Municipal biosolids: What is the best option for the climate?

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Reducing greenhouse gases

Climate Change is a confirmed reality. The scientific consensus also pledges that we must reduce greenhouse gas (GHG) emissions to limit the expected temperature increases. This battle demands immediate and concerted action by all involved.

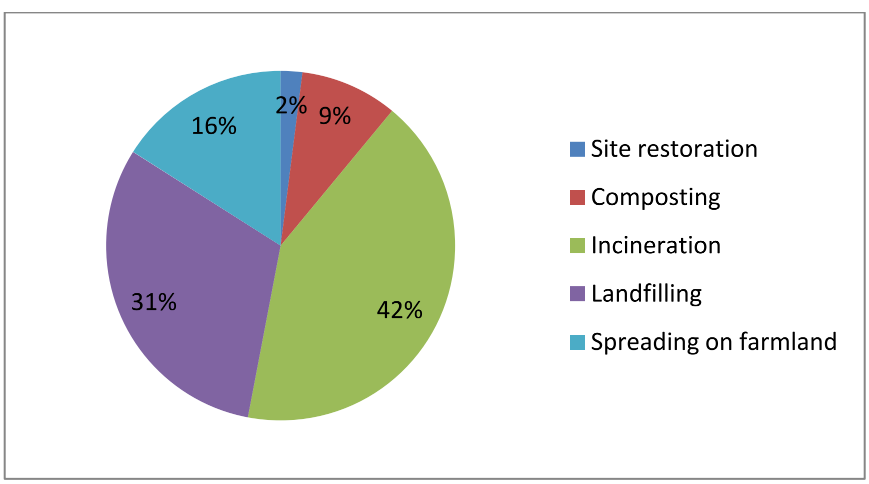
In 2007, Québec's government added new measures and funds to its already existing climate change action plan (Plan d'action sur les changements climatiques (PACC)). This plan aims at eight sectors, including waste management and energy recovery from biomass. The government objective is to reduce GHG emissions by 20% (from the levels of 1990) by the year 2020.

In 2011, in addition to the PACC, Québec set other GHG reduction objectives in its new policy on residual material (Politique québécoise sur la gestion des matières résiduelles) which entails: the complete ban of organic matter (including municipal sludge) from landfills or incineration by the year 2020 and 60% valorisation by 2015, either by biogas generation, composting or the spreading of fertilizing residual materials.

Sludge management in Québec

About 4 million metric tonnes of putrescible organic wastes, of urban or industrial origin, are touched by the new policy banning landfill use. In the specific case of municipal biosolids, the ministère du Développement durable, de l'environnement et des Parcs (MDDEP) estimated that in 2007, only 27% of the 910 000 available tonnes were used benefiacially as fertilizers, a far cry from the 60% to be reached in 2015. This situation is due to the low costs of landfilling in Québec as well as the presence of sludge incinerators in large cities. Figure 1 shows the proportions of municipal sludge used by treatments in Québec, deserving 7 687 423 inhabitants.

Figure 1. Municipal sludge treatments in Québec in 2007



As of now, it is mainly medium-sized cities (Gatineau, Sherbrooke, Saguenay, Victoriaville, Saint-Jean-sur-Richelieu, etc.) that significantly contribute to the volume of municipal biosolids deviated from elimination in Québec.

The city of Saguenay and biosolids

Saguenay had to find alternatives to burying as early as 1991, as the closest landfill (Laterrière) was about to close. The use of biosolids as fertilizers was therefore preconized by combining spreading on farmland and composting.

The objective of 100% beneficial use of municipal biosolids was reached within three years of the beginning of the project. Seventy-five percent of the biosolids are of residential origins compared to 25% from commercial, industrial and institutional. No negative impacts were reported ever since the program was put in place, except for occasional bad odour complaints. The coordinator for the agricultural beneficial use project, M. Guy Gagnon, states that 22 600 tonnes are produced and beneficially used each year, which in total translate to 300 000 tonnes of organic matter diverted from landfills since the beginning of the program. The money saved compared to burying is considerable. Today it would cost more than 2,2 million dollars to bury these biosolids, as opposed to 780 000$ annually for agricultural valorisation and composting. The twenty or so farmers that have access to these biosolids too are making some considerable savings. Delivered for free by the city of Saguenay, the spread biosolids allows them to increase their land's yield by 46% according to the evaluation of the former Régie des assurances agricoles du Québec (RAAQ; today named la Financière agricole), while contributing to soil fertility and saving on mineral fertilizers.

In Québec, only the biosolids corresponding to high quality standards can be spread onto farmland, respecting good agricultural and environmental practices. All these activities are overseen by qualified professionals and subjected to strict follow-ups.

Given that the elimination of organic matter will not be permitted in Québec passed 2020 and that the economical advantages of valorisation appear important, Saguenay's biosolids management is a very interesting model to analyse.

Carbon footprint of biosolids management

In 2010, Saguenay gave the mandate to the Université du Québec à Chicoutimi (UQAC)'s Chaire en éco-conseil to evaluate the carbon footprint (sources' overall emissions minus the sinks and the avoided emissions) of the different ways to treat biosolids, from the primary data available and in a life cycle perspective, i.e., from the factory to the end of life (gate to grave).

Saguenay's beneficially used biosolids originate from three treatment plants: Jonquière (43% of the sludge), Chicoutimi (46%) and La Baie (11%), which corresponds to about 100 000 inhabitants. Every day 102 500 m^3 of waste water are directed towards those plants, generating 22 600 m^3 of biosolids to be disposed of.

In a simplified manner, biosolids are produced in four steps: 1) grit is removed from the waste waters; 2) the sludge is decanted; 3) the supernatant is separated from the sludge; 4) the sludge is dehydrated and thickened to 15% of dried matter (with the use of a polymer), before being transported for use. None of the studied alternative modes of disposition significantly altered this process and the study did not take into account the carbon footprint of these four steps.

Literature is scarce in terms of GHG evaluation of municipal biosolids management. Here are two examples: the report done by Enviro-Accès for RECYC-QUÉBEC (2011) that compared the option of composting to landfilling and Sally Brown of Washington University's work on all the available options.

The emissions pertaining to the valorisation process were accounted for following the good practices of the Intergovernmental Panel on Climate Change (IPCC, 2006) and the most recent literature on waste waters. The BEAM (Biosolids Emissions Assessment Model) software developed by the SYLVIS consulting firm for the Canadian Council of Ministers of the Environment (CCME) was used to evaluate the direct and indirect and other indirect (scope 1,2 and 3) emissions from the different steps of treatment and valorisation: stocking the sludge, cooling and thickening, aerobic and anaerobic digestion, dehydration, thermal drying, alkaline stabilization, composting, burying, combustion, agricultural valorisation and transport, as well as potential leaks, sequestration and chemical fertilizers replacement. This software allowed the creation of a carbon footprint scenario for each thinkable mode of disposal, or their combination, based on the city of Saguenay's primary data.

Before being used, biosolids are subjected to a quarterly characterization. According to the results, they either serve for agricultural valorisation or as compost.

Scenarios of biosolids management

Currently, 65% of Saguenay's municipal sludge are used by spreading on farmland and the 35% remaining is composted during winter, as spreading is prohibited during the cold season and the prevailing climatic conditions (below freezing point) makes it difficult to store the sludge at the farm.

To figure out which management option had the lesser impact, five scenarios were modeled to compare with the actual situation:

1) 100% spreading on farmland
2) 100% composting
3) 100% landfill
4) 100% incinerated at 780°C. The temperature in the incinerator largely determines N_2O emissions. These conditions are similar to those of the sludge incinerators found in Montréal and Longueuil
5) Methanazition treatment before agricultural valorisation and composting (data for the methanization originated from the methanization unit of Gatineau).

Carbon footprint of the current scenario at Saguenay

To evaluate emissions produced by all the different scenarios we asserted that:

1) the quantity of biosolids is that of the year of reference 2010, i.e., 22 600 m^3
2) sludge characterization is similar to that of 2010.

Table 1 presents a summary for the direct emissions/level 1 (emitted on location), indirect/level 2 (energy is used on location but the emissions are produced elsewhere (e.g. electricity)), and other indirect/level 3 (where the emissions can be accounted for by a third party (e.g. fertilizers emissions tabulated by a farmer)).

Over the course of one year, Saguenay's net emissions are almost null (54 tonnes/y or 2,4 kg CO_2e/ tonne) for levels 1 and 2, required for inventory and carbon credits obtainment. In terms of carbon footprint, with the replacement of fertilizers taken into account, the avoided emissions are 655 tCO_2e/y (-29 kg CO_2e/tonne).

The majority of emissions identified for the actual scenario come from the anaerobic decomposition of fertilizing matter during composting. These conditions cannot be thoroughly avoided and are taken into account by the software. During spreading, biosolids are laid in thin layers over the land, minimising emissions and nitrogen (N) loss; making biosolids good replacements for nitrogen fertilizers.

Table 1. Summary of emissions for the current scenario

Agricultural valorisation (65%)	tCO_2e	Composting (35%)	tCO_2e
1-Process direct emissions			
Transportation	80	Transportation	41
Machinery	31	Machinery	88
CH_4 emissions	67	CH_4 emissions	221
N_2O emissions	47	N_2O emissions	360
Sequestration	-599	Sequestration	-287
2- Indirect emissions linked to energy use			
Electricity consumption	0	Electricity concumption	5
3- Other indirect emissions			
N replacement	-393	N replacement	-193
P replacement	-81	P replacement	-42
Total (1 + 2)	**54**		
Total (1 + 2 + 3)	**-655**		

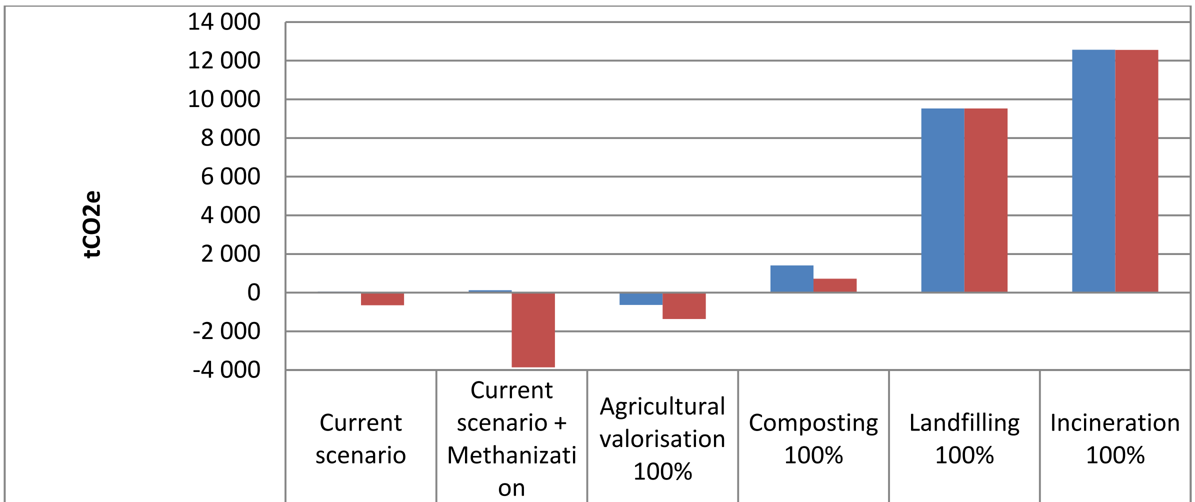
The different scenarios

To compare the options we postulated that:

1) disposition and use sites (landfill, incineration and methanization) were at the same distance than the composting site. In fact, the landfill is less than 5 km away from the composting site and potential incinerator or methanizer would most likely be built in the vicinity;
2) all the processes before loading the sludge are equivalent.

Figure 2 compares the emissions in tCO2e for the five scenarios.

Figure 2. Comparison of annual emissions for five different scenarios of biosolids management for the city of Saguenay.



	Current scenario	Current scenario + Methanization	Agricultural valorisation 100%	Composting 100%	Landfilling 100%	Incineration 100%
Inventory	54	127	-635	1 409	9 532	12 562
Carbon footprint	-655	-3863	-1 364	719	9 532	12 559

Beneficial use through 100% spreading on farmland is the best solution as carbon sequestration in the soil and the reduction in fertilizers used would translate in 1364 tCO2e avoided per annum. Composting (100%) is less advantageous as anaerobic conditions cannot be avoided in swaths.

In the case of technical landfill, sludges are placed in anaerobic conditions. The majority of GHG (69%) are emitted during the first three years. As the hermetic cells take around 2,5 years before closing, the majority of methane (CH_4) leaks cannot be burnt.

Incineration is last in terms of GHG emissions. These are notably due to the N_2O (potential global warming = 310, established reference since Kyoto and the carbon market on IPCC 1995) and to fossil fuel combustion. Note that the BEAM model uses N_2O emission factors based on recent Japanese studies and takes into account combustion temperature, unlike IPCC data based on older sources. Raising the temperature to 850°C would reduce N_2O emissions by 72% but would markedly increase fossil fuel consumption. In the specific case where the heat produced during incineration is reused, the emission balance sheet could improve and incineration would become less damaging than landfilling in terms of GHG. However, incineration requires lower humidity levels (70% instead of 85%), which would entail buying expensive equipment, a hike in electricity consumption and other technical constraints for the treatment plant. The small difference in the incineration carbon footprint and the inventory data comes from the credits accorded for the fertilizing values of the ashes.

Treating the sludge beforehand by methanization, i.e., biogas production under controlled conditions, offers the best carbon footprint balance sheet. The advantages are threefold:

1) there are no leaks during decomposition
2) biogases can be used within the plant or by others
3) digestates can be used for agriculture use

Figure 2 results take into account the use of all the biogases as substitutes and use of all the digestates. The balance sheet of direct and indirect emissions is not as good as the carbon footprint because leaks occur during biogas combustion. Methanization also largely decreases biosolids' odours. However, for practical or economical reasons, it is sometimes difficult to valorise the produced biogases, as is currently the case for the majority of the US treatment plants equipped with anaerobic digesters.

So it is possible?

Saguenay's actual mode of biosolids management presents a negative carbon footprint (-29 kgCO_2e/tonne). In fact, none of the studied scenario was as advantageous as the current management, except the one with the valorisation of a higher proportion of biosolids by spreading on farmland. The positive impacts of this scenario would double compared to the current situation but is of low interest due to the difficulties related to winter storage.

The use of biosolids in agriculture, be it before or after composting or methanization, significantly contributes to the decrease of GHG emissions compared to landfilling and incineration. The intended restrictions prescribed by Québec's government in its new policy "Politique québévoise de gestion des matières résiduelles" is in accordance with the PACC and goes along the precautionary principle relative to climate change.

In the perspective of a complete ban on landfilling and incineration of organic matter starting in year 2020, a combination of agricultural use and composting represents the best solution. The addition of methanization in sludge treatment is also an interesting avenue, although costly, to avoid more GHG emissions. But this implies that all the biogases be used in replacement of other fossil fuels.

By extrapolating Saguenay's primary data to all the municipal biosolids in Québec, one can estimate that GHG direct emissions for this sector were 550 ktCO_2e in 2007. Under the best conditions, the streaming of all the municipal biosolids destined to landfilling and incineration towards agriculture use and composting could reduce Québec's emissions by 470 to 520 ktCO_2e in 2020. This is an attainable objective as both France and Norway are currently spreading 70% and 90% of their municipal biosolids onto their soil, whereas the US valorises about 50% of their fertilizing materials.

Nonetheless, a great number or difficulties remains before achieving this potential, notably at the social acceptance level in certain areas and transportation related costs. Also, Montréal and Longueuil already have invested in incinerators for the disposal of their sludge. Using the energy produced with these existing equipments is feasible but represents major economical and technical challenges to reduce N_2O emissions meanwhile yielding positive global energy balance sheet. In fact, unlike wood and bark residues, municipal sludge have high water and nitrogen contents. Methanization of these cities' biosolids combined with other urban residues could represent a better solution than combustion in terms of GHG emission reduction.

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Figures

Table

Epigraph's suggestion

In 2011, Québec's government embraced GHG reduction objectives in its new policy on residual material management: be it the complete ban of organic matter in landfills by the year 2020 and 60% valorisation by 2015, either by biomethanization, composting or spreading of fertilizer residues.

In the perspective of a complete ban on burying and incineration of organic matter by year 2020, combining agricultural valorisation and composting is the best option.