Leachate Treatment Pilot Plant
Calgary, Alberta

October 2015

Submitted to: Consulting Engineers of Alberta

Full Project Description

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One of the biggest challenges facing municipalities is how to handle landfill leachate, the black, foul-smelling liquid that may contaminate soil and groundwater, and is costly to manage and treat.

In the late 1990s, the City of Calgary began managing leachate from its East Calgary Waste Management Facility (WMF) by collecting it in collections sumps, extracting it using City-operated vacuum trucks, and trucking it to the municipal wastewater treatment plant (WWTP) for treatment. Leachate contains a wide array of contaminants, including heavy metals and many organic compounds that require a significant amount of oxygen to break down (measured as biochemical oxygen demand or BOD). While the BOD concentration of municipal wastewater is typically about 300 milligrams per liter (mg/L), landfill leachate can be at least 10 times that concentration or more. Discharging untreated leachate into the municipal WWTP can potentially disrupt the treatment process with the sewage, and result in failing surface water discharge standards. Also, it may require time for the microorganisms to recover from the adverse organic loadings and for the plant to return to normal operating conditions.

With the potential impact of City's landfill leachate on WWTP operations, The City's Waste & Recycling Services took a proactive approach, by investigating the options to treat the leachate before discharging it into City sewer lines. In 2008, CH2M was retained to conduct bench-scale testing of leachate from the East Calgary WMF to determine the most appropriate pre-treatment processes to achieve compliance with the Calgary Sewer Bylaw, which regulates discharge to The City's wastewater collection systems. Results of the bench-scale tests indicated that leachate from all landfill areas tested could be treated using chemical precipitation and biological treatment processes and would satisfy the Sewer Bylaw discharge standards, with the exception of the criterion for boron concentration. An additional treatment process, such as reverse osmosis (RO), might be required to reduce levels of boron below the Sewer Bylaw concentration limit of 5 mg/L.

Following the bench-testing, The City decided to conduct a long-term pilot study to evaluate selected technologies for leachate treatment at the site. The overall goal was to evaluate the respective technologies' effectiveness in achieving compliance with the pre-treatment standards for discharge to Bonnybrook WWTP, or, alternatively, the water quality guidelines for direct discharge to surface water.

In 2011, The City retained CH2M to develop a conceptual/preliminary design of a leachate treatment pilot plant that would be capable of removing metals, organics, reduce nitrogen forms, boron, and dissolved ions. Specifically, the pilot plant consisted of three treatment operations, which would be carried out in the following order listed:

- **Step #1:** Chemical precipitation using either a high density sludge (HDS) or conventional hydroxide precipitation (CHP) process
- **Step #2:** Biological treatment using a membrane bioreactor (MBR) process
- **Step #3:** Membrane separation using a two-stage reverse osmosis (RO) process

From concept development through to commissioning and operations of the pilot plant, CH2M drew on the expertise of its solid waste management specialists, as well as industry-leading wastewater treatment specialists – one of them a pioneer in the development of the biological nutrient removal process used in MBR.

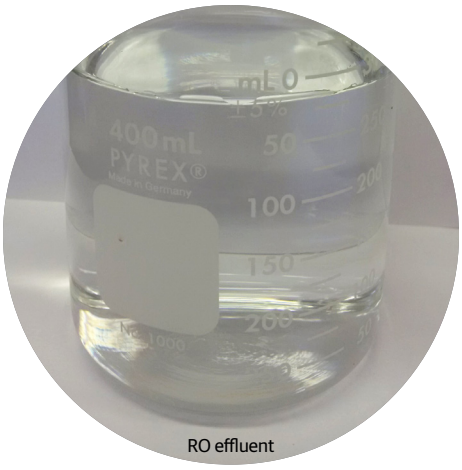
The City then contracted with Dynatec Systems, Inc., a specialized firm located in New Jersey, to complete the detailed design and fabricate the trailer-mounted pilot system. The pilot plant was installed next to an existing Leachate Tank Farm at the East Calgary WMF and commissioned in early 2014.

The Concept

Use the latest wastewater treatment technologies to treat landfill leachate in a pilot plant at the City of Calgary's East Calgary Waste Management Facility, then test the use of the treated leachate as process water and for irrigating plants and trees to enhance the environment – thereby "greening" the landfill.

Objectives for the Pilot Plant

Since the spring of 2014, City staff have been operating the Pilot Plant, with CH2M providing operations support. The City had identified several objectives for the project:



RO effluent

- **To determine how effective the installed equipment and processes are at treating very concentrated leachate.** This involves pushing the plant's limits by "shocking" it. In stress tests with very concentrated leachate (approximately BOD 3,000 mg/L), the plant failed due to limited dissolved oxygen. However, further testing has shown that, with the present configuration of the processes, it is possible to treat leachate with concentrations up to 2,000 mg/L BOD – a level that far exceeds the capabilities of a typical municipal sewage treatment plant.

- **To determine which of the processes will yield the best results while effectively handling the wastewater.** Each of the three treatment processes addresses a specific treatment requirement:
  - HDS removes the heavy metals that have the potential to kill the micro-organisms used in the MBR process. Over the past year, however, the team has discovered that it is possible to treat the leachate to reasonable standards without the HDS process.
  - MBR is essential to remove the heavy organics and ammonia loading that is still in the leachate after the HDS treatment process. This cannot be fed directly into the RO process, as it will foul or decommission the RO membranes.
  - RO is essential for removing boron and total dissolved solids (TDS), including lowering alkalinity. Although the end-product following MBR may be useable, the RO-treated water is more versatile for re-use applications, such as process water or for irrigating plants.

- **To identify potential uses for the effluent treated leachate.** CH2M is working with The City to evaluate how to handle the waste generated from the processes and, at the same time, to determine how to put the process water – particularly the RO process effluent – into beneficial use. Since only minor modifications to the plant would be required to reuse the RO effluent as the process water in the facility's daily operations, plans are now underway to make this possible.

Any Questions?

Why Not Recirculate the Leachate?

In many landfills, the leachate is recirculated by pumping it back onto the landfill through injection systems or infiltration trenches. Although this approach provides a simple, short-term solution, in the long-term, the recirculation systems can become clogged or bio-fouled, leading to "plugging" of the piping where the leachate has been applied. When this occurs, the leachate can seep out and lead to contamination. Removing and treating the leachate minimizes the risk of contamination and plugging.

Leachate treated in the pilot plant already more than meets The City of Calgary's Sewer By-Law requirements.

Why Not Use Untreated Leachate for Growing Trees?

Many other landfills are using their untreated leachate to feed trees on the site. Although the trees will grow, there is no disputing that untreated leachate contains many contaminants that are potentially harmful to both plant and human health, depending on the levels of concentration of the heavy metals.

Studies have shown that trees and plants have the ability to "lock up" heavy metals and other contaminants within their fibres. When the tree or plant has reached the end of its lifespan, these locked up contaminants can easily be released into the environment. When composted, these chemicals may contaminate the soil; when incinerated, they could pollute the atmosphere.

Because the noxious chemicals and other compounds have been removed from treated leachate, using it to feed horticultural plants and trees provides an opportunity to preserve their health while protecting the environment for future generations.

How Would this Work in Winter?

Treated leachate can be stored outdoors, year-round, in lined storage ponds similar to stormwater ponds. In winter, treated leachate from below the ice could be pumped into City greenhouses next to the landfill and put to good use – for example, to irrigate horticultural plants for spring planting by City Parks. The City could also realize further savings by using electricity generated by the Landfill Gas Facility on the East Calgary WMF site. The same would be true for treated leachate being used as process water.

Plant an Idea – Build a Green Future

The pilot plant at East Calgary is operating on a small scale and is now able to treat approximately 12 cubic metres of leachate per day. A full-scale facility for East Calgary alone would have to treat between five to ten times that volume daily to keep pace with landfill needs. The volume of leachate will be significantly greater when all three of the City's landfill are taken into consideration, and will be even greater if the landfill is not capped.

Sending such a volume of treated leachate could hydraulically overload the WWTP, at a time when all of Calgary's wastewater treatment facilities are already challenged to keep up with the volume and treatment capacity demands associated with population growth. Keeping leachate out of that picture altogether makes sense:

- Treating leachate at its source would save taxpayers' money by reducing capital infrastructure costs (upgrades to WWTPs and expansion of sewer conveyance systems, if needed) as well as long-term operating costs.
- Using the treated leachate as a resource to "green up" Calgary offers a sustainable solution that will enhance the environment and transform the landscape of the landfill.

Projects like the Leachate Treatment Pilot Plant represent a paradigm shift – from thinking of leachate as undesirable waste to seeing it as a valuable resource with the potential to beautify the environment and enhance the quality of life for Calgarians.

The Greenhouse: Our Testing Ground for the Leachate Treatment Effluent

During the spring/summer of 2015, The City and CH2M began feeding leachate from the MBR and RO effluent to a small greenhouse adjacent to the pilot plant. The greenhouse itself is a modest structure, constructed from recycled materials – glass from the demolition of an old hockey rink, diverted waste wood from the landfill, and old television glass screens. Discarded household sinks were diverted from the landfill and serve as containers for saplings. With the greenhouse right next to the pilot plant, we have been able to evaluate how horticultural plants and trees respond to the different qualities of treated leachate water.

We selected a number of plant and tree species for testing, choosing them based on their tolerance to drought, cold, heat, and/or salt, as well as availability from a City Parks supplier. These included the hardy Dusty Miller – which tolerates drought, cold, heat, and salt – along with begonias, petunias, pansies, and snapdragons.

We did not expect success with the plants fed with the HDS effluent water, since they would not be able to survive its high concentrations of heavy metals, organics, and ammonia. Our experiments confirmed this: the plants died.

We knew from the chemical analysis of MBR effluent water that it contains high concentrations of total dissolved solids (TDS) – as high as 7,000 mg/L. Its average alkalinity has been in the range of 3,000 mg/L, significantly higher than The City's fresh water level of about 125 mg/L. Horticultural plants typically do not respond well to either alkalinity or salts, so the plants fed with MBR effluent water did not fare well.

However, the plants fed with RO effluent flourished. The TDS content of this process water was low – 20 mg/L on average (compared to The City's water average of 200 mg/L) – and the alkalinity averaged 18 mg/L. The Pilot Plant operators were particularly impressed by the quality of these plants, which they attributed to the very low alkaline levels.

In the pilot plant's first year of operation, the focus has been on getting the greenhouse up and running and testing horticultural plants. The plants provided a quick, visual gauge of our successes and failures with the various effluents. The testing with trees is a longer-term commitment that requires planning and patience but will yield greater year-round rewards. The evergreen saplings now growing in salvaged kitchen skinks can be the key to the eventual greening of Calgary's landfills.

Assessing the Economics of Leachate Treatment

Although advances in treatment technologies allow us to treat a wide range of liquid wastes, these technologies all come at a price. CH2M and The City decided that one way to reduce costs without sacrificing the treatment objectives would be to eliminate at least one of the three treatment steps, so we began experimenting with this possibility in early 2015. Since that time, the HDS process in the pilot plant has been bypassed and raw leachate is fed directly into the MBR process. We have confirmed that, given the existing quality of leachate, the MBR process is able to treat the organics and ammonia, without being impacted by heavy metal concentrations. This would suggest that the MBR process would be a feasible selection for the eventual design of a full-scale leachate treatment plant.

RO technology presents its own challenges. Even though the effluent quality of RO water surpasses The City's sewer bylaws, the remaining RO waste (referred to as RO concentrate) is a watery substance with a very high concentration of TDS. The equipment to evaporate this water requires a significant amount of energy, along with large capital, and other operating and disposal costs. From an economics perspective, the RO process is not a favorable option for integration into a full-scale design, as managing the concentrate is very costly and can still impact the environment. However, since the RO treatment equipment is already in place at the plant, it could be used to mix a portion of the MBR effluent with RO effluent to reduce the TDS.

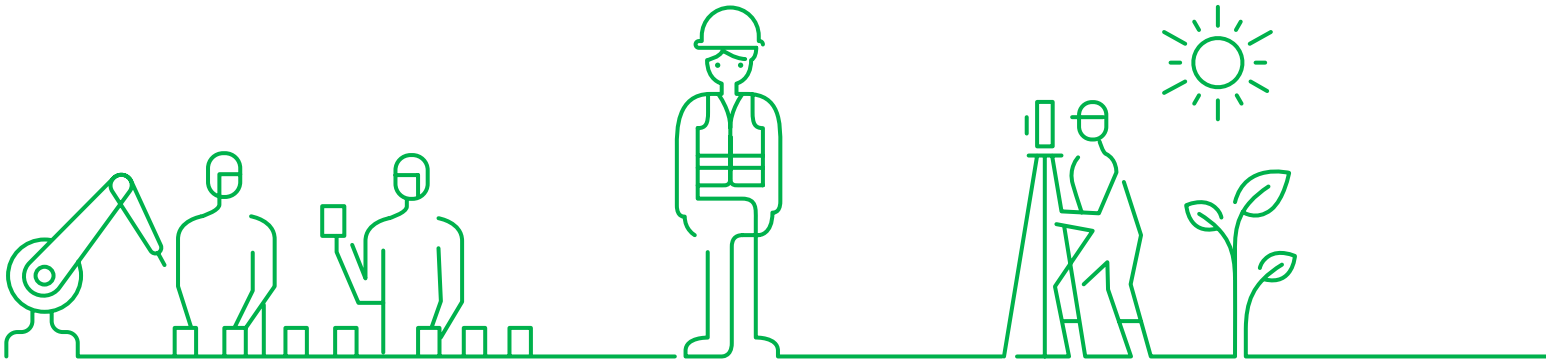
Innovation

Innovative thinking for an efficient facility on a small footprint. From the beginning, designing and fabricating the complex pilot plant required thoughtful planning. Designed to fit within a small footprint in order to ship it to Calgary from Dynatec Systems' headquarters in New Jersey, the plant is an intricate network of pipes, complex instrumentation, pumps, and process and water-holding tanks. Each of the three processes is housed in its own 12-meter-long shipping container, with a lined spill containment system underneath to control possible spill contamination. Innovation also came into play in the design and construction of the greenhouse. The use of repurposed and salvaged materials offered a creative solution that saved construction costs and reflected The City's conscious stewardship of the environment, as well as Waste & Recycling Services' mandate to manage waste.

Leading the way in the study of treated leachate. The City is one of the first municipalities in Canada to use a greenhouse study to examine the opportunities and the pitfalls of using treated leachate. The greenhouse has enabled the team to experiment with different types of plants and trees using different qualities of treated leachate water. Laboratory tests of soil and plant tissue samples provided empirical data to support the visual observations. Limiting the use to horticultural production avoided the potential for contamination in agricultural production (that is, food for humans and livestock).

Making good use of both stormwater and treated leachate water. Like leachate management, managing stormwater is a concern for all landfills, since stormwater has to be continuously captured and used or discharged away from the area to avoid overflowing and flooding the landfill and surrounding areas. An innovative option for the stormwater at the East Calgary WMF would be to mix it with MBR effluent from the pilot plant, thereby lowering the TDS and, possibly, alkalinity. In another City project at the Shepard WMF, CH2M has been developing and constructing low impact development (LID) areas for the beneficial use of stormwater at the new Organics Campus, thus eliminating the need for a new trunk overflow pipe.

CH2M and The City are also exploring other opportunities for innovation at the East Calgary WMF and The City's other landfills. For example, The City has used dewatered biosolids from the Bonnybrook WWTP as a source of fertilizer to enhance the growth of agricultural products at farmers' fields in Calgary's southeast corner. A similar approach could be taken with the LTPP's biological sludge, which could be dewatered and mixed with topsoil for use in capping of the landfill.



Technical Excellence

Leading-edge technology for more predictable results. The pilot plant makes use of innovative, leading-edge technology for biological treatment – a membrane bioreactor (MBR) with an ultra-filtration membrane. The ultra-filter (UF) membranes are extremely efficient, consistently providing more than 90 percent removal of organics than a conventional activated sludge process. In a conventional activated sludge process, the sludge is retained in an aeration tank before being sent to the clarifier, where it is separated from the treated wastewater through gravity settling. The heavy sludge (micro-organisms) that remains after this settling is pumped back to the aeration tank. But if operators are not vigilant about the quality of sludge, the undesirable micro-organisms can grow and can rise to the surface of the clarifier, clouding the treated wastewater. In the pilot plant's MBR system, the UF filtration membranes serve as the clarifier, separating the solids (the micro-organisms) effectively and leaving a very clear effluent. The operators don't have to worry about the effluent quality, regardless of the sludge's composition.

Management of Risk

Managing the risk of leachate release from landfill cells. The risk of leachate being released to nearby water bodies and/or land is a significant one that must be well managed. Alberta Environment and Parks' regulations stipulate that leachate levels within engineered landfill cells must not exceed 30 cm in depth above the liner. When the leachate reaches this level, it must be lowered. The leachate head on the liner system is monitored and the leachate is extracted (pumped out) to maintain the level below 30 cm. A portion of the extracted leachate is then taken to the pilot plant for treatment.

A pilot plant and tank farm designed to pre-empt risks related to spillage. A containment constructed below the Pilot Plant allows any spillage to be pumped out manually before it contaminates the groundwater. The tanks at the tank farm were also placed inside a concrete containment area so that any spillage could be visually inspected and spillage contained if it occurs.

Careful planning to mitigate safety risks to operators. The safety risks on any landfill are significant and a critical part of the design. Gas sensors were installed to detect the presence of dangerous gases, such as ammonia and hydrogen sulphide, and to trigger alarms when lower explosive limits (LEL) are reached. Exhaust fans were also installed in strategic areas where operators and visitors to the facility may be exposed to odours and gases.

Environmental Value

Ensuring The City's stewardship of the environment for present and future generations. By collecting and treating the leachate to comply with The City's Sewer Bylaws and surface water discharge requirements, The City is protecting all Calgarians – both today and into the future. Testing the treated leachate in the Pilot Plant's greenhouse has enabled CH2M to support The City in:

- Demonstrating how the treated leachate can be used for "greening up" the landfill
- Identifying the species of plants and trees that will thrive on treated leachate water
- Promoting the use of innovative approaches to handling treated leachate
- Studying the use of treated leachate as a resource rather than a waste
- Reducing the use of The City's fresh water supply as process water
- Reducing the impact and costs to The City, including capital costs, utilities, and operating costs

Added Value

This project at the East Calgary WMF offers added value to The City in several key areas:

- It has the potential to achieve zero waste discharge from the landfill (both water and waste by-products from the treatment process).
- By eliminating the need to rely on municipal WWTPs to handle daily inflow from the landfill leachate, the overall pollution load on the WWTPs is reduced.
- Greening the landfill space will help to improve air quality and have a positive impact on the Calgary ecosystem, becoming a sanctuary for attracting wildlife.

Degree of Difficulty

Integrating all of the design elements to create a functional facility that met The City's objectives. Within the three treatment containers, thousands of parts and pieces of equipment are synchronized to convert a foul, odorous, black substance into a clean and clear liquid that can be used as a resource. The facility had to function optimally despite harsh environmental conditions, including temperatures that have ranged over more than 80 degrees Celsius – from -48° C to +35° C. Such wide variations in temperature have challenged both the treatment processes and the equipment. For example, the insulation and heat tracing on the leachate supply lines into the plant had to be doubled in order to prevent freezing. From a process perspective, warmer temperatures have an adverse effect on keeping up with dissolved oxygen levels in the MBR process – in other words, the cooler the ambient temperature, the more efficient the MBR process becomes, with the optimal range being between +10° and +15° C.

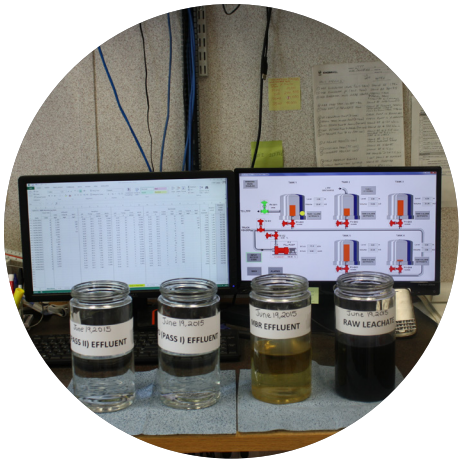
Benefit to Society

Helping The City to achieve its vision for sustainability and environmental stewardship. Initiatives such as this one to reuse landfill leachate for beneficial purposes represent small but important steps in the direction of big changes for the better. Overall, The City's commitment to protecting the environment is evident in Calgary's international reputation as a vibrant "green city." In 2015 alone, Calgary has been ranked #1 on the MBC Group's **"12 Cleanest Cities in the World"**, #1 on ABC News Point's **"Top 10 List of Most Cleanest Cities in the World"**, and #1 on TopTensCentral's **"Top 10 Cleanest Cities in the World 2015"**.

Eventually, initiatives to green all The City's landfills will improve the micro-climate, reduce greenhouse gases, and improve quality of life for Calgarians.

Advancement of Technology

Integrating advanced technologies from diverse areas of science. By drawing on expertise and technologies from different fields of science, including wastewater treatment and horticulture, The City and CH2M have been able to mimic nature's ability to sustain itself. By breaking down the biological nutrients and ammonia in the leachate, the pilot plant has become a laboratory to "fast-track" natural treatment processes at the microscopic level.



Facts and Figures

- The City prefers to keep the total capital cost and design/engineering costs confidential; however, the budget exceeded what was expected, for a variety of reasons. Cost and schedule challenges included equipment delivery delays, the need for site modifications to address environmental and safety requirements at the WMF, and an unexpected period of extremely cold weather that resulted in burst pipes and other technical challenges.
- Having proven successful at the East Calgary WMF, the concept and principles behind the Leachate Treatment Plant and Greenhouse can be applied at all three of The City's WMFs with similar benefits.
- The findings from this pilot study will be used to develop the concepts for detailed design of the eventual full-scale leachate treatment facility. The City is planning to truck in leachate from the other two WMFs for treatment and data collection at the East Calgary WMF pilot plant. In the future, The City hopes to have full-scale facilities at each of the landfills. The lessons learned from the operation of the pilot facility will be of considerable value in the design of those new facilities.