Innovative energy recovery and reuse at a Canadian municipal wastewater biosolids composting facility

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Abstract: The Greater Moncton Sewerage Commission (GMSC) has developed an innovative energy recovery and reuse system as part of its new Biosolids Composting Facility. The GMSC composting process, carried out on an outdoor concrete pad, combines bottom aeration and a proprietary cover system referred to as the GORE TM Cover System. The challenges of winter operation required unique solutions. The cornerstone of the GMSC system is an innovative heat recovery and heating system using glycol/water solution in a polyethylene pipe system installed in the concrete slab. This paper provides an overview of ongoing research and presents pilot testing results using this system to extract heat from the composting process to be used to facilitate winter operation by melting snow and ice and keeping the cover free from the concrete pad. Using the GORE TM Cover System, and in concert with the GORE TM team, the GMSC has also successfully dealt with many challenges dealing with a design suited for winter operation. The implementation of a hold down strap system for high wind conditions, housing of the blowers in an enclosure, pre-heating of blower air were all integrated with the system.

Keywords: Biosolids, energy recovery, sludge, GORE TM Cover System

INTRODUCTION

The Greater Moncton Sewerage Commission (GMSC) was created in 1983 with a mandate to implement a regional Wastewater Collection and Treatment System for the Atlantic Canada communities of Dieppe, Moncton and Riverview. The serviced population is approximately 95,000. The current wastewater conveying and treatment assets of the GMSC consist of 30 kms of collector sewers and tunnels, eight (8) sewage lift stations, one large pumping station and the Wastewater Treatment Facility (W.T.F.). Located in Riverview, this 115 000 m3.d -1 facility provides chemically assisted primary treatment and incorporates sludge dewatering, alkaline treatment and handling facilities. Over the years, the GMSC has developed several land based resource programmes utilizing lime stabilized biosolids and it has also developed composting techniques in cooperation with the private sector. With the dual purpose of controlling the treatment of its biosolids, at a very high quality, and addressing the public’s concerns and perception of biosolids, the GMSC constructed its own unique composting facility. This new composting facility, now operational, has been constructed on a newly acquired property located approximately 10 kms from the W.T.F. The design of this facility is based on a low energy usage approach and incorporates an innovative heat recovery and energy management in the composting of biosolids in cold climate. This paper describes the principal aspects of this energy recovery and management system which is intended to improve the composting operation on an open air concrete pad in a cold climate application. A pilot testing programme was setup in 2006 and 2007 to gather data on the practical applications of this system, on the integration of other energy sources and to determine the best configuration for equipment, piping, tanks and pumping. This paper summarizes the findings of work done to date which demonstrate that the concept can become a practical feature of an overall energy management system for a Composting Facility.

HISTORY OF BIOSOLIDS MANAGEMENT IN GREATER MONCTON

Raw sludge from three large floculating clarifiers is dewatered via high speed centrifuges producing a normal sludge cake of approximately 30% solids by weight. Hydrated lime is added to the dewatered sludge via a pug mill. The resulting biosolids are carried by open conveyor belt to a shipping building for subsequent haulage to composting and beneficial use activities. The GMSC produces approximately 210 wet tonnes per week of biosolids, resulting in an annual production of 11,000 wet tonnes per year.
Over the years, the GMSC has developed several land based resource programmes utilizing lime stabilized biosolids, namely: sod farming, landfill cover, open pit mine site rehabilitation, golf courses, tree farming, and as a soil additive in agriculture. The limited time frame during which direct land application can be used due to seasonal conditions posed a real challenge to the day to day operation of the plant. The GMSC needed to further stabilize the material for storage and handling to be nuisance free. Consequently, over the years, GMSC developed composting techniques to the point that it currently processes all of its biosolids into compost.

Today, this compost is used in horticulture as a mulch, in the manufacture of topsoil, and in land reclamation projects. The GMSC is involved in various land reclamation projects, with the largest being at Canadian Forces Base Gagetown some 200 km from the plant.

THE GMSC COMPOSTING SYSTEM

The composting process used by the GMSC combines bottom aeration and a proprietary cover system referred to as the Gore™ Cover System. The key to the composting process is the mix ratio of biosolids and wood wastes consisting of pieces of bark and wood chips. The bulking material provides a source of carbon but is essential in obtaining a porosity that will facilitate the migration of air for a thorough and complete aerobic process. In this application, the process can generate temperatures of over 70°C for an extended period of time. Windrows are 50 metres long, 8 metres at the base and 3 metres high. During the active phase, these are turned three times by a large loader.

The main process is carried out on an outdoor concrete pad of 56 metres by 115 metres. This large pad is laid out to have four (4) compost windrows on the north portion of the pad (56m x 50m) and four (4) windrows on the south portion of equal size. The space between the two sets of windrows is 15 m wide. This is a modular design so that additional pads of equal size could be constructed as needed. Two air trenches per compost windrow provide air and allow drainage of excess leachate and water. These extend the whole length of the windrow and are spaced 1.25 metres apart.

The north and south portions of the pad end with a push wall (retaining wall) which facilitates loader operation. Aeration blowers are installed on the back side of the wall, and one fan is connected to its two respective air trenches through a yee. At the back of the wall, an enclosure shelters the electrical and control equipment of the composting process. At ground level, there is an open grating platform while the below ground level houses piping, headers and valves associated with the Glycol heat recovery and reuse system. The pads (north and south) slope towards the centre space. Water in the aeration trenches drain to the sanitary sewer through a siphon air lock. Installation and removal of the Gore™ cover is done with a mobile winder also referred to as a Power Winding Monster (PWM).

The Gore™ Cover System has been applied successfully in several countries primarily for green waste composting. It is preferable to operate this system outdoors as it eliminates the need for large buildings and the extensive ventilation system required in a closed environment. Even though odours are effectively controlled by the process, turning of the windrows results in considerable moisture vapors being released making it difficult to control within a building enclosure.

AN INNOVATIVE COMPOST HEAT UTILIZATION SYSTEM

Challenges of a Cold Climate Operation

The Gore™ Cover System is now well proven and is effective at controlling odours, retaining heat, controlling the addition of moisture from excess rain, and draining leachate away.

During the planning period, the GMSC design and operational team recognized challenges that should be addressed in the cold Canadian climate. These are summarized as follows:

1. Snow, as well as melting snow and ice can build up on the Gore™ Cover and in particular on the perimeter which is held down with weights. When it comes time to remove the cover to turn the pile, this ice and snow become a serious challenge to operators. It has to be broken off and removed manually without damaging the cover material. The cover perimeter also bonds to the surface due to the moisture.
2. Weights normally used to seal the perimeter of the cover to the surface usually consist of a fire hose filled with water. In a cold climate, this is not practical once frozen.

3. Wind is variable and of higher intensity in Eastern Canada as compared to many sites where this system has been used.

4. The blower normally installed on the back of the end wall would draw outside cold air. Cold air can be as low as -30°C in winter. Aside from impeding the composting process, this can result in freeze-up of the aeration trenches.

5. Following short durations of mild conditions, melting snow and/or rain can result in a sheet of ice forming on pad surfaces that are not in use. This makes it difficult to operate with the equipment and retards the composting process.

**Cold Climate design Features**

The solution developed by the GMSC involved the installation of a network of pipes in the concrete slab carrying a glycol/water solution. The network of pipes is made of NPS 1 Polyethylene Brine type pipes normally used in arena ice surface construction. These are spaced 100 mm apart and are installed in groups of two connected at the far end with a loop connector section.

These pipes are connected to headers in the pipe trench located behind the compost pad end wall (push wall). An open grating walkway is designed with ladders to access the lower piping/valving/header system while providing easy access to all aeration blowers, electrical boxes and control systems which are installed in the upper part of the enclosure.

The unique feature is that under each windrow, these pipes are connected to three sets of double headers. The central header and piping can be used to pre-heat the pad; however, its primary role is collecting heat from the core of the compost windrow. On either side of this central system, there are two zones with individual headers and piping to provide coverage from the edge of the compost heap to beyond the edge of the cover. These two edge sections of piping are primarily used to heat the perimeter for melting snow and ice prior to removing the cover during winter months. The overall design principal is that the heat produced from the composting process itself will be used to melt snow and ice on the edges of windrows.

The headers are connected in the enclosure to four carrier pipes which will separate the hot supply, cold return, cold supply and hot return. The design will allow any zone to be active or inactive by integrating motorized valves, pumps and a central storage system consisting of two large storage tanks. The glycol header and carrier pipe system within the enclosure dissipate heat from the composting process itself and reduces the need for pre-heating the blower air from external sources.

The GMSC design team also worked closely with representatives of GORE™ to improve the weigh down system used on the perimeter of the cover. Straps have been incorporated in the manufacture of the covers with special tie-down hooks installed in the slab at 5 meter intervals.

The above features have been effective in dealing with all of the challenges identified. Work is ongoing in evaluating these innovative concepts, quantifying benefits, and developing design/construction guidelines that could be integrated into future systems.

**Potential Benefits for this System**

The overall design is based on a minimum energy usage. The aeration blowers provide oxygen to the process to sustain itself. These are 2.4 H/P and normally operate 12-20 minutes every hour.

The Gore™ Cover System acts as an in-vessel system. Combined with maintaining aerobic conditions at all times, the cover acts as an insulation and a barrier against weather elements, and effectively controls odours. This system also eliminates the need for large ventilation, air scrubbing and biofiltration which are normally large energy users.
Integration of other Energy Sources

Large storage tanks and piping will be installed in the main operation’s facility. Heat will be captured from active compost windrows on an intermittent basis while its use on melting snow and ice will be used only when needed to remove a cover. On normal operation, heat will dissipate from carrier pipes and headers located in the trenches and help pre-heat blower air, thus minimizing the use of auxiliary air heating systems.

Future building heating and cooling will also be integrated into the large heat storage system.

Other sources of heat being considered are solar panels on the roof of the equipment enclosures and the burning of excess oversize wood chips from the screening operation.

Additional heating will be needed with the implementation of truck and equipment sheds, equipment facilities and administration space.

PILOT TESTING

Objectives of the Pilot Testing

Glycol piping was installed in the concrete slab and terminated in the piping trench. All piping has been connected to a header system which separates the core zone from the edge zones. A preferred configuration for carrier piping, pumping, valving and a storage reservoir has been designed. However, prior to completing this work and integrating operator controls, a pilot set-up was needed to evaluate the true potential of this concept and to provide information that could be used in the final design of pumping, piping, and valving arrangements.

The objectives of this first phase of pilot work can be summarized as follows:

1. Determine effectiveness of Glycol Compost Heat Recovery System in the operation of the GORE™ Cover System in winter.
2. Determine sustainable quantity of heat that can be recovered from the Composting Process.

Set-up of Pilot Testing

Preliminary pilot work was carried out in the winter of 2005-2006. This was followed by a new elaborate set-up for the winter of 2006-2007. This latest pilot set-up was installed at windrow No. 4 position and considered as a full scale model on one pile only. The pump having a capacity of 10 l/sec. would have the same capacity as the permanent system. The storage tank of 4000 litres represents the approximate volume needed per pile or one quarter of one large tank’s total volume. Piping and valving constructed of P.V.C. plastic was configured to circulate the centre zone only, the centre zone with the two edge zones, and the centre zone with one of the edge zones only. Flow monitoring at two key locations allows measurements and balancing in every line. Temperature measurement and data logging was provided at the tank outlet, heat recovery zone (pile core) outlet, and cold zone outlets.

DISCUSSIONS OF RESULTS

Effectiveness of Heat Recovery

The glycol in-slab piping system used by GMSC is a standard system used in arenas for ice surfaces or can be used to keep a slab warm. In the case of the GMSC, an external boiler could be used for heating the glycol as needed. The pilot testing was needed to determine if using the unique header configuration combined with the intended flow controls and storage would be effective at extracting heat from the “hot” zone of the compost heap. This recovered heat could then be used to melt snow and ice, to free up the cover from the slab, to pre-heat another pad and to pre-heat blower air. An intermediate storage system was simulated to determine if heat could be extracted on an intermittent basis while usage would be on the operational schedule.
During the initial installation of the glycol in pad system, piping was connected in series to provide a continuous system so that pressure testing could be done. Prior to connecting to the header system in the winter of 2005-2006, this temporary arrangement allowed the design team to configure one windrow in two zones. One pump would circulate glycol from the centre line of the windrow toward the west edge and return to the pump while a second pump would circulate glycol from the centre toward the east edge. From the centre, heat would be extracted from the first 3 meters (very hot zone) while heat would be lost on the last 3 meters strip before returning to the tank. There was no intermediate storage during this test.

Using this arrangement, testing was carried out on April 12, 2006 and then from May 1 to May 8, 2006. The May 1 to May 8 showed that the process stabilized as follows:

<table>
<thead>
<tr>
<th>Temperature Type</th>
<th>Temperature</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Temperature</td>
<td>47°C - 48°C</td>
<td></td>
</tr>
<tr>
<td>Heap Temperature (Compost in its active phase)</td>
<td>68°C</td>
<td></td>
</tr>
<tr>
<td>Heat Recovery Zone Water Temperature In</td>
<td>28°C</td>
<td></td>
</tr>
<tr>
<td>Heat Recovery Zone Water Temperature Out</td>
<td>37°C</td>
<td></td>
</tr>
<tr>
<td>Cold Zone Water Temperature In</td>
<td>37°C</td>
<td></td>
</tr>
<tr>
<td>Cold Zone Water Temperature Out</td>
<td>28°C</td>
<td></td>
</tr>
</tbody>
</table>

Using this arrangement, testing was carried out on April 12, 2006 and then from May 1 to May 8, 2006. The May 1 to May 8 showed that the process stabilized as follows:

During this testing period, it was observed that the exposed concrete surface and the area where the GORE™ Cover was sealed to the ground became free of snow and ice and dry. Enough heat from one pile can be extracted and used along the edge to achieve the objective. Water circulating at 37°C in the cold zone is more than adequate in melting snow and as the temperature dropped by only 9°C to 28°C. The flow rate during this pilot phase was low at 8 litres per minute providing a retention time of 3.3 hours in the heat recovery zone and 3.3 hours in the cold zone.

### Sustainability of Heat Recovery

The design of this system is to recover heat on an intermittent basis from all active composting windrows and to use large storage tanks for accumulation of the energy. Stored heat can then be used to pre-heat a pad before placing the mixture, to melt snow and ice on any of the piles, and possibly to pre-heat the blower air as well as other building floor slabs such as the equipment garage or office building.

This second test using the header configuration was carried out from March 3, 2007 to March 27, 2007. The circulation pump would run for 3.5 minutes so as to completely extract the hot water from the central zone of the heap and to replace it with tank water that had cooled down. The pump off time would allow the water to reach maximum temperatures. The off time was varied from 1 hour to 24 hours to determine trends. (Figure 1)

From this graph, we can see that the longer the off time, the higher the temperature will rise or the closer the glycol/water temperature will be to the compost windrow temperature. The maximum glycol temperature reached for off periods up to 24 hours is approximately 20°C less than the core of the compost heap. For this particular test, maximum closed loop glycol temperature reached 40°C while the compost heap remained at approximately 60°C and seemed unaffected by the heat extraction. At 4 hours and 6 hours off time, the maximum temperature reached was consistent for every cycle while the tank temperature also remained stable. At 12 hours off time, while the tank temperature remained stable there was a gradual slow rise in the overall maximum temperature of the glycol.
Figure 1 Temperature profile under various cycle time

Even though the system will be designed for maximum flexibility, it is important to find the rate of energy that can be extracted for each time off interval and at which interval this rate of heat extraction would be sustainable over several days. Based on these preliminary results, the heat that can be extracted was calculated as follows for eight (8) windrows on the active compost pad at 60°C. It has to be noted that temperatures normally remain above 65°C for extended periods.

<table>
<thead>
<tr>
<th>Time off Interval (hrs.)</th>
<th>BTU Recovery per Hour (BTU’s per hr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20,400</td>
</tr>
<tr>
<td>2</td>
<td>23,300</td>
</tr>
<tr>
<td>4</td>
<td>21,800</td>
</tr>
<tr>
<td>6</td>
<td>15,500</td>
</tr>
<tr>
<td>12</td>
<td>9,100</td>
</tr>
<tr>
<td>24</td>
<td>6,500</td>
</tr>
</tbody>
</table>

While higher temperatures are achieved at longer off time intervals, maximum BTU’s will be recovered at relatively frequent pump operation that is sustainable. It also appears from the graph that the 1 and 2 hour off time results in maximum temperatures decreasing indicating that this would not be sustainable if the energy extracted was used at the same rate. However, these results also indicate that 4 to 6 hours between pump cycle time allows enough time for water to reach maximum achievable temperatures considering the compost heap temperature. At this rate, there seems to be no effect on compost heap temperature due to heat extraction.

The above information will be used to develop design guidelines for the overall system of storage, piping, valving and control and will also be used in the planning of pilot work to be continued in the winter of 2007 – 2008.

ENVIRONMENTAL STEWARDSHIP IN ENERGY USE AND ENERGY RECOVERY

The beneficial use of wastewater treatment by-product (biosolids) needs to be integrated to the overall environmental strategy of any municipality.

Composting of biosolids can be a viable option especially if combined with other waste streams generated by the municipality such as green wastes. Other by-products of the forest industry, the farming community, fisheries, etc. can be incorporated to produce high quality composts. Value added products can be beneficial to the environment by displacing chemical fertilizers, reducing the need to excavate natural topsoils while it can be used to revegetate and re-establish forests thus improving water retention, and reducing greenhouse gases.
The composting system with heat recovery requires much less capital investment and resources than most industrial type biosolids processing/treatment/thermal destruction systems. The operation only requires low energy input as large ventilation equipment, air scrubbing, blowers, biofilters, heat treatment systems are not required. The GMSC System uses low energy aeration blowers, small pumps and motorized valves to complete the entire process. Piles are turned using a high capacity loader only three (3) times during the two month intense composting phase. Long haul of biosolids which are over 70 percent water is also avoided with a composting facility in close proximity to the Wastewater Treatment Facility which further avoids burning of fossil fuels by excessive trucking.

REFERENCES


