids, in the wastewater, are removed through primary treatment (primary sludge), and the biological contaminants are removed through secondary treatment (secondary sludge). The solids, in the sludge, are typically processed in a digester system, in which biodegradable materials are "digested" into stable organic matter. The solids that result from the digester are known as biosolids, sewage biosolids or, simply, sewage sludge.

Sewage sludge may be further treated through dewatering, heat drying, alkaline (lime) stabilization, composting, or other processes. Regardless of the treatment technology, there are limited options for end use or ultimate disposal of sewage sludge. In Canada, approximately 388,700 dry tonnes of biosolids are produced every year. About 43% of the sewage sludge is applied to land, 47% is incinerated, and 4% is sent to landfill, with the remainder used in land reclamation and other uses. Land application has been increasing in recent years as many municipalities move away from incineration and landfill disposal due to environmental concerns with these processes. By comparison, the USA and the European countries apply approximately 60% and 34%, respectively, of their sewage sludge to an agricultural land.

There is a variety of conventional as well as modified, patented, and proprietary SSMTs available, and all these technologies may or may not necessarily be "appropriate" for the City of Iqaluit, particularly in consideration of "appropriate" technology for Iqaluit, and the "northern context" needed for the technology consistent with the proposed WWTP improvements. Nevertheless, all the technologies need to be identified and documented, in order to provide a benchmark from which to state that "no stone was left unturned." This technology identification process does not guarantee that the City will be questioned about "alternative" technologies at some point in the future; however, it will reduce the potential scope of the question.

4.2 Class A Sewage Sludge Technologies

Class A Technologies, also known as Processes to Further Reduce Pathogens (PFRP) or Exceptional Quality (EQ) Sludge Technologies, are thermal treatment technologies including heat treatment, heat drying, autothermal thermophilic aerobic digestion (ATAD), composting, and pasteurization. Radiation (Beta ray or Gamma ray) may also be used as a technology to destroy certain organisms in the sewage sludge, by altering the colloidal nature of the cell contents (protoplasm). These technologies produce sewage sludge that can be land applied without any pathogen-related restrictions at the site. Class A sewage sludge can be bagged and marketed to the public for application to lawns and gardens.

4.2.1 Heat Treatment

Heat treatment processes are used both to stabilize and condition the sewage sludge. The processes involve heating sewage sludge under pressure (up to 2,760 kN/m^2) in a pressure vessel, to a temperature of 180°C (or 356°F) or higher for a short period of time (usually for 30 minutes). The sewage sludge becomes sterilized and bacterial slime layers are solubilized, making it easier to dewater the remaining sewage sludge solids. Sewage sludge must be properly stored after processing because organic matter has not been reduced and, therefore, regrowth of pathogenic bacteria can occur.

Two processes have been used for heat treatment: the "Porteous" and the "Zimpro" processes. The *Porteous process* requires that the sewage sludge be preheated and then injected into a reactor vessel. The resulting sewage sludge can generally be concentrated and dewatered to high solids concentrations. The *Zimpro process* is similar to the Porteous process, however, air is injected into the sewage sludge before it enters the reactor and the vessel is then heated by steam to reach the required temperature.

4.2.2 Heat Drying

Heat drying is used to reduce both pathogens and the water content of sewage sludge (volume of biosolids). In this process, the sewage sludge is dried by direct (active dryers) or indirect (passive dryers) contact with hot gases to reduce the moisture content of the sewage sludge to 10 percent or lower. Either the temperature of the sewage sludge particles exceeds 80°C (or 176°F) or the wet bulb temperature of the gas in contact with the sewage sludge as the sewage sludge leaves the dryer exceeds 80°C (or 176°F). This technology results in a product (pellets) that can be used as a fertilizer or soil amendment; the product may also save significant transportation because of the very low water content, and hence lower weight. Three processes (dryers) are commonly used for heat drying sewage sludge: Flash Dryers, Spray Dryers, and Rotary Dryers.

Flash dryers pulverize sewage sludge in the presence of hot gases. The process is based on exposing fine sewage sludge particles to turbulent hot gases long enough to attain at least 90% solids content. *Spray Dryer* typically uses centrifugal force to atomize sewage sludge into a spray that is directed into a drying chamber. The drying chamber contains hot gases that rapidly dry the sewage sludge mist. *Rotary Dryers* function as horizontal cylindrical kilns. The drum rotates and may have plows or louvers that mechanically mix the sewage sludge as the drum turns. There are many different rotary kiln designs, utilizing either direct heating or indirect heating systems. Direct heating designs maintain contact between the sewage sludge and the hot gases. Indirect heating separates the two with steel shells.

4.2.3 ATAD Digestion

In ATAD process the pre-thickened sewage sludge is heated to 55 to 60°C (131 to 140°F) and aerated for about 10 days (compared to 40-60 days treatment for conventional aerobic digestion). This autothermal process generates its own heat, and reduces volume. Due to higher temperature, this process achieves higher rates of biodegradable organic solids reduction (up to 70%) than are achieved by conventional aerobic digestion, which operates at ambient air temperature. The result is a high quality Class A product acceptable for reuse as a liquid fertilizer.

4.2.4 Composting

Composting is an environmentally friendly way to recycle the nutrients and organic matter found in sewage sludge. Composting converts sewage sludge, mixed with a bulking agent (wood chips, sawdust, municipal yard waste, bark, rice hulls, straw or previously composted material), to a humus-like material through biological degradation. The bulking agent absorbs moisture, increases porosity and adds a source of carbon to the sludge.

There are three commonly used methods of composting: windrow, static aerated pile, and within-vessel. *Windrow composting* involves stacking the sewage sludge or bulking agent mixture into long piles, generally 3 to 6 feet high and 6 to 16 feet wide. These rows are regularly turned or mixed using a front-end loader to ensure steady oxygen supply for the microorganisms and to reduce the moisture content. *Static aerated pile* use forced-air rather than mechanical mixing to supply oxygen and reduce moisture. The entire pile is covered with a layer of cured compost for insulation and odor control. *Within-vessel composting* takes place in an engineered reactor where the operating conditions may carefully be controlled.

In static aerated pile or within-vessel composting methods the temperature of the sewage sludge is maintained at 55°C (or 131°F) or higher for three days, and in windrow composting method the temperature of the sewage sludge is maintained for 15 days or longer. In general, within-vessel composting attains the required conditions in approximately 10 days. The static-pile and windrow processes generally require about 3 weeks or more. Longer composting periods (curing) may be necessary to fully stabilize the sludge. If volatile solids remain in the sludge, fecal coliform can later regrow to significant numbers.

4.2.5 Pasteurization

In the pasteurization process, the batches of sewage sludge are heated to at least 70°C (or 158°F) for 30 minutes; this extreme heat kills the pathogens in the sludge. The sewage sludge can be heated by heat exchangers or by steam injection. The *steam injection method* is preferred because it is more effective at maintaining even temperatures throughout the sewage sludge batch being processed. The sewage sludge must be properly stored after processing because the organic matter has not been stabilized, and therefore odors and regrowth of pathogenic bacteria can occur.

4.2.6 Irradiation

Sewage sludge may be irradiated with Beta rays from an particle accelerator at a dosage of at least 1.0 megaradian at room temperature of 20°C (or 68°F), to reduce pathogenic viruses, bacteria, and helminths to below detectable levels. The sewage sludge must be properly stored after processing because organic matter has not been reduced and therefore regrowth of pathogenic bacteria can occur. It should be noted that, Beta rays have limited penetration through the sewage sludge, therefore, beta rays are introduced by passing a thin layer of sludge under the radiation source.

Sewage sludge was also be irradiated with Gamma rays, produced from certain isotopes such as Cobalt 60 and Cesium 137, at a dosage of at least 1.0 megaradian at room temperature of 20°C (or 68°F). Gamma rays can penetrate substantial thicknesses of sewage sludge, and can therefore be introduced to sewage sludge by either piping liquid sewage sludge into a vessel that surrounds the radiation source or by carrying composted or dried sewage sludge by hopper conveyor to the radiation source.

4.3 Class B Sewage Sludge Technologies

Class B Technologies, also known as Processes to Significantly Reduce Pathogens (PFRP) or Non-Exceptional Quality (Non-EQ) Sludge Technologies, include anaerobic digestion, aerobic digestion, composting, air-drying, and alkaline (lime) stabilization. These technologies produce sewage sludge (biosolids) that is subject to buffer requirements, public access and crop harvesting restrictions. Class B sewage sludge can be marketed to the public for restricted application to farms, landfills, forests, and for land reclamation.

4.3.1 Anaerobic digestion

Anaerobic digestion treats the sewage sludge in an enclosed tank, in the absence of air for a specific mean cell residence time at a specific temperature; between 15 days at 35 to 55°C (or 95 to 131°F) and 60 days at 20°C (or 68°F). Under anaerobic conditions, the anaerobic bacteria convert volatile solids into carbon dioxide, methane and ammonia.

Due to high cost, this technology is useful for large plants with flow capacity of greater than 5 million gallons per day (or greater than 0.2 cubic meters per second). There are two types of anaerobic digestion systems, standard rate and high rate. *Standard-rate anaerobic systems* take place in a simple storage tank with sludge added intermittently. The only agitation that occurs comes from the natural mixing caused by gases rising to the surface. Standard-rate operations can be carried out at ambient temperatures, although heat is sometimes added to speed up the biological activity. *High-rate anaerobic systems* use a combination of active mixing and carefully controlled, elevated temperatures to increase sludge stabilization. These systems mostly use pre-thickened sewage sludge introduced at a uniform rate to maintain constant conditions in the reactor.

4.3.2 Aerobic digestion

Aerobic digestion treats the sewage sludge by mixing in an open or enclosed vessel, with air or oxygen to maintain aerobic conditions for a specific mean cell residence time at a specific temperature; between 40 days at 20°C (or 68°F) and 60 days at 15°C (or 59°F). Under aerobic conditions, the volatile solids in the sewage sludge are converted to carbon dioxide, water and nitrates. The process can be batch mode (feeding and aerating the sludge for 2-3 weeks or longer and removing the batch) or continuous mode (feeding sludge and removing stabilized solids on the same day). This process is used primarily in treatment plants with flow capacity of less than 5 million gallons per day.

4.3.3 Composting

In in-vessel and windrow composting methods the temperature of the sewage sludge is maintained at 40°C (or 104°F) or higher for five days with at least one 4-hour period at 55°C (or 131°F), followed by a maturation period to complete the composting process.

4.3.4 Air-drying

Partially digested sewage sludge may be dried naturally, in the open air, on sand drying beds or on paved or unpaved basins (with underlying drainage system), to a depth of approximately 9 inches. The sewage sludge is left to drain and dry by evaporation for a minimum of three months. During two of the three months the ambient average daily temperature should be above 0°C (or 32°F). Mechanical mixing or turning is frequently added to paved or unpaved basins. The effectiveness of this process depends on the local climate; drying will occur faster in warm, dry weather.

4.3.5 Alkaline (Lime) Stabilization

The alkaline stabilization uses hydrated lime ($Ca(OH)_2$), quick lime (CaO) or lime containing kiln dust or fly ash which is added to the sewage sludge in sufficient quantities (120 to 340 pounds per ton dry solids for primary sludge with solids concentration of 3 to 6%) to raise the pH of the sewage sludge to 12 for 2 hours (to pH of greater than 11 for several days). The dose of lime decreases with increase in solids concentration for a constant temperature increase. Lime may be introduced to liquid sewage sludge prior to dewatering or after dewatering.

Lime stabilization does not reduce volatile solids. If the pH of lime-stabilized sludge drops below 11, remaining pathogenic bacteria may regrow at a rapid rate. Long-term storage of alkali-treated sewage sludge will most likely require additional lime treatment to maintain an elevated pH, drying or further treatment to reduce volatile solids.

4.4 Conjugated Sewage Sludge Technologies

For the proper application or disposal of sewage sludge, Class A and Class B sewage sludge technologies are used in conjunction with other sewage sludge technologies. These conjugated technologies such as sludge thickening, sludge conditioning, and sludge dewatering can contribute significantly to efficient and economical operations.

4.4.1 Sludge Thickening

Sludge thickening is a process used to increase the solids content of sewage sludge by removing a portion of the liquid fraction. The process is beneficial to subsequent treatment processes such as digestion, dewatering, drying, and combustion in terms of tank capacity and equipments, chemicals quantity, and heat/fuel amount. Sludge thickening is accomplished by physical means including gravity settling, flotation, centrifugation, gravity belts, and rotary drums. In small plants, gravity thickening is accomplished in primary settling tank or in the sludge digestion units, or both.

Gravity thickening is most effective on the primary sewage sludge. *Flotation thickening* (dissolved-air, vacuum, dispersed-air) is used most efficiently for sewage sludge from suspended growth biological treatment processes (activated sludge) and for primary sludge and aerobically digested sludge to some extent. *Centrifugal thickening* (for thickening and dewatering) is efficient for only waste activated sludge at large facilities (greater than 5 million gallons per day) due to substantial maintenance and power costs. *Gravity Belt thickening* is used for sewage sludge with solids concentration of less than 2% such as raw and digested sludge with polymer addition. *Rotary drum thickening*, coupled with a belt filter press and polymer addition, provides both thickening and dewatering. It requires low maintenance, less energy use, and small space.

4.4.2 Sludge Conditioning (Pre-Dewatering)

Sludge conditioning is a process used to improve sludge dewatering characteristics and is achieved by two methods – chemical conditioning and heat treatment.

Chemical conditioning is used in advance of mechanical dewatering systems (vacuum filtration, centrifugation, belt filter presses, pressure filter presses) resulting in the increased yields and greater flexibility. This method can reduce 90-99% incoming sludge moisture content to 65-85%. Various sludge-conditioning agents (chemicals) can be used for the purpose such as polymers, iron salts (ferric chloride) or lime, however the method require chemicals storage with corrosion resistant materials and also require metering pumps (positive displacement type with variable-speed or variable-stroke). The sewage sludge properties (source, solids concentration, age, pH, alkalinity), the type of mixing and dewatering devices affect the selection of the type and dosage of chemicals, therefore requires laboratory or pilot-scale testing to determine the type and dosage of chemicals.

Heat treatment is a stabilization as well as conditioning process, requiring heating the sewage sludge for short periods of time under pressure. This method is most applicable to biological sludge at large plants or where the space is limited. This method also requires close supervision and a strong preventive maintenance program because this method can result in production of significant odorous gases and formation of scales in the heat exchangers and pipes

4.4.3 Sludge Dewatering

Sludge dewatering, a physical (mechanical) process, is used to remove the water from sewage sludge resulting in substantially reduced trucked sludge volume to ultimate disposal, especially for incineration. Sludge dewatering often is a necessary process before treatment or use, such as before composting (to reduce the requirements for bulking agents or amendments), heat drying or sewage sludge preparation for land application. The dewatered sludge is also easier to handle than thickened or liquid sludge and also render the sludge odorless and non-putrescible. However, aerobically digested sludge is not amenable to mechanical dewatering and need to be dewatered on sand beds.

The process requires bench-scale or pilot studies to select the optimum dewatering device (or trailer-mounted full-size equipment for field-testing purpose). For smaller plants where land availability is not a problem, drying beds or lagoons can be used for the purpose.

Typical dewatering methods include air drying and mechanical systems. *Air drying* involves placing biosolids on a sand bed and allowing them to dry through evaporation and drainage. This process can produce solids content in primary biosolids of as high as 45 to 90 percent. Air drying systems are relatively simple in terms of operation but require large land areas and relatively long periods of time and, therefore, tend to be used by small public owned treatment works (POTWs) that generate small amounts of sewage sludge.

Larger POTWs rely on mechanical dewatering systems such as vacuum filters, plate-and-frame filter presses, centrifuges, and belt filter presses. *Vacuum filters*, which typically achieve 12- to 22-percent solids content, involve rotating a drum submerged in a vat of biosolids and applying a vacuum from within the drum, drawing water into the drum, and leaving the solids or "filter cake" on the outer drum filter medium. The dewatered biosolids are scraped off the filter. This form of dewatering is now being replaced by belt filter presses, centrifuges, and, in some cases, plate-and-frame presses. *Centrifuges* spin sewage sludge in a horizontal, cylindrical vessel at high speeds, with the solids concentrating on the outside of the vessel. These solids are then scraped off. Centrifuging can result in a 25 to 35% solids content. *Belt filter presses* can achieve 20 to 32% solids content.

They work by exerting pressure on biosolids placed between two filter belts, which are passed through a series of rollers. The pressure forces water out of the sewage sludge, and the dried sewage sludge cake is retained on the filter belt. *Plate-and-frame presses* are the most expensive system to operate and can produce 35 to 45% solids content. They work by squeezing the sewage sludge between two porous plates or diaphragms. The pressure forces water out of the sewage sludge, and the dried sewage sludge cake is retained on the plates.

4.5 Innovative SSMTs

Many of the innovations can be categorized as either "sludge disintegration" or "biosolids productification".

Sludge disintegration is a group of approaches for breaking down waste activated sludge (WAS) prior to digestion, since WAS is naturally resistant to digestion and difficult to dewater. Several different technologies have been recently subject to pilot testing at wastewater treatment facilities:

- *Cambi*, a thermal hydrolysis process, uses a high temperature/pressure reactor (133-200°C) to disintegrate the microbial cells in WAS;
- *Sonix*™ ultrasound technology for enhanced digestion from Sonico uses ultrasound to break down the cell walls in thickened WAS ahead of conventional digestion;
- Kady's *Biolysis* system (BLS) is a process that reduces the volume and weight of disposable sludge by shearing and breaking apart solid particles and rupturing microbial cell membranes in sludge through cavitations pressures created by Kady's mixing/dispersion mills, causing return of solubilized cytoplasm, fragmented particles, and freed water to the aeration system rather than its removal as solid waste;
- USFilter's *Cannibal*™ solids reduction process uses a dual aerobic/anaerobic bioreactor to treat the organic fraction of WAS. The complete destruction of biological solids is accomplished through an "interchange" recycle flow between the aerobic activated sludge process and a specially controlled sidestream bioreactor (Cannibal); and
- Paradigm Environmental Technologies Inc.'s *MicroSludge*™ process liquefies the secondary sludge (WAS), using some caustic, Na(OH) and a high-pressure homogenizer (12,000 psi or more), prior to anaerobic digestion. This process was developed at the University of British Columbia by Dr. Rob Stephenson, to provide a pre-treatment to the WAS in an anaerobic digester and to reduce solids content for disposal.

The results of trial studies are still not published. The proprietors of disintegration technology claim lower polymer costs during dewatering, higher solids in the cake and less foaming problems (VSS reduction), environmentally sustainable process and usable energy recovery (biogas production). However, there are issues with process odors, equipment complexities, high organic/nutrient loads back to the treatment plant, high energy inputs and high skill levels needed for operation.

The other major area of innovation is "productification" technologies. While we already have compost, advanced alkaline stabilization and heat-dried pellets, some new approaches have been introduced in recent years:

- *Unity Fertilizer* technology is demonstrating that biosolids can quench the reaction of ammonium nitrate and sulfuric acid in producing a micronutrient and organic matter enhanced ammonium sulfate fertilizer;
- *Harmony* process (Nutri-Green® Compost) was trialed at Hampton Roads Sanitation District (Virginia) successfully as a nutrient balanced, heat-dried biosolids pellet;
- *Enertech* (California firm) is proposing to turn sewage biosolids into a fuel rich "char" useful to the cement industry; and

- *Thermal Depolymerization Process (TDP)* of Changing World Technology, Inc. is a process for the reduction of sewage sludge (and other waste products) to light crude oil. This process is similar to the geological processes that produced the fossil fuels used today, except that the technological process occurs in a timeframe measured in hours. TDP may turn 100 pounds of sewage into 26 pounds of oil, 9 pounds of gas, 8 pounds of minerals and carbon, and 57 pounds of water.

4.6 Sewage Sludge Ultimate Disposal Technologies

There are mainly three sewage sludge disposal options, which are land application, landfilling (surface disposal), and lagooning. The incineration method is highly discouraged in Canada due to air emission concerns.

4.6.1 Land Application

Land application involves the spreading of sewage sludge on the soil surface or incorporating or injecting sewage sludge into the soil. Land application of sewage sludge has been practiced for decades and continues to be the most common method for using sewage sludge. Sewage sludge serves as soil enrichment and can supplement or replace commercial fertilizers.

Nutrients (e.g., nitrogen and phosphorus), micronutrients including essential trace metals (e.g., copper, zinc, molybdenum, boron, calcium, iron, magnesium, and manganese), and organic matter in the biosolids are beneficial for crop production, gardening, forestry, turf growth, landscaping, or other vegetation. Sewage sludge has generally lower nutrient contents than commercial fertilizers. Sewage sludge typically contains 3.2% nitrogen, 2.3% phosphorus, and 0.3% potassium, while commercial fertilizers might contain 5 to 10%, 10% phosphorus, and 5 to 10% potassium.

The use of sewage sludge reduces the impacts of high levels of excess nutrients entering the environment. However, this disposal option requires characterization of sewage sludge quantity and quality; review of pertinent regulations, evaluation and selection of site and disposal option, determination of process design parameters such as loading rates, land area, application method (liquid sludge or dewatered sludge) and scheduling.

Sewage sludge treatment before land application can involve digestion, composting, alkaline treatment, heat treatment or other methods. Some of the uses for sewage sludge (composts) include their application to various types of land including agricultural lands, forests, mine reclamation sites and other drastically disturbed lands, parks, and golf courses. Although ventures in developing composted or further processed sewage sludge products involve additional costs for communities over direct land application, the sale of these products can generate revenue that offsets some of the costs.

Liquid or dewatered sewage sludge can be applied by surface spreading or, in the case of liquid biosolids, by subsurface injection. Surface application methods include spreading by farm manure spreaders, tank trucks or special applicator vehicles. After being applied to the surface and allowed to dry partially, sewage sludge is commonly incorporated into the soil by plowing, discing or other methods. Liquid sewage sludge may be malodorous but can be injected below the soil surface by tank trucks with injection shanks to minimize odours.

4.6.2 Landfilling (Surface Disposal)

Most sewage sludges that are disposed of in, or on land are *landfilled* with municipal solid waste. *Surface disposal* is defined as sewage sludge placed on an area of land where only sewage sludge is placed for final disposal. It does not include sewage sludge that is placed on land for either storage (generally less than 2 years) or treatment (e.g., lagoon treatment for pathogen reduction). It involves *landfilling* of sewage sludge in monofills (dedicated land disposal or DLD site), disposal in permanent piles or lagoons used for disposal (rather than treatment or temporary storage), and dedicated surface disposal practices. Dewatering of sewage sludge is usually required to reduce the transported volume and to control the leachate.

The difference between surface disposal, and land application primarily involves the application rate. Any time the application rate exceeds the agronomic rate, the practice is considered to be surface disposal. *Monofilling* is typically undertaken using a series of unlined trenches dug into the ground, into which dewatered sewage sludge is placed and then covered with soil. Other techniques less commonly used include fill mounds, area fill layers and diked containment.

4.6.3 Lagooning

Lagooning is simple and economical if the wastewater treatment plant is in a remote location. In the lagoon, untreated or digested sludge can be deposited. However, lagooning method may give rise to objectionable odors and nuisance conditions, and it requires lining of the earth basin for leachate control.

4.7 Summary of Available SSMTs

Figure 4.1 summarizes technologies (unit processes) available for municipal sewage sludge management (treatment) and Table 4.1 summarizes all the above SSMTs and their major function. Table 4.2 summarizes possible end uses, advantages, and disadvantages of each SSMT. Table 4.3 presents some of the common stabilization technologies and the use or disposal method typically associated with each technology. Table 4.4 presents advantages and disadvantages of end uses of sewage sludge. Table 4.5 summarizes dewatering technologies and their relative advantages and disadvantages.

It is appropriate to mention that technologies such as electro-osmotic and electro-acoustic conditioning and dewatering, high-energy electric arc disinfection, or enzymatic-alkaline hydrolysis, are still in the experimental phase. Pyrolysis and deep shaft high-pressure stabilization have limited full-scale experience as their cost-effectiveness against other technologies has not been assessed through a value engineering approach.

SSMTs that are currently available only at bench or pilot scale have not been presented at this time. Also the systems/processes developed by various vendors are not identified and discussed. The main reason, although these vendors claim superior process yields or final total solids content there is very little in the literature that compares the processes side by side in large pilot or full-scale studies.

4- Technology Identification

Table 4.1: A Summary of SSMTs and their Major Function/Purpose

SSM Technology (SS Treatment Method)	Function/Purpose
Thickening	
Gravity thickening	Volume reduction
Floatation thickening	
Centrifugation	
Gravity belt thickening	
Rotary drum thickening	
Stabilization	
Alkaline (lime) stabilization	Stabilization
Heat treatment	
Anaerobic digestion	Stabilization & mass reduction
Aerobic digestion	
Composting	Stabilization & product recovery
Conditioning	
Chemical conditioning	Sludge conditioning
Heat treatment	
Disinfection	
Pasteurization	Disinfection
Long-term storage	
Dewatering	
Vacuum filter	Volume reduction
Centrifuge	
Belt filter press	
Filter press	
Sludge drying beds	
Lagoons	Storage & volume reduction
Heat Drying	
Flash dryer	Weight & volume reduction
Spray dryer	
Rotary dryer	
Thermal Reduction	
Multiple-hearth incineration	Volume reduction & resource recovery
Fluidized-bed incineration	Volume reduction
Co-incineration with solid wastes	
Wet-air oxidation	Stabilization & volume reduction
Vertical, deep-well reactor	
Ultimate Disposal	
Land application	Final disposal
Landfilling	Final disposal
Lagooning	Volume reduction & final disposal

Table 4.3: A Summary of Stabilization Technologies and Associated Use or Disposal Methods/Options

Stabilization Technology/Process	Use or Disposal Method/Option
Aerobic or Anaerobic Digestion	Produces sewage sludge used as a soil amendment and organic fertilizer on pasture and row crops, forests, and reclamation sites; additional treatment, such as dewatering and composting, also can be performed
Alkaline Treatment	Produces sewage sludge useful for land application and for use as daily landfill cover
Composting	Produces highly organic, soil-like sewage sludge with conditioning properties for horticultural, nursery, and landscape uses
Heat-Drying/Palletizing	Produces sewage sludge for fertilizers generally used at a lower rate because of higher cost and higher nitrogen content

Note: Two or more SSMTs are often used for treating sewage sludge (e.g., digestion with dewatering and composting). **Source**: USEPA, *Biosolids Generation, Use and Disposal in the United States*, 1999.

Table 4.4: A Summary of Advantages and Disadvantages of End Uses of Sewage Sludge

Possible End Uses	Products (after SS treatment)	Advantages	Disadvantages
Land application on agricultural land	Liquid digested biosolids	Beneficial use	Cost of transporting
	Dewatered cake		Public concerns
	Dried biosolids	Good saving for farmers	Requires pathogen-free material
	Composted biosolids		
Landfill/ Landfill Cover	Dewatered cake	Less public issues	Not re-use
	Partially dried biosolids	Low cost alternative	Consumes landfill space
		Short custody time	Operational difficulties
Co-disposal in landfill (with MSW)	Dewatered cake	Reduced operational difficulties	Not re-use
	Partially dried biosolids	Potential for landfill gas recovery	Consumes landfill space
	Composted biosolids		
Land Reclamation	Dewatered cake	Beneficial use	Transportation cost
	Dried biosolids	Recovers/improves land	Public concerns
	Composted biosolids		

Table 4.5: A Summary of Dewatering Technologies

Sludge Dewatering Method	Advantages	Disadvantages
Vacuum filter	Skilled personnel not required	Declined use due to alternative equipments
		System complexity
		Need for conditioning chemicals prior to filtration
		High O&M costs
		Optimim solids content for filtration is 6-8%
		Highest energy consumption
Solid Bowl Centrifuge	Suitable for a variety of sludge dewatering applications	Requires polymer conditioning to improve solids capture and centrate quality
	Can be used to dewater sludges with no prior chemical conditioning	Requires grit removal and a sludge grinder in the feed system
	Easy to install	Requires skilled maintenance personnel
	Minimal odor problem	Moderately high suspended solids in centrate
	Fast startup and shutdown	
Imperforate Basket Centrifuge	Suitable for small plants	Disposal of centrate difficult due to high suspended, non-settling solids
	Can be used to dewater WAS with no chemical conditioning, at solids capture of upto 90%	Requires increased residence time to control fine solids discharge & to increase capture of return solids
	Use of same machine for thickening and dewatering	Limited size capacity
	Minimal odor problem	Consumes more energy (less than vacuum filter only)
	Fast startup and shutdown	May produce significant recycle load
	Very flexible	Produces lowest cake solids conc.
	Not affected by grit	
Belt Filter Press	Continuous-feed sludge dewatering device	Require chemical conditiong and mechanically applied pressure
	Effective for almost all types of municipal wastewater sludge	
	Solids throughput is greater; cake dryness improves with higher solids conc. in feed sludge	Sensitive to wide variations in sludge characteristics; requires sludge-blending facility
	Low energy requirement	Requires sludge grinder in feed stream
	Relatively low capital and O&M costs	
	Minimal effort for system shutdown	
Recessed Plate Filter Press	Highest cake solids concentration	Batch operation
	Low suspended solids in filtrate (high solids capture)	High equipment and O&M cost
		Requires large floor area and support structure
Sludge Drying Beds	Most widely used method in the USA	Requires large area of land
Conventional Sand	Typically used to dewater digested sludge	Requires stabilized sludge
Paved	After drying, sludge can be disposed of in a landfill or used as a soil-conditioner	Design requires consideration of climatic effects
Artificial Media	Lowest capital cost method where land is available	Sludge removal is labor intensive
Vacuum-assisted	Low O&M costs	
	High solids content in the dried product than mechanical methods	
	Low to no chemical consumption	
	Less sensitive to sludge variability	
Freezing & Thawing	Converts the jelly-like consistency of sludge to a granular-type material that drains readily	Requires digested sludge for dewatering on freeze-thaw drying beds
	Solids conc.>20% occurs when the material thaws; may rise to 50-70% with more drying time	A storage facility required to contain the sludge during thawing period (summer months)
	3 inch (80 mm) layer of sludge is practical for most locations in cold climates	Need to treat the drained water from the sludge bed & a loader/tractor to remove dried sludge
Sludge Lagoons	Used as a substitute for drying beds	Potential odor and vector problems
	Not suitable for dewatering undigested sludge or sludge with high-strength supernatant	
	Applicable in areas with high evaporation rates	Potential for groundwater pollution
	Low energy consuption	
	No chemical consumption	
	Low capital cost where land is available	Design requires consideration of climatic effects
	Least amount of skill required for operation	