Wastewater Sludge as a Resource

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Integrated, long term sustainable, cost effective biosolids management at a large Canadian wastewater treatment facility

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Abstract. The Greater Moncton Sewerage Commission's 115 000 m3/d advanced, chemically assisted primary wastewater treatment facility located in New Brunswick, Canada, has developed an integrated, long term, sustainable, cost effective programme for the management and beneficial utilization of biosolids from lime stabilized raw sludge. The paper overviews biosolids production, lime stabilization, conveyance, and odour control followed by an indepth discussion of the wastewater sludge as a resource programme, namely: composting, mine site reclamation, landfill cover, land application for agricultural use, tree farming, sod farm base as a soil enrichment, topsoil manufacturing. The paper also addresses the issues of metals, pathogens, organic compounds, the quality control program along with the regulatory requirements. Biosolids capital and operating costs are presented. Research results on removal of metals from primary sludge using a unique biological process known as BIOSOL as developed by the University of Toronto, Canada to remove metals and destroy pathogens are presented. The paper also discusses an ongoing cooperative research project with the Université de Moncton where various mixtures of plant biosolids are composted with low quality soil. Integration, approach to sustainability and "cumulative effects" as part of the overall biosolids management strategy is also discussed.

Key words: Beneficial use, BIOSOL, biosolids, sludge, sustainability.

Introduction

The Greater Moncton Sewerage Commission (Commission) was formed in 1983 by the Province of New Brunswick (Canada) in consultation with the Town of Dieppe, City of Moncton and Town of Riverview. Its mandate was to undertake the design and construction of a wastewater collection and treatment system in order to eliminate the direct discharge of raw wastewater to the Petitcodiac River.

From 1983 to 1994, a 30 km trunk wastewater collection system was constructed including a system of tunnels, which transport wastewater to the on-site Main Pumping Station (capacity 265 000 m3/d) in Riverview. This station is the largest of its king in Atlantic Canada. All wastewater is pumped to the plant for subsequent treatment and discharge to the Petitcodiac River. The 115 000 m3/d wastewater treatment plant, includes screening, aerated grit removal, advanced chemically assisted primary treatment to meet Provincial guidelines for effluent BOD (12 700 kg/d) and suspended solids (7600 kg/d), utilizing flocculation type clarifiers with integral picket thickening, raw sludge dewatering via high solids handling centrifuges, lime stabilization of raw sludge and odour control facilities using wet scrubber and biofilter.

Effluent disinfection is not required under the current regulatory agency certificate of approval. The current serviced population is some 93 000 with average daily flow for year 2002 of approximately 67 100 m3/d or 722L/cap/d. The raw sewage BOD and TSS are 202 mg/L and 173 mg/L respectively. Considerable septage is also handled at the plant. The facility was designed to accommodate one of the highest tides in the world – up to 10 m.

The Commission has an existing biosolids beneficial use programme which is integrated, sustainable and cost effective.

Biosolids production and associated costs

Ferric chloride (average dosage 1.9 mgFe/L and polymer (average dosage 0.06 mg/L) are added to the clarifier influent on a flow proportional basis. Each clarifier (39 m diameter with side water depth of 3.7m) has a large inlet stilling well which is a flocculation area with mechanical mixers. The surface settling rate on the clarifiers is 32 m3/m2/d at average daily design flow and 60 m3/m2/d at peak flow. In order to increase the concentration of raw sludge prior to pumping, a central integral "picket" thickener (depth of the central picket thickener is 6.9 m) is incorporated into the overall collector mechanism. The raw sludge is macerated and pumped on a semi-continuous basis to sludge holding tanks where lime slurry is added.

Raw sludge from the holding tanks, is again macerated and conditioned with polymer prior to centrifuge dewatering. Three fully automated high solids handling centrifuges dewater the sludge. Each machine is rated at 17 L/s capable of handling 4500 kg/h dry solids. The resultant sludge cake is normally 30% solids by weight. Hydrated lime is from two steel silos (a total volume of 92m3) is added to the dewatered sludge via a pug mill. The pH of the sludge/lime mixture is elevated to 12 for 2 hours and maintained at pH of 11.5 for at least 22 hours. The resulting biosolids are carried via open conveyor belt to the Biosolids Shipping Building for loading onto trucks for subsequent haulage to beneficial use programme and composting sites. This method of lime stabilization produces a US EPA Class B biosolids.

Odours associated with the processing of biosolids are confined to the raw sludge holding tanks, the enclosed biosolids screw conveyor system and the Dewatering Buidling. The plant ventilation system air stream is treated separately in a dual wet scrubber system and a biofilter (compost filter). In order to reduce odours generated in the Sludge Storage Tanks and conveyance system, the odour collection and treatment system is complemented by dosing liquid lime slurry directly into the sludge holding tanks.

The capital cost for the raw sludge to biosolids component of the wastewater treatment facility including associated buildings, centrifuges, conveyance systems, lime feed system, chemical feed systems and ancillary equipment was approximately Cdn $10,000,000. Total operating cost from raw sludge to biosolids, excluding capital depreciation for 2002 was Cdn $31.36/wet tonne: with breakdown as noted in Table 1.

Table 1 Operating costs: raw sludge to biosolids*

Item	Per Wet Tonne	Per Dry Tonne
Labour	$ 9.24	$ 31.11
Lime	$ 2.74	$ 9.23
Polymer	$ 8.38	$ 28.21
Power	$ 8.00	$ 26.91
Maintenance	$ 3.00	$ 10.13
Total	**$ 31.36**	**$105.64**

*Year 2002 Canadian Dollars

Wastewater sludge (biosolids) as a resource programme

Utilization of biosolids as a soil additive in agriculture

The Commission actively promotes biosolids as a soil additive in agriculture as a beneficial reuse and has been working closely with major area farmers in setting-up application programmes that are in accordance with established guidelines. Requirements include filing applications, sampling for metals before and after processing and ensuring that waiting periods are respected.

Biosolids must meet the metals restrictions listed in Table 2. The Commission's average values for 1999-2001 are shown along with other Canadian jurisdictions and US EPA limits. Typically, the application rate on agriculture is 8 dry tonnes per hectare. The Commission transports the material to the farm field at no cost while the farmer is normally responsible for spreading. The Greater Moncton biosolids are well within the maximum allowable metal concentration in biosolids for land application in New Brunswick and other jurisdictions as noted in Table 2.

Table 2 Greater Moncton Sewerage Commission biosolids metals content (mg/kg concentrations) Compared with regulatory limits for biosolids land application

Parameter	1999-2001 mean* (10 samples)	New Brunswick, Canada guideline	Ontario, Canada guideline	Alberta, Canada guideline	Agriculture Canada guideline	US EPA 503 PC limit
Arsenic	1	75	170	___	75	41
Cadmium	3	20	34	27	20	39
Chromium	14	1100	2800	2000	___	1200
Cobalt	4	150	340	___	150	___
Copper	215	850	1700	2700	___	1500
Lead	32	500	1100	2000	500	300
Mercury	1	5	11	13	5	17
Molybdenum	4	20	94	___	20	18
Nickel	80	180	420	400	180	420
Selenium	2	14	34	___	14	36
Zinc	213	1850	4200	4000	1850	2800

*Greater Moncton Sewerage Commission samples

There are currently no specific guidelines in New Brunswick relating to the monitoring of organic compounds contained in biosolids.

The ongoing biosolids quality control/monitoring program is aimed at maintaining environmental quality and protecting public health. Plant equipment design and operation control ensures optimum lime dosage as well as other operating parameters. Testing for pH is carried out daily to ensure a pH of 12 is maintained for at least 2 hours. Prior to hauling to an end user, all necessary applications are filed with the Department of the Environment. Comprehensive soil samples are taken from the receiving sites and analyzed for metal concentrations prior to the application and following the application. Metals testing of the biosolids is done on a monthly basis and all sampling results are recorded in a database. Periodically, samples are collected for bacteriological testing.

Sod farming

The use of biosolids for sod farming is of interest to the Commission as the biosolids can be spread and incorporated directly following production and lime stabilization thus eliminating the need for further processing and storage. Over the last few years considerable volumes of lime stabilized biosolids have been used on one of Atlantic Canada's largest sod farms located some 100 km from the plant. The use of biosolids on the sod farm replaces a significant portion of nitrogen and phosphorus now obtained from commercial fertilizers as well as provides much needed organic matter, thus improving the soil structure. Lime added to the biosolids also helps in reducing the soil acidity.

Landfill cover

The use of biosolids as landfill cover eliminates the need for large volumes of topsoil which reduces not only the cost but also the demand on valuable topsoil normally stripped from local farms. The Commission has had successful experience in the beneficial use of biosolids for cover of the former City of Moncton and Town of Sackville landfill sites. The revegitated City of Moncton landfill now incorporates a network of walking, hiking and biking trails.

Mine site rehabilitation

Central New Brunswick has been the site of extensive strip mining for coal extraction. Lands left unconditioned for many years have experienced little revegetation and in these areas can contribute to acidic runoff as well as erosion. Through cooperation between the Commission and a local contractor, this land is being regarded and conditioned with lime stabilized biosolids. The lime added also adjusts the normally acidic soils. Typical application rate is in the range of 30 dry tonnes per hectare. An ongoing monitoring program via soil sampling and testing for indicator organisms is aimed at evaluating the revegetation, pH stability and pathogenic organisms.

Golf courses

Composted biosolids were used in the soil conditioning for the construction of a local, family owned golf course. The project not only saved his family business considerable money but also eliminated the need for importing topsoil.

Tree farming

The extensive forestry product industry offers a great potential and could benefit from application of lime stabilized biosolids. Following harvest, thousand of acres are replanted with a planting pattern that is more favourable to spreading equipment. Practical experience gathered at a local Christmas tree farm will be used in larger scale. Areas where trees were subject to wind damage (turning brown) recovered and growth rate increased. Biosolids compost/topsoil mixtures are also being used as a planting medium with great success. Young trees grow faster while losses are kept to a minimum.

Operating costs for the beneficial use programmes

The overall expenditures (year 2002 Canadian dollars) directly related to biosolids beneficial reuse programmes is noted in Table 3. Even though costs vary depending on the end use, the Commission will continue with a diversified programme.

Table 3 Overall operational costs for biosolids production and beneficial use programmes

ITEM	OPERATIONAL COST
A. To direct use (land application)	
Production (Table 1)	$31.36/tonne
Trucking to direct use	$12.00/tonne
Total direct use	**$43.36/tonne**
B. To compost	
Production (Table 1)	$31.36/tonne
Trucking to compost site	$14.00/tonne
Processing (composting)	$25.60/tonne
Total to compost	**$70.96/tonne**

Composting and its reuse potential

The current and future direction of compost and its uses in Greater Moncton

Land application of biosolids has become challenging when integrated with the management efforts associated with identification of land, relationships with landowners, sampling and testing, approvals, monitoring and reporting. Also even though the Commission will still continue with land application, it realizes the need for a sustainable program during the winter and spring periods. For the off-season, preference has been given to composting biosolids with amendments derived mainly from the forestry industry (sawdust, bark, wood waste) and the farming sector (shredded hay). This tendency is a result of greater flexibility of operation with a program that runs year around.

The Commission has over time, developed a cooperative network with private compost site owners who have an Environmental Certificate of Approval to operate. The process followed is agreed to by Commission staff and the owner so as to provide the best finished product that is stable, odourless and free of undesirable contaminants. The site operators may screen and use this compost in a soil blending operation (topsoil), in land reclamation, on farmland, etc. The tipping fee paid covers the transportation, the amendment materials, mixing and turning. At this stage, the marketing is left to the private site operator. As noted in Table 4, the compost complies with established limits of the Canadian Council of Ministers of the Environment (CCME), for Class B compost utilization purposes. However, for Class "A" compost, the copper content is slightly elevated. The high concentration of copper in the compost is probably associated with the leaching of copper from residential and industrial plumbing. With the implementation of a Water Treatment Plant, the copper levels have been dropping significantly on raw sludge and those reductions should reflect in future fully cured compost.

Table 4 **Concentration of trace elements in compost**

Trace elements	**GMSC compost**** (mg/kg dry weight)	**Category A (CCME)** Maximum concentration within product (mg/kg dry weight)	**Category B (CCME)** Maximum concentration within product (mg/kg dry weight)
Arsenic (As)	3	13	75
Cadmium (Cd)	1.2	3	20
Cobalt (Co)	6.2	34	150
Chromium (Cr)	30	210	1060*
Copper (Cu)	291	100	757*
Mercury (Hg)	0.6	0.8	5
Molybdenum (Mo)	1.7	5	20
Nickel (Ni)	17.5	62	180
Lead (Pb)	46.2	150	500
Selenium (Se)	1.7	2	14
Zinc (Zn)	185.2	500	1850

*BNQ standard; not provided in CCME **sampling results 1997 to 2000

Research and experience with topsoil manufacturing

The Greater Moncton Sewerage Commission has maintained close relations with the local Université de Moncton on various research activities related to wastewater treatment and in particular, biosolids related research.

Initially, the research activities were focused on literature reviews, understanding of regulations and guidelines related to the quality control and environmental concerns associated with land application of lime stabilized biosolids. Considerable sampling and testing over the years was focused on pathogen reduction and identification of parasites and metals.

As a continuation of research activities, the Université de Moncton and Commission staff undertook another important phase in 2002. As the production of compost is now well understood and private operators carry out soil blending on their own, it became evident that providing guidance in this area was a priority. In order to develop representative mix designs, scientifically designed field trial was undertaken. The mixes were developed from a common and representative sample of compost and readily available sandy soils. Mixes were prepared from screened compost and sand. A control mix of sand, as well as ten compost/sand mixes starting at 10% compost going up to 100% compost were prepared. Three different indicator crops were selected for the experimental work, Garden Cress (Lepidium sativum L), White Dutch Clover (Trifolium repens) and Tall Fescue (Festuca arundinacea). In order to have representative results that could be analyzed statistically, 30 samples per mix were prepared for each of the three plant species and placed in 75mm x 75mm pots. All pots were randomly placed in an outdoor area prepared with a base of wood waste. The total number of sample was 990. Other flats were planted for visual presentation only. Each of the pots were controlled as to the number of plants/seeds and for weeds. Plants were then harvested and measured for length of the aerial part and root system as well as the wet and dry weight of the aerial and root system.

Table 5 summarizes preliminary results relating to the increase in growth for selected percent compost on two of the indicator crops.

Table 5 Plant dry weight after 4 weeks of growth (aerial)% difference from control 0%

% Compost	Garden Cress (Lepidium sativum L)	Tall Fescue (Festuca arundinacea)
0 (control)	0%	0%
30	85%	47%
60	149%	99%
90	153%	98%

The BIOSOL process

A biological process known as BIOSOL was developed in the environmental engineering laboratories of the University of Toronto, Canada to remove metals and destroy pathogens in wastewater treatment plant sludges (Henry et al 1999; Prasad et al 2000; Henry Prasad, 2000). Primary, secondary or digested sludges are amenable to this treatment but it is most effective with raw primary sludge as in the Greater Moncton Wastewater Treatment Facility. Future planning focuses on compost and products derived from compost such as mulches and manufactured soils. For long term marketing and usage flexibility, it is desirable to produce a Class 'A' compost (see Table 6). The Greater Moncton Sewerage Commission's (GMSC) facility has always produced biosolids that meet metal concentration limits for application on agricultural land and for land reclamation. However, copper exceeds the acceptable limits in biosolids for the production of compost for unrestricted use.

An on-site demonstration project was conducted to assess the suitability of the BIOSOL process to extract metals from GMSC's raw sludge to the levels required for composting (Class A). A single-stage BIOSOL process was operated for a period of 27 days with a S° concentration of 4g/L. The results are presented in Table 6. The pH dropped from 5.3 to 2.0 on day 24 and stayed around 2.0 until the termination of the experiment. Metal solubilization efficiencies ranged between 12.5 and 77% (Table 6). The finished product (i.e. leached sludge) contained about 52 mg of Cu/kg and could meet CCME Class A guidelines. Thus, for the GMSC sludge, the single-stage system was adequate to achieve the requirements for biosolids used to produce compost for unrestricted use.

Table 6 Comparison of metal concentrations

Meals	Primary Sludge Mg/kg	*Leached Sludge mg/kg	Metal Solubized %	Compost CCME** Class A mg/kg	Land Application CCME** Class B mg/kg	Land Application NB*** Guideline mg/kg
Arsenic	2	1	50	13	75	75
Cadmium	0.6	0.2	66	3	20	20
Cobalt	2.4	1.6	19	34	150	150
Chromium	16	13	33	210	1060++	1100
Copper	226	52	77	100	757++	850
Mercury	0.65	0.24	63	0.8	5	5
Molybdenum	3.6	3.7	-	5	20	20
Nickel	8	7	12.5	62	180	180
Lead	37.0	26	30	150	500	500
Selenium	2	1	50	2	14	14
Zinc	322	174	46	500	1850	1850

*After 27 days to reach pH 2.0. ** Canadian Council of Ministers of the Environment.
***Province of New Brunswick ++BNQ standard; not provided in CCME
Source: CCME Compost Standards for Canada, 1993.

Future direction

Following the successful demonstration of the single-stage BIOSOL process to remove metals to the levels suitable for producing compost, GMSC plans to install a pilot scale batch plant. The upcoming work will be used to establish operating parameters such as reactor sizing, minimum sulphur dosage, retention time, dewaterability, metal reduction and pathogen reduction.

The conversion of sludge from a waste product to compost suitable for unrestricted use will allow the Commission to access more markets in their biosolids beneficial use programmes.

Integration and sustainability

The sustainability of biosolids management is totally dependent on the ability to produce a consistent product and define markets that will perform over the long term, the integration of the biosolids programmes with changes in the liquid wastewater stream and the cumulative effects of the programmes. In order to achieve full sustainability, the Commission believes it must control the process to a high standard be it lime stabilization or especially the compost process. In future, the Commission will be developing its own long term integrated compost site that will incorporate strict process controls combined with an on-site research center, partnership with the local university, product development and well informed targeted markets.

Conclusions

As part of the sustainable development objectives, biosolids must be regarded as a recyclable resource that can be put to beneficial use. Many traditional disposal options such as landfilling and incineration are becoming less acceptable from an economic and environmental standpoint. As a result, many jurisdictions are moving quickly to develop a long term beneficial use strategy for wastewater sludge/biosolids that is cost effective and environmentally acceptable. The Greater Moncton Sewerage Commission is also moving in this direction with highly successful results in its management and beneficial use of lime stabilized biosolids from the Greater Moncton Wastewater Treatment Facility.

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