Report on the 2010 Nitrogen Treatment Project for the St. Louis County MSW Regional Landfill Leachate Ponds

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Secondary leachate treatment pond with pond curtain installed

Executive summary for nitrogen treatment project at the SLC MSW Regional Landfill

The SLC Regional Landfill in Virginia MN currently consists of 27 acres of lined landfill. It has been in operation since November 15, 1993, and has disposed of approximately 1,510,000 cubic yards of waste (MSW, Industrial, Demolition and Asbestos) and daily/intermediate/final cover through December 31, 2009. Leachate from the landfill is collected and stored in two HDPE-lined ponds. The leachate is aerated and then land applied through a network of 21 fixed head rotary gun type sprinkler nozzles, to a 22.25 acre spray field site of predominately reed canary grass.

The landfill spray field is operated under MPCA SDS permit # SW 405. Nitrogen, as a constituent of concern (COC) is monitored along with other COCs in the leachate ponds, and in monitoring wells at the landfill boundaries. In 2008, as a condition of permit, a nitrogen management plan was written and submitted to the agency. This nitrogen management plan is referenced in current SDS permit.

In 2010, in an effort to further implement the nitrogen plan for the facility and fulfill MPCA permit requirements, a research/ demonstration was conducted. This project was done in coordination with the MPCA under MN rule 7035.0400. During this project, an internal nitrogen monitoring plan for the landfill leachate ponds was developed and implemented. Available literature and known processes for nitrogen treatment were reviewed. Following the review, in pond suspended growth processes were identified as the most cost effective method of nitrogen treatment of leachate.

A coated geo-textile pond curtain was installed in the secondary pond in an attempt to isolate treatment processes from the rest of the pond. Nitrogen treatment processes were designed and implemented for the curtained 500,000 gallon portion of the secondary leachate pond. The process utilized activated sludge as a nitrifying bacteria source. Several carbon amendments were tried in the denitrification process, including methanol, candy manufacturing waste, and a hemi-cellulose extract (HCE) obtained from Georgia Pacific. The HCE proved to be the most cost effective carbon amendment. Several bench tests were utilized to develop this.

The pond curtain did not prove to be completely effective in isolating pond nitrogen treatment processes. The nitrification process, in particular, was found to extend into the rest of the pond, probably due to an incomplete effectiveness of the curtain. Overall the suspended growth nitrogen treatment processes, while successful, took approximately nine weeks. Reasons for the slow process included trial and error elements in the treatment processes, large volumes of wastewater, leakage of the pond curtain, wind mixing and oxygenation during the denitrification phase. The treatment process may have been influenced by significant concentration of biological inhibitors such as boron, VOCs, metals etc., in the leachate water, as well as settling, and wind mixing. The nitrogen treatment was extended to the entire secondary pond as part of the project.

The project resulted in the treatment and removal of 2600# of nitrogen from the leachate pond. Total nitrogen was reduced from 117 mg/L to 30 mg/L for 3.5 million gallons of leachate. Suspended growth nitrogen treatment potential in a cost effective manner was demonstrated. The treatment of nitrogen will continue to be explored and refined in the following years. The findings will be incorporated into the SLCRLF nitrogen plan.

Based on this Research / Development Project, the County recommended that the intervention limit of 2.5 mg/l total nitrogen at the property boundary continue to be the MPCA permit threshold. Nitrogen treatment may be employed by the County to help meet that requirement. Treatment of nitrogen should be adopted as a best practice to keep land application at roughly the optimal agronomic application rates.

Introduction:

Project Description and Characterization:

St. Louis County, in cooperation with the MPCA permitting authority, is interested in developing nitrogen treatment capacity at its MSW Regional Landfill (Landfill) in order to reduce nitrogen levels, protect groundwater and improve its current leachate spray irrigation processes. In April 2010, a Research / Demonstration Project was approved by the MPCA for the purpose of studying and treating nitrogen in the landfill leachate.

The purposes of this project were to:

1. **Develop a clearer understanding of the fate of nitrogen as it moves through the landfill leachate ponds and is eventually spray irrigated.** [Accomplishment of this purpose involved examining the existing nitrogen reporting data, permits, and guidelines. Literature and similar landfill operations were also reviewed. Enhanced in-pond sampling was done for ammonia and nitrate nitrogen (see page 10).]

2. **Identify, refine, and develop practical and affordable methods of nitrogen treatment for Saint Louis County's landfill leachate**. [Current MPCA permit language specifies this report will make site specific nitrogen loading rate recommendations (see page 22 for recommendations).]

3. **Remove nitrogen from the landfill leachate ponds.** [Accomplishing this involved attempting to treat nitrogen in the pond through a suspended growth process. The treatment involved separate treatment processes to initially nitrify the ammonia, and then to denitrify the nitrates and remove the nitrogen as atmospheric gas. An attempt was made to isolate part of the pond water by means of a pond curtain to make the treatment processes more manageable (see page 11).]

4. **Develop best practices of nitrogen treatment at the landfill and further implement the SLC Regional Landfill Nitrogen Management Plan**. [The SLCRLF Nitrogen Management Plan is referenced in the MPCA permit to operate the landfill.]

Background

The Landfill currently consists of 27 acres of lined landfill area in Phases 1 through 5. This facility, in operation since November 15, 1993, has disposed of approximately 1,510,000 cubic yards of waste (MSW, Industrial, Demolition and Asbestos) and daily/intermediate/final cover through December 31, 2009. The current permitted capacity issued for the facility is 2,090,470 cubic yards. The design capacity is 4,208,670 cubic yards.

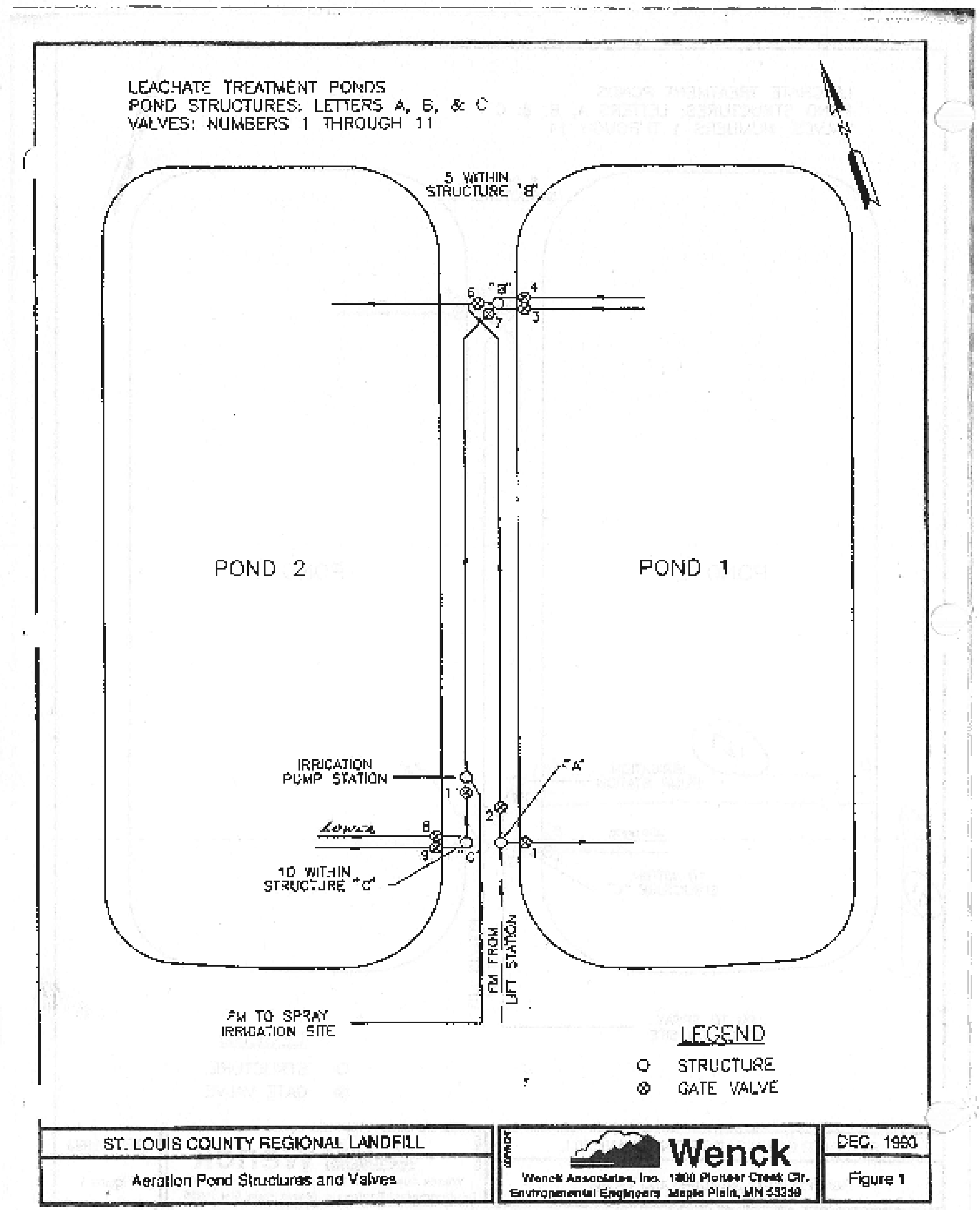
St. Louis County Environmental Services Department (County) contracts with Northeast Technical Services (NTS) to operate the leachate land application facility. Leachate from the landfill is collected and stored in two HDPE-lined ponds. The leachate is aerated, and then land applied. The annual volume of leachate applied has ranged from 2.76 to 6.74 million gallons per year, averaging about 4 million gallons per year. The leachate is applied to 22.25 acres of spray field through a network of 21 fixed head rotary gun type sprinkler nozzles to a predominately reed canary grass crop. (See photo page 9)

A detailed report of the leachate management program is available in the 2009 St. Louis County Regional Landfill Spray Irrigation Facility (SDS Permit # SW-405) annual report. In 2009, a St. Louis County Regional Landfill Nitrogen Management Plan (Project # 59092) was developed by Leisch and Associates for St. Louis County to meet a requirement of the 2008 MPCA permit review. This plan gave an overview of the current nitrogen management efforts. While some nitrogen treatment is ongoing with current leachate pond management, additional nitrogen treatment of the leachate was identified as a goal.

Sampling background

Incoming landfill leachate has historically been sampled in the primary pond intake manhole structure (diagram, page 5, letter A). The incoming leachate concentrations will be affected by which landfill pump (and corresponding cell) is providing leachate to the structure at the time of sampling.

The NTS reported spray leachate (outgoing) is taken from the irrigation pump station supplied by an intake pipe at the South end of the pond located about 5 feet from the bottom (mid-pond) (diagram, page 5). Permit reported nitrogen levels (TKN, Ammonia, Nitrate +Nitrite Nitrogen) are based on several annual samples taken by NTS.



Secondary leachate pond (left) and primary leachate pond (right)

Leachate Characterization

The characterization of the leachate as collected prior to spray irrigation onto the field is as follows:

TREATED LEACHATE POND EFFLUENT DURING IRRIGATION

PARAMETER	UNITS	5/1/09	6/30/09	7/29/09	9/2/09	9/29/09
PH	SU		8.16	8.62	7.93	8.68
Conductivity	µmhos/cm	6286	5349	4344	4975	4583
Alkalinity, Total	mg/L	1750	1860	1590	1810	1640
Biological Oxygen Demand	mg/L	18	25	34	34	30
Chemical Oxygen Demand	mg/L	230	295	246	363	289
Chloride	mg/L	688	653	611	667	643
Ammonia as N	mg/L	58.4	153	58.3	90.7	64.5
Total Kjeldahl Nitrogen as N	mg/L	101	144	78.9	107	81.6
Nitrate + Nitrite as N	mg/L	0.67	0.48	<0.1	0.41	<0.1
Total Dissolved Solids	mg/L	3240	2540	2680	2900	2750
Total Suspended Solids	mg/L	7.5	28	20	34	12
Sulfate	mg/L	134	81.9	90.4	77.1	84.9
Cation-Anion Balance	% Diff	5	1.3	1.1	3.1	2.9
Calcium	mg/L	14.3	31	21.1	41.1	35.2
Magnesium	mg/L	160	145	149	148	149
Sodium	mg/L	677	720	641	652	614
Potassium	mg/L	199	217	208	218	210
Iron	mg/L	1610	1350	433	716	472
Manganese	mg/L	156	464	452	901	439
Arsenic	µg/L	7.3	14.2	8.97	10.7	10.0
Cadmium	µg/L	1.5	2.96	1.17	1.6	1.3
Chromium	µg/L	8.26	14.7	<20	19.5	14.9
Copper	µg/L	16.2	<4	<8	<8	9.37
Lead	µg/L	1.5	2.3	<2	<.5	0.55
Mercury	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc	µg/L	<100	<50	<100	<100	<100
Boron	µg/L	13200	11200	10400	12200	10500
SAR	µg/L	10.9	12.0	10.4	10.0	10.1
Temperature	^{o}C	5.1	13.33	5.5	18.8	---

Nitrogen Treatment Background and Potential in the Leachate Ponds

Leachate from the landfill enters the primary pond and undergoes preliminary treatment in the form of settling, precipitation, and oxidation before being transferred to the secondary treatment pond. Nitrogen, mostly in the form of ammonia, is present in high levels in both the primary pond and the secondary pond. Landfill leachate from the secondary retention pond is spray irrigated during the growing season.

The incoming total Kjeldahl nitrogen (TKN) in the primary pond has averaged 289 mg/l since 2000. In the secondary pond, TKN has averaged 119 mg/l since 2000. There appears, on the whole, to be significant nitrogen removal between the two ponds. The differences in total nitrogen concentrations between the two ponds may be due in part to: dilution from rainfall during the year; biological denitrification processes in the ponds; precipitation of nitrogen into the sediments; settling of solids; or a combination of these factors. One end product, nitrogen gas, may be off gassed into the atmosphere.

There was no significant nitrite + nitrate present in almost all of the historical leachate samples taken from the ponds. The one notable exception occurred in 2008 when 13 mg/l nitrites + nitrates were found in the August and September samples. This significant finding coincides with the only year the diffusers were operated continuously throughout the summer. The outgoing TKN in the 2008 season averaged 88 mg/l.

Temperatures necessary for the denitrification process to occur (above 7 C) were observed from May through October. During that period, significant variation of reported TKN was observed. The understanding of the fluctuating TKN numbers is complicated by the addition of water from the first pond (with higher incoming TKN) to the second pond during the spray season. Examination of pond water transfer dates, spray application rates, and the fate of other indicator chemistries may yield additional understanding.

Reviewing the pH present in the ponds, the average pH in 2009 was 8.3. This number is slightly higher than the acceptable range of 7.0-8.0 for nitrification and denitrification processes to occur (see appendix page 25).

There are a number of biological inhibitors such as boron, VOCs, and metals, found in the leachate. Their effect on nitrogen treatment is unknown.

Crow Wing County and other literature sources have found landfill leachate to be carbon limited for nitrogen treatment purposes. In review of the available carbon electron donors to complete the denitrification process, BOD and COD levels may be used as possible indicators. There may be other denitrification electron donors in the leachate, however. The BOD’s since 2005 averaged 45 mg/L. This BOD is low from a wastewater treatment standpoint (i.e. carbon limited), but is typical of landfill leachate. There was wide variation in CODs between the ponds. From 2005-2009, the COD's averaged 1278 mg/l in pond 1 and 563 in the pond 2. The COD/BOD ration is within an acceptable range for nitrogen treatment processes.

An examination of alkalinity is also of interest in determining whether nitrogen cycle processes are occurring in the ponds. Biological nitrification requires high alkalinity. The average alkalinity from 2005 through 2009 averaged 3803 mg/l in pond 1 and 2053 mg/l in pond 2. In 2008 the alkalinity in pond 1 averaged 4550 mg/l and 1536 mg/l in pond 2. These alkalinities are in the acceptable literature range for nitrification to occur.

A dilution of up to 40% of the leachate can be anticipated (less evaporation) based on leachate flow into the ponds and precipitation falling on the ponds and surrounding small watershed (assuming 29 inches of precipitation per year). As an indicator of dilution, potassium, for example, appears to be stable in the leachate. The average potassium level from 1994 through 2009 is 385 mg/l in pond 1 and 237 mg/l in pond 2. If potassium is non-reactive, (which is unknown), these numbers would indicate a 60 % change in concentration between the two ponds of the incoming leachate on an average. Magnesium shows a similar pattern with a 50% change indicated from 1994 and 2009.

Based on current available data, nitrogen biochemical processes occurring in the ponds are not well understood, and are difficult to quantify.

The analysis suggests that nitrogen removal is occurring and some biological nitrification and de-nitrification processes may also be occurring in the ponds during the summer months. Additional in pond sampling and bench testing will be beneficial to the understanding of the processes.

Additional information on parameter requirements for nitrogen treatment is found in the appendix pages 24-26.

Leachate valve assembly (with valve for stirrer attached) and spray field in background

Methods and materials:

Bench tests: Both suspended growth and fixed film technologies were reviewed as treatment methods that could be studied utilizing bench testing. After viewing the results of Crow Wing County's successful MSW landfill nitrogen treatment process, a decision was made to delay (or forgo) the bench tests and proceed directly with suspended growth field trials.

Pond sampling: A 16-foot john boat borrowed from the St. Louis County Public Works Department, Bridge Division, was used for sampling purposes. Appropriate safety devices including life jackets, rubber gloves, first aid kits, and other items were used during the project. Other items obtained for the project included: a peristaltic pump was borrowed from Northeast Technical Services, a 12-volt car battery purchased to run the pump, and a tygon sampling tube attached to a rod calibrated with one foot markings to allow sampling with depth.

Three sampling points per pond were marked on the shoreline for reference purposes (1/4, 1/2, 3/4 pond), with lathe and surveyors ribbon. Sampling occurred at each sampling location at 1-foot (surface), 4.5 foot (mid-pond), and 8 foot (bottom) depths. Samples were place in a polycarbonate container for field testing and whirl-pack bags for additional field tests.

Sampling apparatus and john boat

Pond curtain: A used poly-coated geotextile fabric pond curtain (300 feet x 12 feet) was obtained from the Hinckley municipal wastewater treatment plant. The curtain was installed using heavy concrete anchors on the shore and steel cable fastened to the cabled float line. Sand bags were attached by means of a rope and carabineers to hold down the bottom anchor line. The curtain was set between diffuser banks. The approximate volume of the controlled section of the pond was 500,000 gallons. The purpose of the curtain was to isolate the smaller quantity of water in order to more easily mange the nitrogen treatment processes.

Pond stirrer: An anaerobic pond stirrer was constructed by Kangas Excavating using valves and 6-inch irrigation pipe. The stirrer was “T” shaped with ½-inch holes drilled into the cross arms. It was suspended by inner tubes and secured with polypropylene rope. The stirrer was connected to the irrigation pump and isolated by means of valving. Leachate could be circulated between the pump intake and discharge holes of the pond stirrer, allowing for non-aerated pond mixing. (Anoxic conditions are required for denitrification.)

Pond stirrer recirculation system before installation into pond

Field Testing:

Physical characteristics including pH, conductivity, temperature and total dissolved solids were measured using an Oakton multi-parameter testing unit. In-pond sampling occurred in a john boat. A small testing lab was set up in the blower building adjacent to the ponds. The nitrogen species were tested using a Hach DR 980 colorimeter and appropriate Hach reagents. Periodic certified lab results were run by Northeast Technical Services and the NRRI, to verify results. Nitrogen species examined during the field tests included ammonia and nitrate nitrogen. The certified lab results included nitrates plus nitrites, TKN, and a total nitrogen concentration.

Hach colorimeter and nitrogen sample showing ammonia about to be read

Nitrogen treatment selection: Three methods of treatment approaches were initially considered: 1) suspended growth process adding amendments and processes to the controlled pond section; 2) construction of a fixed film wood chip recirculating filter; and 3) ammonia stripping.

A suspended growth process would ideally involve a separate batch pond but this would involve expense to properly construct and a potentially lengthy permit process.

A fixed film wood chip filter appeared promising, but had a high initial cost to construct the filter and would involve extending the security fence and possible encroachment onto the spray irrigation field.

Ammonia stripping was rejected because of the unknown consequences of elevating the pH to 10.5 and the probable harm that would occur to the spray irrigation system through scale buildup. The technology also appeared to have a poor track record.

A decision was made to utilize a pond curtain and isolate a section of the secondary leachate pond for suspended growth treatment. The entire secondary pond was isolated for treatment during the course of the summer. Leachate for spray irrigation purposes was drawn from the primary pond.

Nitrification: The two step nitrification process involved the reproduction of specific bacteria, dissolved oxygen, and a possible carbon amendment to support cell growth. This process is discussed in greater depth in the appendix and in the EPA *Nitrogen Control Manual*. For the nitrification phase, activated sludge from the Virginia Municipal Treatment Plant was added to the curtained pond area. It was anticipated the activated sludge contained both of the necessary biological cultures. The Manual and other related literature contains examples of activated sludge being used for biological seeding. Landfill diffusers were run on both sides of the curtain to avoid “billowing” the curtain. Approximately 2,000 gallons of activated sludge were added via a rinsed sewage pumper truck to the controlled pond area.

Denitrification: The denitrification process involves the development of facultative bacteria and an anaerobic environment. For this phase the diffusers were shut off and a culture of bacteria and conditioners called Biobug Red was added to the controlled pond area at a rate of 40 pounds per million gallons. The pond stirrer was used to mix the leachate in the curtained area.

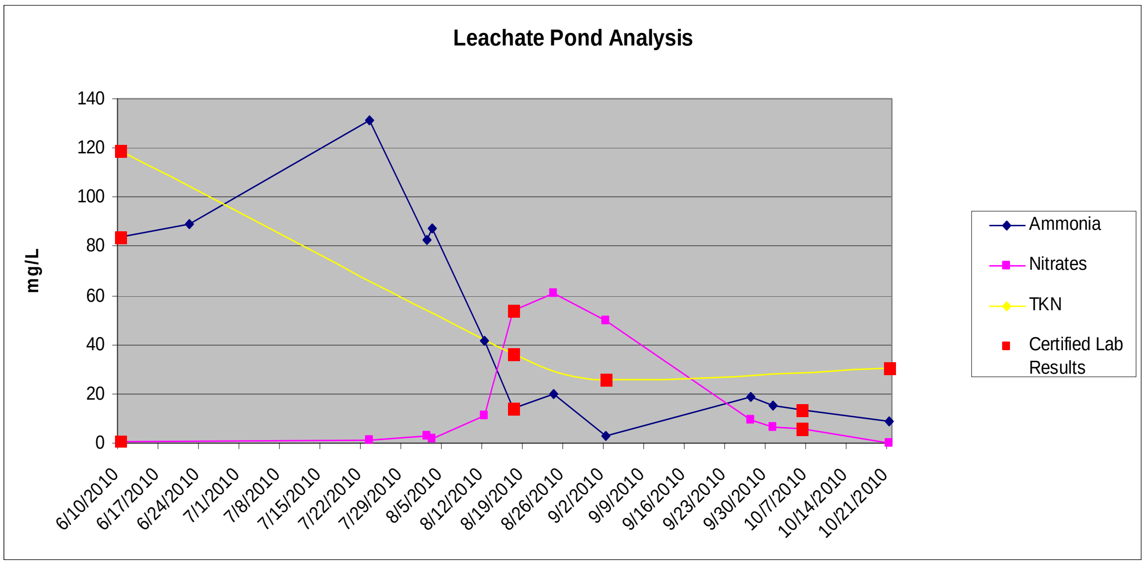
Carbon source: Several carbon sources were identified as being potentially useful for the denitrification process. The first source was a waste trap sugar and water solution from the Brach Candy factory in Winona, Minnesota. The sugar concentration was measured upon delivery. An unused, culled 2,000 gallon septic tank donated by Carlson Concrete Products of Duluth was placed next to the pond for storage of the sugar solution. The second source, methanol, was obtained through Hawkins Chemical was also added to the pond. A final carbon source utilized was a Hemi Cellulose Extract (HCE) obtained from the Georgia Pacific plant in Duluth. The HCE product was made available at a reasonable cost by Quality Liquid Feed in Minneapolis who buys the HCE and uses it as a binder in animal feed.

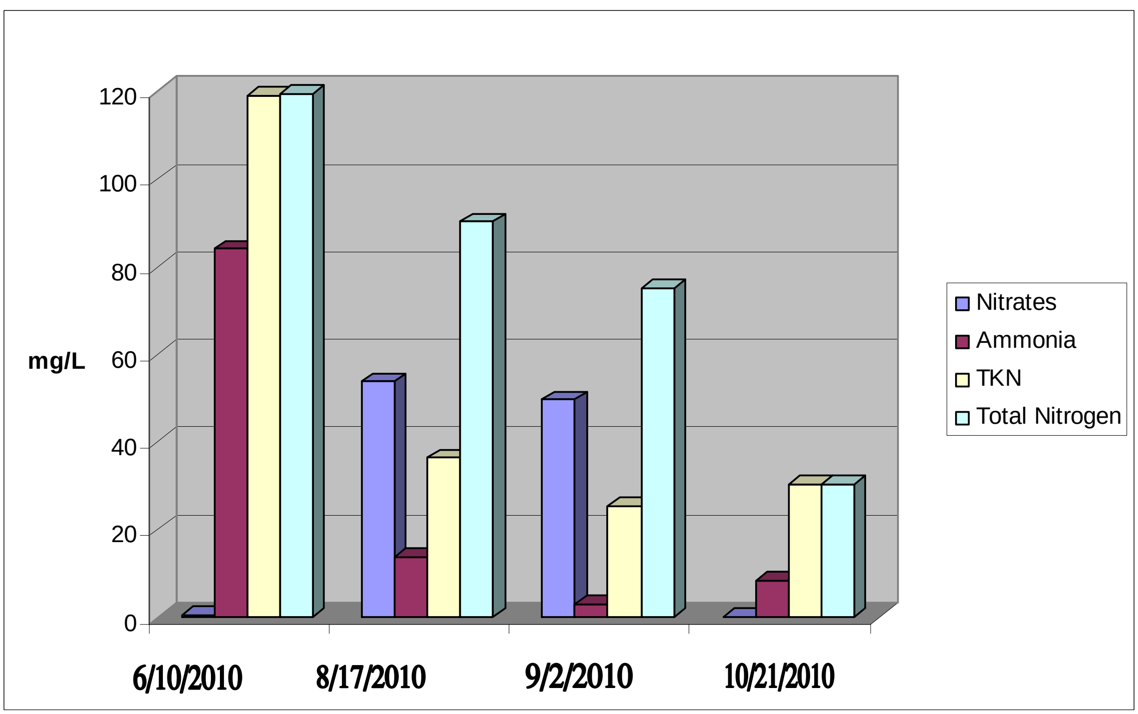
5 gallon pail of hemi cellulose extract (used as a carbon amendment)

The MPCA was given periodic updates on the project and visited the site during the project.

Results and discussion:

Initial pond sampling: The internal pond sampling results are provided in the following graphs.





The results show an overall decrease in the total amount of nitrogen over time. It is notable that there is a conversion of ammonia to nitrates resulting in a decrease in the TKN. Due to the significant margin of error inherent in the TKN test (up to 30%); caution should be exercised in interpreting small changes in the TKN parameter. As the nitrates are converted to nitrogen gas and off-gassed, the amount of total nitrogen in the pond is reduced to between 20 and 30 mg/l.

Nitrification process: The initial treatment process proved to be slower than anticipated. The oxygen levels were elevated far above the required 2 mg/l to approximately 7 mg/l. Activated sludge was added on July 30th and over time the ammonia in the controlled area slowly converted to nitrates. During the process, the conversion also occurred on the non-controlled side of the secondary pond with a slight lag time (several days). Staff observed wind blown foam generated by the diffusers moving across the top of the curtain and some water movement around the curtain edges. At the end of the process, ammonia in the entire secondary pond was nitrified. There remained a residual amount of ammonia of approximately 10 mg/l at the end of the nitrification process.

Diffusers running on both sides of the pond curtain and foam possibly carrying nitrifiers across the curtain

Denitrification process: This portion of the process required anoxic conditions, a carbon source and a biological culture. It was later in the season before nitrification of the pond was achieved (August 17th), and the project faced the prospect of dropping water temperatures. For this portion of the process, the diffusers were turned off. Waste sugars were added as the initial carbon source. During the period it was stored in the septic tank, the sugar solution fermented and its carbon content was relatively low (500 mg/l). After seeing little denitrification with the addition of the sugar, staff added 65 gallons of methanol and additional biological cultures to the controlled area.

There was little additional change in the nitrogen species in the controlled area. The stirrer was utilized to mix the pond initially, windy conditions kept the dissolved oxygen levels at relatively high levels in the pond (6 mg/l). The methanol may have been volatilized and/or displaced by non-contained leachate.

At this time staff conducted a bench test using methanol and HCE in a controlled and warmer environment of the blower building. A small quantity of Biobug Red was added to test containers of 5, 30, and 50 gallons of leachate. (The sizes of the containers were based on availability). All suspended growth tubs used in the bench tests denitrified completely in several days.

50 gallon batch denitrification test using HCE (volume calculation)

Staff decided to utilize HCE extract as a carbon source in an attempt to denitrify the entire secondary pond. The time of the year (September) presented potential issues with the overall response time of the processes. For this purpose, staff added 14,000 pounds of HCE throughout the pond on September 23rd. The diffusers were turned on for several hours to stir the pond. Staff then added 30 pounds of Biobug Red to the entire pond and within days the pond began to denitrify. Bubbles were observed on the surface of the pond and the ponds denitrified completely in approximately two weeks.

Biobug Red denitrifying bacterial amendment

Timetable of project:

March 1-July 12th	project research and development
June 10th	background leachate samples taken from Pond 2
July 15-28th	pond curtain obtained and repaired
July 28th	curtain installed in pond
July 28th	aerator turned on
July 30th	2,000 gallons of activated sludge added to curtain side
July 30th	treatment sampling begins
August 12th	nitrates 11 mg/l, Ammonia 38 mg/l
August 12th	added 500 gallons sugar/ yeast liquid to "push" nitrification
August 17th	secondary pond nitrified, aerator turned off
August 24th	installed stirrer "Nessy"
August 26th	added waste sugar/yeast solution
September 8th	sampling, reports of bubbles observed in pond
September 10th	165 gallons methanol added to curtain side
September 12th	stirrer on
September 13	stirrer off
September 15th	(nitrates still stalled)
September 15th	bench tests begin in warm blower building using Biobug Red, methanol, and HCE
September 20th	denitrification processes bench tests conclude successfully
September 23rd	staff adds 14 tons of HCE to secondary pond (both sides) as carbon amendment and 25 lbs Biobug Red
October 6th	Denitrification process completed

Conclusions and discussion:

Nitrogen treatment using a suspended growth process is possible in the leachate ponds. The process requires aeration, a carbon amendment, biological culture seeding, and stirring.

In the initial approach to the treatment of nitrogen in the leachate ponds, staff assumed a highly toxic environment that would be difficult for biological processes to occur. The conditions within the ponds did not prove to be as severe an environment as first assumed, as evidenced by biological indicators present in the leachate. During the course of the project, algae growth was noted along the shoreline of the ponds. Extensive zooplankton hatches (daphnia), a few turtles, and waterfowl such as ducks and geese were occasionally observed floating on the pond. The chemical contaminates found in the leachate were not at levels that would stop biological growth, although they may have slowed bacterial growth during treatment activities.

Daphnia and Daphnia bloom in the secondary treatment pond

The pond curtain proved to be successful in nitrifying, but not successful in isolating the processes within the controlled area from the rest of the pond. The large surface area and volume of the pond appeared to make the leachate resistant to change. The bench tests indicated a much faster process was possible with warmer leachate temperatures and smaller volumes.

The hemi-cellulose extract (HCE) proved to be an effective carbon source and amendment for treatment purposes. The HCE mix contained a number of larger carbon containing molecules such as cellulose and lignin, which may provide an additional carbon sink in the sediments for future processes. The HCE amendment also proved effective in consuming dissolved oxygen. HCE was reported to have a high content of 5 carbon sugars which may be more difficult to biologically break down. Our cultures appeared to break them down successfully. It was noted the tannins, in the HCE, colored the leachate a tea color.

The project appeared generally successful in treating the nitrogen initially in the form of ammonia. The larger organic nitrogen molecules (proteins and amino acids) appeared to remain stable through the treatment process and contributed to a 25-30mg/l residual total nitrogen level at the end of our treatment effort. It is anticipated that additional degradation may occur through the winter, as these larger molecules change into ammonia, nitrates, and eventually nitrogen gas.

Pond with nitrogen gas bubbles (successful denitrification)

Nitrogen treatment process discussion

The nitrogen treatment process for leachate within the secondary pond took approximately two and a half months to complete. During that time, approximately 2,600 pounds of nitrogen was removed from the pond. In the future, a shorter time frame is desirable, as this will provide more latitude in the sprayfield application process, and could allow several cycles of treatment in the course of a year.

There are a variety of possible reasons for the lengthy timeline. First, there may have been acclimation of both the nitrifiers and the denitrifiers due to inhibitors found in the leachate. Second, the process was delayed by the installation of the pond stirrer, pond curtain, recirculation valves, etc. Third, due to a general need to improvise, there were several trial and error elements to the project which have since been resolved. This was particularly true of the carbon amendment process.

It was recognized that a carbon amendment was needed in the denitrification process. Because of the slow rate during the nitrification process, questions arose concerning the amount of adequate carbon needed to support nitrifying cell growth. In the process staff added limited carbon via activated sludge and some additional carbon from the candy/yeast solution. It is estimated that a combined total of 1 mg/l of carbon (BOD) was added to the controlled area from both sources. It is unknown if this had a significant effect on the nitrifying processes.

The size of the ponds (3.5 million gallons of leachate) makes them difficult to run for treatment processes. A curtain was used to partially isolate 0.5 million gallons for treatment purposes. The isolation of the controlled area was complicated by the wind mixing of leachate in the remainder of the pond. At the end of the project, staff was uncertain of the effectiveness of the curtain on the treatment processes. It was unknown if the curtained area may have allowed for the right environmental conditions for biological cultures to acclimate, multiply, and then spread to the remainder of the pond.

In the future, each nitrogen treatment attempt will have slightly different variables such as temperature, wind mixing, etc. Using a pond curtain for the nitrification processes seems to be acceptable, although not necessarily required. Using a whole pond denitrification approach also appears to be an acceptable method.

Suggested future pond management strategies

Given the success of the nitrogen treatment project, future leachate pond management consideration is warranted. The secondary pond currently has a TKN of 25-30 mg/l. This pond may now be considered “nitrogen treated”, and used for spray irrigation purposes.

The current method of pond management will allow a mixing of nitrogen heavy water (120mg/l TKN) from the primary pond, and a gradual increase in the overall nitrogen level of the secondary pond. It may be possible that the secondary pond could work as a mixed facultative pond and experience ongoing reductions in nitrogen levels.

Sprayfield nitrogen levels will have to be frequently measured to accurately reflect nitrogen application rates.

A second method would be to pump exclusively from the secondary pond and use up the nitrogen-treated water. A third method would be to alternate the ponds used for spray irrigation without mixing.

For reporting simplicity, emptying the secondary pond initially would be preferred. There are limitations on the minimum drawdown levels due to intake pipe levels, but most of the leachate in the pond can be drawn down. Once a drawdown is accomplished, leachate can be transferred from the primary pond and the pond treatment sequence can be repeated. The drawback to this approach is that the hydraulic limitations of the spray field may necessitate much of the summer to draw down the pond, forcing a late 2011 season nitrogen treatment attempt.

If this secondary pond only method is employed, an attempt to denitrify the primary pond could be made while the secondary pond is drawn down. This approach is made more difficult by a constant inflow of high TKN nitrogen leachate from the landfill, but may be possible.

If the mixed pond method is employed for spraying, both the primary pond treatment, and a later treatment of the secondary pond are possible. If the ponds are alternated for spray purposes, treating the primary pond would appear to be the most likely strategy.

The in-pond sampling during the 2010 season demonstrated a stratification of water. The nitrogen levels varied with depth. Based on this finding, it is recommended that a modification be made to the intake structure of the pond that would allow adjustment to the water level intake. This could be a flexible pipe and some type of attachment structure such as a raft or platform.

Given the success of this demonstration project, some level of ongoing nitrogen treatment seems to be warranted in the leachate ponds. The approach will be governed in part by the spray field application method.

Based on the 2010 experience, several recommendations can be made. 1) An earlier start to the nitrogen treatment process should be undertaken (June).
2) Whole pond treatment should be attempted but using the controlled area to seed the rest of the pond for nitrification is recommended. 3) Denitrification of the entire pond using HCE as a carbon source is recommended. (Using a lesser amount of HCE (75%) may be attempted.) 4) If the primary pond is used for treatment, two rounds of treatment may be necessary.

Going forward, consideration should be given to include nitrogen treatment as a component of leachate treatment. It is suggested that nitrogen be reported as total nitrogen instead of TKN during the next permit application process because of the significant margin of error of the TKN test (up to 30%).

If resources allow, the construction of a 1 million gallon, two compartment pond could be considered. This would allow for easier nitrogen treatment and it would allow spray irrigation to operate independent of the nitrogen treatment.

Projected 2011 spray field nitrogen levels

Should the following conditions be met, the nitrogen loading rate will be less in 2011 than in previous years:

a. the average leachate spray application volume of 4 million gallons is sprayed in 2011
b. 2 million gallons of treated leachate with a Total Nitrogen concentration of 30 mg/l and 2 million gallons of leachate with the last measured TKN of 117 mg/l are sprayed
c. no additional dilution or ongoing leachate treatment is realized in the ponds

The projected total nitrogen application rate will be 112.5 lbs of nitrogen per acre per year over the 22.25 acre spray field. As per the 2009 SLC Regional Landfill Nitrogen Management Plan, the predicted application rate without treatment is 192 lbs of nitrogen per acre per year. The recommended agricultural application rate is 150 lbs/acre/year.

Recommended annual loading rates

It is the recommendation of the County that the Nitrogen Management Plan be amended to include the research demonstration project findings. It is further recommended that the Nitrogen Management Plan be used as a guideline for best practices in the spray field application of leachate. It remains the County's position that the baseline permit nitrogen threshold remains the intervention limit of 2.5 mg/l, which is 25% of the safe drinking water standard, at the property boundary.

Use of Nitrogen treatment methods demonstrated in this research/ demonstration project to maintain groundwater quality, (i.e. suspended growth nitrogen treatment), is a reasonable best practice, as conditions allow. Nitrogen treatment that influences loading limits should be used to maintain groundwater levels below the intervention limits.

Appendix:

Improvements to the leachate land application system:

In the fall of 2009, the County upgraded its leachate land application system with the installation of a larger vertical turbine pump, seven (7) electronically actuated valves, an electromagnetic flow meter, 6-inch pipe (replacing 4-inch pipe) throughout the system, and five (5) additional fixed head rotary gun-type sprinkler nozzles. These upgrades will increase spray application coverage to the entire 22-acre spray field.

Background nitrogen treatment information:

At the onset of our project we determined the following:

1. We had an insufficient understanding of the fate of nitrogen in our existing pond system. We had an incoming quarterly nitrogen sample, and an outgoing monthly nitrogen sample, but little knowledge of the internal processes in the ponds.
2. While the primary use of the ponds is for leachate storage for spray field application, some overall nitrogen reduction appeared to be occurring in the ponds in addition to dilution from rainwater.
3. Biological process removal of nitrogen appeared to be the best option for denitrification of our leachate, but the use of this process has its challenges. These challenges include leachate toxicity, low temperatures, low available carbon, and lack of suitable conditions in our leachate for bacteria to thrive.
4. The large 3.5 million gallon ponds are cumbersome for denitrification processes.
5. The blower system in place appeared to be an effective method to both stir and aerate the ponds.
6. Bacteria cultures are available for assisting the nitrogen removal process. These included purchased cultures, and activated sludge from a wastewater treatment plant.
7. Crow Wing County had achieved denitrification with similar leachate using suspended growth biological processes.
8. Our most viable options for denitrification were suspended growth (in pond) and fixed film (external filters), or a combination of the two.
9. The suspended growth process had cost involved in purchasing supplemental carbon, electricity to run the blowers, an anaerobic pond stirring method, and possible purchase of biological cultures.
10. The fixed film process has cost involved in constructing the filters and possibly constructing a batch pond or a pond divider in order to store nitrified water prior to denitrification.
11. Biological processes were limited by temperature.
12. While there was significant literature examples of leachate fixed film nitrification /denitrification, there are not a lot of landfill examples of the processes known to us. This is complicated by a relatively low number of landfills and a significant number that discharge to a municipal treatment plant. Of the examples located,

most are shrouded in proprietary protection and/or have a warmer climate application.

In order to further our goals we proposed the following actions:

1. Develop a better model of overall fate of nitrogen in our entire system over time and amend our nitrogen plan to reflect this.
2. Purchase a spectrophotometer and sample the ponds spatially and with depth during the ice free months for a variety of parameters including ammonia, nitrites, nitrates, pH, dissolved oxygen, temperature, alkalinity, and conductivity.
3. Explore the feasibility of bench tests for the purpose of demonstrating nitrification and denitrification potential. These might include suspended growth, and fixed film (recirculating gravel filters and up flow wood chip filters)
4. Make minor modifications to the pond leachate intake structure in order to isolate a treatment pond and a separate spray pond for short periods in the summer. Following this we proposed to attempt in pond nitrification /denitrification when the water reaches 55 degrees.
5. Consider the construction of a small onsite filter system to the West of the secondary pond in order to prove our treatment potential, and study the processes on a pilot basis.
6. Visit the Crow Wing landfill and observe and discussed their processes.
7. Explored the toxicities and the affect of biological inhibitors in our leachate.
8. Develop specifications and estimates for a fixed film treatment design.
9. Explore alternative low cost supplemental carbon sources for denitrification.
10. Continue to search for cold climate examples of fixed film leachate treatment examples and further develop our ongoing “working alternatives analysis”.

Initially we reviewed parameters necessary for nitrogen treatment and determined the following:

Nitrification parameters:

$NH_4^+ + 2O_2 == NO_3^- + 2H^+ + H_2O$

Temperature: Nitrification can occur between 39 and 113 F (4-45 C). The rate of nitrification will roughly double for each 10 degree C increase from the low end up to about 85 F or 30 F.

Bacteria: Two types of reaction and two types of bacteria are necessary for nitrification from NH_4 to NO_3. The first reaction to NO_2 requires a bacteria group called Nitrosomas and the second to NO_3 requires bacteria called Nitobacter. The reactions are sequential.

pH: Optimum pH for nitrification is 6.5-8.0. Nitrification will consume alkalinity and thus lower the pH with reaction.

Alkalinity: The amount of alkalinity required is up to 10x the amount of ammonium nitrified in order to maintain a pH above 6.0 in a closed system and slightly less in an open system. Alkalinity is replaced back into the water in the denitrification process. The design coefficient is 7.1 CaCo3 to 1 NH4.

Dissolved Oxygen: Nitrification has been shown to occur from .5 -2.5 mg/l. It has been suggested that nitrification have a DO in the neighborhood of 2.0 mg/l. The ratio of oxygen used to nitrify is 4.6 O2 to 1 NH4

Time: Time needed to denitrify can range from hours to weeks if the reactions occur at all. The above listed variables all influence time of reactions. Establishment of the bacteria growth and bacteria / NH4 contact methods (mixing, circulation, etc.), also affect rates.

Inhibitors: Metals, VOC's, organic compounds, as well as physical and other chemical parameters can act as inhibitors or toxins to nitrifying bacteria. Bacterial cultures will acclimate over time to some extent.

Denitrification parameters:

NO3- + 5/6 CH3OH + 1/6 H2CO3 = ½ N2 + 4/3 H2O + H2O3-

pH: The optimum range of pH for denitrification is 6.0-8.0. Denitrification will produce alkalinity so the pH will increase with the reaction.

Alkalinity: Denitrification will produce alkalinity and replace some of the alkalinity used in the nitrification process. The ration is 3.57 mg/l CaCO3 to 1 mg/l NO3.

Inhibiters: Denitrifying bacteria are less sensitive to inhibitors than are nitrifying bacteria. Biological cultures can acclimate to inhibitors with time.

Temperature: Denitrification can occur between 40 and 85 F (5 and 30 C). The rate of denitrification roughly doubles with each 10 degree increase above the minimum.

Bacteria: The denitrifying bacteria include a broad range of bacteria that are ubiquitous to the environment. These bacteria are generally facultative, meaning they can thrive in aerated and anoxic environments. These bacteria can metabolize using available oxygen first and in the absence of oxygen will move on to nitrates and nitrites, sulfates, etc.

Carbon sources: Carbon is a useful element in denitrification of Nitrate nitrogen to Nitrogen gas. We currently have some available carbon but it is unknown if the amount is sufficient to achieve significant denitrification.

Several options for supplemental carbon were explored and these include:

1. Methanol: This is a common carbon source and is used at many wastewater treatment plants to assist in denitrifying wastewater (tertiary treatment). Crow Wing landfill uses methanol to denitrify their leachate. Cost is similar to gasoline.

2. Hemi-cellulose extract: This is concentrated wood byproduct currently being produced by Georgia Pacific in Duluth and is being sold as an animal feed additive. It is low cost $80 a ton)
3. Landfill gas: Landfill gas contains up to 50 % methane, which is a building block of methanol. The literature demonstrates that it can be used as a carbon source for denitrification, but use has been mostly confined to laboratory tests. It is readily available at the landfill and is free. The challenge would be to manage the gas, probably by covering the pond to keep the gas in solution and dealing with potentially explosive gas pockets under the cover or in clouds around the pond.
4. Sewage: Typical holding tank sewage has a concentration of 300 mg/l of BOD. It also has additional nitrogen and is readily available. A biosolids application site is located adjacent to the landfill. There are potential public health concerns with using sewage spray irrigation. Its' use could also result in additional pond sedimentation.
5. Sugars and industrial food byproducts: Sugars from food processing centers are useful to assist in denitrification, and generally quite inexpensive. There does not seem to be this type of industry on the Iron Range however. One particular source that was mentioned in literature is brewery waste.
6. Corn syrup and molasses: These would be a good source of carbon and may be comparable to methanol in price.
7. Wood chips or sawdust: These would be employed in an anoxic up flow filter. Their use has been shown in literature to be useful as a carbon source for landfill leachate denitrification. It is relatively low in cost. Chips could be available on site by the processing of brush at the landfill, or by purchasing wood chips from area loggers. The longevity of the woodchip is unknown but is suggested to be 7 years. The filter would be designed so the chips could be replaced when needed.
8. Existing organic carbon in the leachate: There is some available carbon in the leachate as indicated by the BOD and COD levels of 30 and 200mg/l respectfully.
9. Charcoal: Carbon sources such as activated charcoal have been added to leachate ponds to provide a carbon source in the pond for denitrification.

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Hemi-cellulose extract (HCE) composition

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Sample # 15536
Sample: Liquid #1 GP-HCE
Other ID: 2/15/2010

Date Received: 02/17/2010
Date Reported: 02/22/2010
Total Fee: 95.50

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ANALYSIS

	Dry Basis	As Received	
Moisture, Karl-Fischer		41.00	%
Dry Matter		59.00	%
Protein, Crude	2.85	1.68	%
Fiber, Crude		Less than 0.2	%
NEL: Net Energy-Lactation	0.93	0.55	Mcal/lb
NEG: Net Energy-Gain	0.71	0.42	Mcal/lb
NEM: Net Energy-Maintenance	1.03	0.61	Mcal/lb
TDN: Total Digestible Nutrients	88.51	52.22	%
Fat By Acid-Hydrolysis	7.08	4.18	%
Ash	8.93	5.27	%
NFE-Nitrogen Free Extract	81.14	47.87	%
Calories Per Pound		236	calories
Carbohydrates Per 100 Grams	81	47.9	grams
Calcium	1.05	0.62	%
Phosphorus	0.10	0.06	%
Potassium	1.61	0.95	%
Magnesium	0.34	0.20	%
Sodium	1.36	0.80	%
Sulfur	0.02	0.01	%
Aluminum	652.54	385.00	ppm
Cobalt		Less than 0.2	ppm
Copper	10.34	6.10	ppm
Iron	245.76	145.00	ppm
Manganese	250.85	148.00	ppm
Molybdenum		Less than 0.3	ppm
Zinc	63.73	37.60	ppm
pH		4.59	s.u.
TSI-Total Sugars as Invert		16.7	%

Approved By: [signature]

Copies

ANALYTICAL RESULTS APPLY ONLY TO THE SUBMITTED SAMPLE AND MAY NOT REFLECT RESULTS OF SEEMINGLY IDENTICAL MATERIAL OR PRODUCTS.

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