

April 22, 2016

File No. 15-0107-015



City of Winnipeg - Solid Waste Services Division  
1120 Waverley Street  
Winnipeg, Manitoba  
R3T 0P4

ATTENTION: Mr. Irvin Slike  
Project Coordinator

RE: Laboratory Investigation into the Effect of Temperature  
on Treatment of Leachate

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Dear Mr. Slike:

Please find below the KGS Group Draft Letter Report into the Effect of Temperature on Treatment of Leachate.

## 1.0 INTRODUCTION

Kontzamanis Graumann Smith MacMillan Inc. (KGS Group) was retained by the City of Winnipeg to investigate the effect of temperature on the treatment of leachate from the Brady Road Resource Management Facility (BRRMF). This study was carried out in the Environmental Engineering Laboratory at the University of Manitoba under controlled laboratory conditions.

## 2.0 PROPOSED SCOPE OF SERVICES

KGS Group carried out the scope of services related to the effect of temperature on the treatment of leachate from BRRMF as follows:

1. Collected a representative sample of leachate from BRRMF and blended the samples to produce a composite sample, representative of leachate contained within the leachate system. The sampling carboys were filled to the rim to minimize biogas escape.
2. Transported the leachate samples to the Environmental Engineering Laboratory (EEL) and kept them at 4°C to minimize biological activity and metals precipitation.
3. Leachate studies were carried out at lab temperatures 25°C, 30°C, 35°C, 40°C, 45°C, 50°C, 55°C and 60°C (Max allowable temperature in Sewer By-law).
4. The testing used two (2) stirring jars (duplicate) of 3 L (approximate) and one (1) jar without temperature change / stirring (control).
5. The heating time was determined by running a pre-test study with leachate at the ambient lab temperature of approximately 22°C with spraying and

monitoring ammonia (NH<sub>3</sub>) removal versus time. Where NH<sub>3</sub> removal was maximized in 2 hours, that contact time for heating / spraying was used for all the jars.

6. The settling time was determined with the same test as (5) by measuring Total Solids (TS) at different times, after heating and spraying were turned off. If after 24 hours most of the precipitants had accumulated at the bottom of the jars, the leachate quality was assessed.
7. The two best results (temperature conditions) were repeated, and samples were sent to an accredited lab for Sewer By-law, Schedule B analysis. The precipitants will be collected / weighed and further characterized for metals and carbonate.
8. The optimum temperatures for leachate treatment were estimated.
9. Management of off-gases (and precipitants) to mitigate potential odour concerns were defined.

### 3.0 BACKGROUND

The expected outcomes by increasing leachate temperature are:

- Releasing ammonia from dissolved to gas phase
- Releasing CO<sub>2</sub>, increasing the pH and precipitating metals
- Precipitating calcium carbonate (CaCO<sub>3</sub>) and co-precipitate different metals in suspension.
- Releasing Volatile Organic Compounds (VOCs).

On January 2016, KGS Group teamed up with the Environmental Engineering Laboratory at the University of Manitoba to carry out the leachate heating tests under controlled laboratory conditions.

### 4.0 METHODOLOGY

Landfill leachate was collected on February 15<sup>th</sup>, 2016 from the BRRMF. A composite sample from two different wells was prepared in order to have a more representative sample of the overall leachate composition. The sampling carboys were filled to the rim to minimize biogas escape. The leachate samples were transported to the Environmental Engineering Laboratory (EEL) and kept at 4°C to minimize biological activity and metals precipitation.

A pretest was carried out utilizing a jar test of 2 L of leachate, operated at room temperature (22°C approx.) under spraying conditions for four (4) hours. Samples were taken every 30 minutes to measure ammonia (NH<sub>3</sub>) concentration. The ammonia removal versus time was plotted in Appendix A. Due to the highest ammonia removal achieved at four hours, it was decided that heating/spraying contact for all the laboratory tests would be carry out for four hours.

Initially, the jar tests were mixed using a magnetic stirrer with a stir bar while the leachate was maintained at the targeted temperature. After internally discussing the low ammonia removal results obtained, and comparing with leachate spraying experiences observed in Poveda *et al.* (2015) and Lozecznic *et al.* (2012), it was decided to use an aquarium pump to lift the leachate up to 1.5 cm (approximately) above the leachate level, spraying it back onto the leachate

surface. It was hypothesized that this spray effect would increase degasification, hence ammonia removal.

A water bath was used as mean of heating. As discussed in Section 3.0, the leachate temperatures tested were room temperature, 25°C, 30°C, 35°C, 40°C, 45°C, 50°C, 55°C and 60°C (Max allowed in Sewer by-law). All tests were conducted using two (2) stirring jars (duplicate) of 3 L and one (1) jar without temperature change/stirring (control). An aquarium pump was used to facilitating spraying. All the jar tests were conducted in the water batch. Appendix B shows the set up at room temperature and heating arrangement with water bath.

An initial sample was taken from each jar to measure Total Solids (TS) and ammonia (NH<sub>3</sub>). During the jar test, samples were taken for 4 hours, at 30 min intervals to measure ammonia. After spraying, leachate was left settling at room temperature for 24 hours. Then, leachate samples were taken for solids measurement.

Samples of raw leachate, leachate mixed at room temperature (22°C) and heated at 60°C were sent out to ALS Laboratory for Total Metals, Conductivity, pH, Chloride, Sulfate and Sodium Adsorption Ratio (SAR) analysis. The SAR analysis indicates the suitability of the water to be used in agricultural irrigation and it is expressed as follows (Lesch and Suarez 2009);

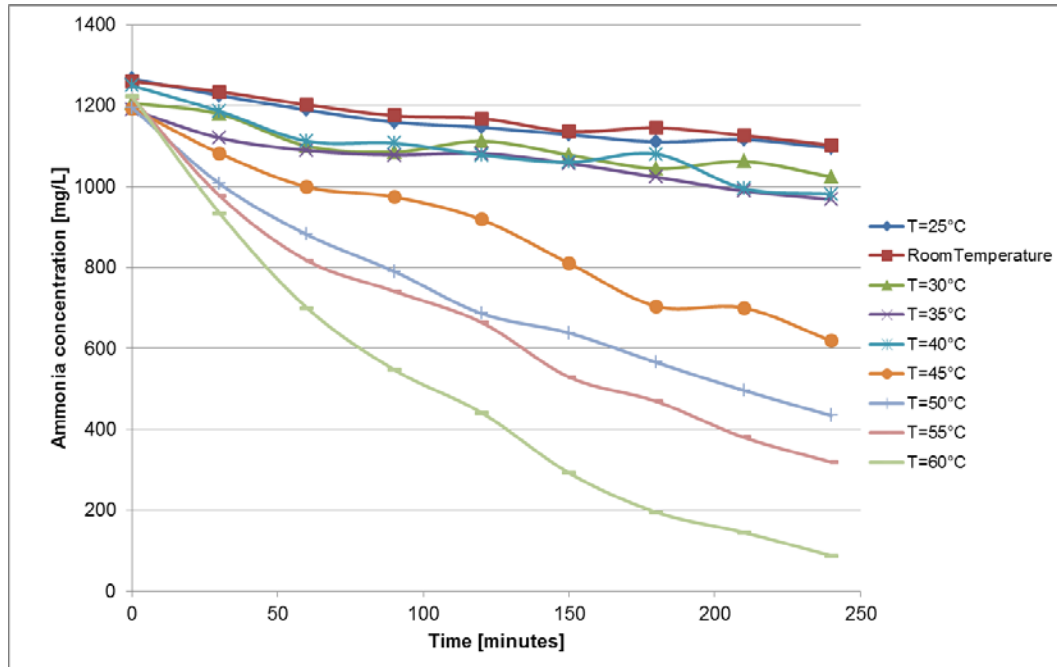
$$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Where Na<sup>+</sup> is the sodium concentration, Ca<sup>2+</sup> is the calcium concentration and Mg<sup>2+</sup> is the magnesium concentration. The Environmental Quality Guidelines for Alberta Surface Waters (2014) established a relationship between the SAR and conductivity values to determine the irrigation suitability of the water as follows:

SAR	Conductivity (umhos/cm)	Irrigation suitability
≤ 5	≤ 10,000	Safe
>5 <10	>10,000 to 20,000	Possibly Safe
≥ 10	≥ 20,000	Hazardous

## 5.0 RESULTS AND DISCUSSIONS

The spraying tests showed that ammonia removal increased at higher temperatures, as shown in Figure 1 (Results in Appendix C). Figure 1 shows that tests carried out at temperatures ranging from room temperature to 40°C did not exhibit a high removal of ammonia, less than 25% (< 300 mgNH<sub>3</sub>/L) of the initial concentration value of approximately 1,200 mgNH<sub>3</sub>/L. For the temperatures ranging between 45°C to 55°C, removal rates of 45% (575 mgNH<sub>3</sub>/L) to 75% (900 mgNH<sub>3</sub>/L) were achieved after 4 hours of spraying. The highest removal of ammonia was attained at the highest temperature tests (60°C), resulting in 92% (1,134 mgNH<sub>3</sub>/L) removal after 4 hours of spraying.



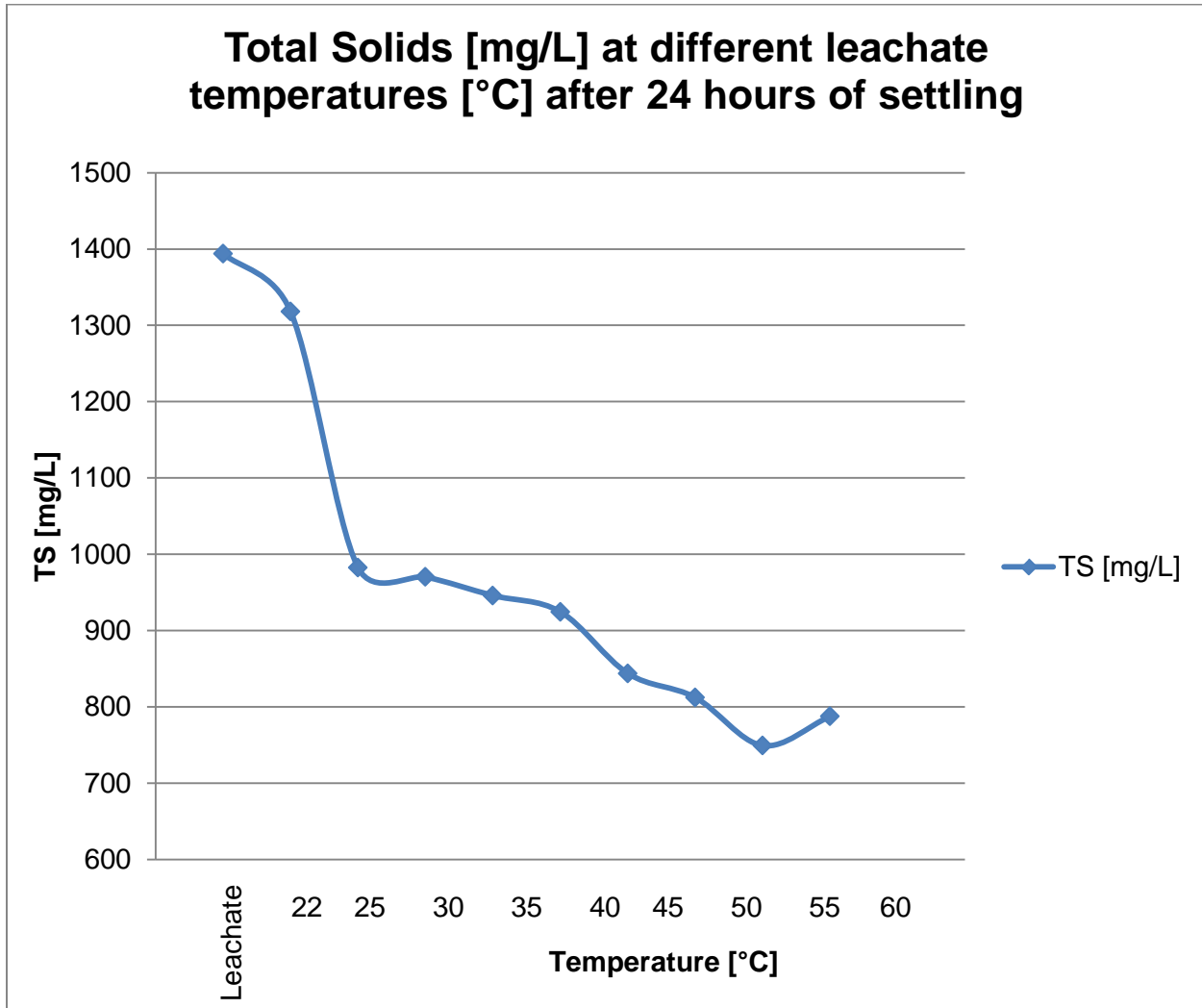
**Figure 1.** Average ammonia (NH<sub>3</sub>) concentration (mg/L) versus time (minutes) for the leachate temperatures tested at 25°C, 30°C, 35°C, 40°C, 45°C, 50°C, 55°C and 60°C.

Poveda *et al.* (2015) carried out air stripping tests on leachate at different pH's from BRRMF (average 646 mgNH<sub>3</sub>/L with a standard deviation of 84 mgNH<sub>3</sub>/L) to assess the removal, if any, of COD, TSS, BOD<sub>5</sub>, DOC, NH<sub>3</sub>-N and TP. At room temperature (22°C approximately), the overall ammonia removal rate was in the range of 65%-86% (420 to 555 mgNH<sub>3</sub>/L) after 48 hours, and it was proportional to higher initial pH.

Lozeczniak *et al.* (2011) assessed the effects of turbulence and temperature on leachate chemistry by using a no sealed/sealed reactor with rotating impellers under controlled laboratory conditions. This study showed that by increasing turbulence under atmospheric conditions, CO<sub>2</sub> dissolved within the leachate evolved from the solution, increasing the leachate pH. The pH increase due to CO<sub>2</sub> evolution during spraying, higher temperatures and atmospheric exposure resulted in approximately 20% of initial dissolved Ca<sup>2+</sup> being removed out of solution.

Table 1 shows the metals content in the leachate for being the initial leachate, leachate mixed at room temperature (22°C) and leachate heated at 60°C after 4 hours of spraying. It can be observed that as the temperature increased, pH values increased from initial leachate (pH of 7.68) to leachate at 22°C and heated at 60°C (pH 8.7 and 9.1, respectively), and the dissolved Ca<sup>2+</sup> was removed out of solution from both leachate tests at approximately 75% and 90% respectively.

Since the pH increased after the 4 hours, it was expected that any existent and formed TS would precipitate out during the 24 hours of settling, as shown in Figure 2 (results shown in Appendix C).



**Figure 2.** Total Solids (TS) concentration (mg/L) versus temperature (minutes) for the leachate temperatures tested at 25°C, 30°C, 35°C, 40°C, 45°C, 50°C, 55°C and 60°C.

Figure 2 shows that after the pH had increased, different concentrations of existent and/or formed TS within the leachate, settled out after 24 hours. Higher removal of TS was observed at higher temperatures, also demonstrates the removal of metals shown in Table 1, such as  $\text{Ca}^{2+}$ , aluminum (Al), Iron (Fe), etc.

Past research on clogging in leachate columns (Rowe *et al.* 2004) has shown that changes in pH and carbonate content combined with high concentration of metals such as  $\text{Ca}^{2+}$  or  $\text{Mg}^{2+}$ , results in carbonate minerals precipitation.

For the leachate heated at 60°C (see Table 1), it can also be observed that sodium ( $\text{Na}^+$ ) and chloride ( $\text{Cl}^-$ ) increased 76% and 96% from the initial leachate values. Concurrent with  $\text{Na}^+$  and  $\text{Cl}^-$  increases, conductivity increased 6.5% (from 11,800 to 12,600 umhos/cm) with time. Concurrent with the increase in  $\text{Na}^+$  and  $\text{Cl}^-$ , sulfate ( $\text{SO}_4^{2-}$ ) decreased 73% from the initial leachate value, from 172 mg/L to 47 mg/L. The  $\text{Mg}^+$  increase was similar to the  $\text{Ca}^{2+}$  decrease, however, as  $\text{Na}^+$  increased substantially, the SAR increased 86%, from 10.36 to 19.32. Based

on the Environmental Quality Guidelines for Alberta Surface Waters (2014), this leachate could not be used to irrigate agricultural soils without significant dilution water especially for the clay soils in Southern Manitoba.

For the leachate at room temperature (see Table 1 – 22°C), it can also be observed that  $\text{Na}^+$ ,  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ , as well as the conductivity values remained almost constant (from 11,800 to 10,500 umhos/cm) after 4 hours of spraying and heating. Since there was removal of  $\text{Ca}^{2+}$ , constant  $\text{Mg}^{2+}$ , and small increase in  $\text{Na}^+$  using the raw leachate, SAR increased 13% approximately, from 10.36 to 11.74. Based on Environmental Quality Guidelines for Alberta Surface Waters (2014), this leachate could not be used to irrigate agricultural soil without significant dilution.

## 6.0 CONCLUSIONS

This study has shown that increasing the turbulence (spraying) and temperature of leachate results in  $\text{CO}_2$  degassing from solution, increasing the pH, removing  $\text{NH}_3\text{-N}$  up to 92%, and some metals (e.g.  $\text{Ca}^{2+}$ ) from the dissolved phase.

A higher leachate temperature (60°C) resulted in a higher pH (9.1) compared to room temperature (pH 8.7) after 4 hours of heating and spraying. This also resulted in a higher removal of ammonia and metals. Since leachate pH increased from 7.68 to 9.1 after heating, dissolved  $\text{Ca}^{2+}$  was removed. As would be expected, higher removal of dissolved  $\text{Ca}^{2+}$  was observed at higher leachate pH. It is recognized that metals precipitation (e.g.  $\text{Ca}^{2+}$  as  $\text{CaCO}_3$ ) from leachate results in inorganic clogging that can produce piping blockage, and/or sludge in treatment tanks or lagoons.

This study has provided a better understanding of the advantages and disadvantages of enhancing the turbulence and heating of leachate from BRRMF. The advantages are the reduction of ammonia and some metals, as well as some VOC's and odours (not measured during this study). The disadvantages are the impact on the salinity ( $\text{Na}^+$  and  $\text{Cl}^-$ ), increasing the SAR, and reducing the irrigation potential of the leachate for agricultural and industrial land. The increase in SAR can be explained as the reduction in  $\text{Ca}^{2+}$  and increased  $\text{Na}^+$  compared to  $\text{Mg}^{2+}$  after heating the leachate from room temperature to 60°C. This clearly indicates that leachate heating under turbulent conditions can be a successful treatment alternative for removing ammonia and metals, but the increase in salinity needs to be taken into consideration with regards to further disposition of the leachate.

Finally, the type of turbulence utilized affected the degree of removal of dissolved gases and metals. This study demonstrated that changing from the use of a magnetic mixer to spraying leachate on the free surface of the jar tests, increased this removal.

## 7.0 STATEMENT OF LIMITATIONS

### THIRD PARTY USE OF REPORT

This report has been prepared for Southeast Resource Development Council Corporation to whom this report has been addressed, and any use a third party makes of this report, or any reliance or any decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

## ENVIRONMENTAL STATEMENT OF LIMITATIONS

KGS Group prepared this report in a professional manner using the degree of skill and care exercised for similar projects under similar conditions by reputable and competent environmental consultants. The information contained in this report, including its conclusions, is based on the information that was made available to KGS Group during the investigation and upon the services described, which was performed within the time and budgetary requirements of Southeast Resource Development Council Corp. As the report is based on available information, some of its conclusions could be different if the information upon which it is based is determined to be false, inaccurate or contradicted by additional information. KGS Group makes no representation concerning the legal significance of its findings or the value of the properties investigated.

### 8.0 REFERENCES

1. Environmental Quality Guidelines for Alberta Surface Waters (2014)
2. Lesch, S.M. and Suarez, D.L. (2009). Soil and Water Division of ASABE 52(2): 493-496.
3. Lozecznik, S., Oleszkiewicz, J.A., Sparling, R., Clark, S. and VanGulck, J. (2012). Effects of turbulence and temperature on leachate chemistry. Journal of Environmental Engineering 138(5), 562-569
4. Poveda, M., Yuan, Q., Lozecznik, S. and Oleszkiewicz, J. (2015). Evaluation of Physico-Chemical Pretreatment Methods for Landfill Leachate Prior Sewage Discharge. Journal of Residuals Science & Technology. Vol 12, No. 3.

Thank you for the opportunity to provide engineering services for this very worthwhile and interesting project. If you have any questions or require additional information, please feel free to contact Mr. Stan Lozecznik P.Eng., or Mr. Rob Sinclair, P. Eng..

Prepared by:

Approved by:

Stan Lozecznik, Ph.D., P.Eng  
Environmental Engineer

Rob Sinclair, P. Eng.  
Manager of Environmental Services

SL/aa  
Enclosure

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**TABLES**



**TABLE 1  
METALS IN WATER AND GENERAL WATER QUALITY  
LOCATION**

Well No.	Date	Parameter <sup>(1)</sup>																		
		Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Calcium	Cesium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Magnesium	Manganese	Molybdenum
RAW LEACHATE	7-Apr-16	1.36	0.0023	0.0152	0.524	<0.0020	<0.0020	<b>6.77</b>	0.00017	181	<0.0010	0.061	0.0311	0.0248	<b>11.1</b>	0.00864	0.366	372	0.469	0.0051
ROOM TEMPERATURE	7-Apr-16	0.585	0.0027	0.0144	0.232	<0.0020	<0.0020	<b>6.96</b>	0.00023	47.3	<0.0010	0.051	0.0307	0.167	<b>7.00</b>	0.00473	0.379	370	0.0901	0.0053
60°C TREATMENT	7-Apr-16	0.054	0.0052	0.0189	0.144	<0.0020	<0.0020	<b>12.5</b>	<0.00010	18.6	<0.0010	0.054	0.0494	0.0296	1.58	0.00325	0.640	522	0.126	0.0090
EQL		0.05	0.002	0.002	0.002	0.002	0.002	0.1	0.0001	1	0.001	0.01	0.002	0.002	0.1	0.0009	0.02	0.1	0.003	0.002
<b>CCME<sup>(2)</sup></b>																				
<b>Canadian Water Quality Guidelines for the Protection of Agriculture</b>																				
Agriculture - Irrigation		5	-	0.1	-	0.1	-	0.5 - 6 <sup>(3)</sup>	0.0051	-	-	0.0049 (III), 0.008 (VI)	0.05	0.2 - 1 <sup>(3)</sup>	5	0.2	2.5	-	0.2	0.01 - 0.05
<b>Manitoba Conservation (Manitoba Regulation 282/87)</b>																				
Leachate Quality Criteria		-	-	5	100.0	-	-	500	0.5	-	-	5	-	-	-	5	-	-	-	-

Well No.	Date	Parameter <sup>(1)</sup>																		
		Nickel	Phosphorus	Potassium	Rubidium	Selenium	Silicon	Silver	Sodium	Strontium	Tellurium	Thallium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zinc	Zirconium
RAW LEACHATE	7-Apr-16	<b>0.222</b>	4.6	440	0.134	<0.010	21.5	<0.0010	1060	3.23	<0.0020	<0.0010	<0.0010	0.0214	0.102	0.0036	0.0045	0.0209	0.086	0.0529
ROOM TEMPERATURE	7-Apr-16	<b>0.233</b>	3.2	459	0.137	<0.010	19.7	<0.0010	1090	1.95	<0.0020	<0.0010	<0.0010	0.0156	0.0596	0.0041	0.0038	0.0184	0.110	0.0521
60°C TREATMENT	7-Apr-16	<b>0.399</b>	2.0	859	0.254	<0.010	30.3	<0.0010	2080	2.20	<0.0020	<0.0010	<0.0010	0.0079	0.0347	0.0083	<0.0010	0.0239	0.121	0.0841
EQL		0.02	1	0.2	0.002	0.01	1	0.001	0.3	0.001	0.002	0.001	0.001	0.002	0.005	0.001	0.001	0.002	0.02	0.004
<b>CCME<sup>(2)</sup></b>																				
<b>Canadian Water Quality Guidelines for the Protection of Agriculture</b>																				
Agriculture - Irrigation		0.2	-	-	-	0.02 - 0.05 <sup>(4)</sup>	-	-	-	-	-	-	-	-	-	-	0.01	0.1	1 - 5 <sup>(5)</sup>	-
<b>Manitoba Conservation (Manitoba Regulation 282/87)</b>																				
Leachate Quality Criteria		-	-	-	-	1	-	5	-	-	-	-	-	-	-	-	2	-	-	-

Sample No.	Date	Parameters <sup>(1)</sup>					
		pH (units)	E.C. (µS/cm)	Chloride <sup>(6)</sup>	Sulphate	T.D.S.	S.A.R.
EQL		0.1	1	5	15	20	0.03
RAW LEACHATE	7-Apr-16	7.68	11,800	<b>1,420</b>	172	<b>7,640</b>	10.36
ROOM TEMPERATURE	7-Apr-16	8.7	10,500	<b>1,340</b>	179	<b>6,800</b>	11.74
60°C TREATMENT	7-Apr-16	9.1	12,600	<b>2,510</b>	47	<b>8,180</b>	19.32
<b>CCME<sup>(2)</sup></b>							
<b>Canadian Water Quality Guidelines for the Protection of Agriculture</b>							
Irrigation		-	-	100 - 900 <sup>(6a)</sup>	-	500 - 3,500 <sup>(7)</sup>	-

**Notes:**

EQL = Estimated Quantitation Limit = Lowest level of the parameter that can be quantified with confidence

- All values are expressed in milligrams per litre (mg/L).
- CCME - Canadian Council of Ministers of the Environment. Canadian Environmental Quality Guidelines, 1999. Updated February 6, 2014. Guidelines for Canadian Drinking Water Quality.
  - Canadian Water Quality Guidelines for the Protection of Agriculture
- Guideline depends on crop.
- For continuous use on all soils, guideline is 0.02 mg/L; for intermittent use on all soils, guideline is 0.05 mg/L.
- For soil pH<6.5, guideline is 1 mg/L; for soil pH>6.5, guideline is 5 mg/L.

6. Chloride toxicity to freshwater organisms was evaluated using tests with both CaCl<sub>2</sub> and NaCl salts.

>710 mg/L for cauliflower, cotton, safflower, sesame, sorghum, sugar beets, and sunflowers

7. Guideline is dependant on type of plant. See CCME summary table for details.

lettuce, peppers, muskmelons, sweet potatoes, sweet corn, potatoes, celery, cabbage, kohlrabi, cauliflower, cowpea

**BOLD** - Exceedance of CCME Criteria

**TABLE 1  
METALS IN WATER GENERAL  
WATER QUALITY LOCATION  
KGS 15-0107-015**

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**APPENDIX A**

**RESULTS FROM PRE-TEST**

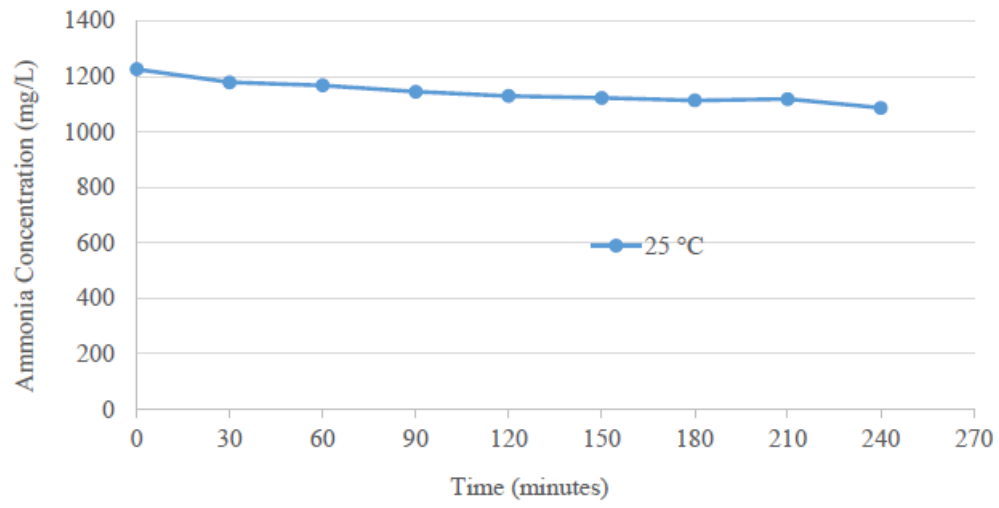


Figure 1. Results from pre-test at room temperature

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**APPENDIX B**

**SITE PHOTOGRAPHIC LOG**

**SITE PHOTOGRAPHIC LOG**  
**LABORATORY INVESTIGATION INTO THE EFFECT OF TEMPERATURE ON TREATMENT OF LEACHATE.**



Photo 1. Beginning of the study at room temperature.



Photo 2. Operation at 3 hr at room temperature



Photo 3. Settling after 24 hr at room temperature



Photo 4. Water bath set-up.

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**APPENDIX C**

**AMMONIA AND SOLIDS RESULTS**

Table a. Summary of the ammonia concentration in the leachate samples

Time (min)	Temperature								
	Room temperature	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C	55 °C	60 °C
0	1260	1266	1206	1189	1249	1193	1194	1219	1222
30	1234	1225	1179	1120	1186	1082	1007	977	934
60	1202	1189	1100	1089	1112	999	881	817	700
90	1175	1159	1085	1078	1107	974	790	741	547
120	1168	1146	1112	1082	1078	918	686	664	441
150	1136	1128	1078	1057	1060	810	638	529	292
180	1145	1110	1044	1023	1080	704	565	469	195
210	1126	1116	1062	989	995	700	496	380	145
240	1102	1095	1024	968	981	619	434	319	88

Table b. Summary of the Total Solids (TS) concentration of leachate samples after 24 hours of settling

	Total Solids (mg/L)
Raw Leachate	1393.3
Room temperature	1318.3
25 °C	982.6
30 °C	970.3
35 °C	946
40 °C	924.7
45 °C	844
50 °C	812.5
55 °C	749.4
60 °C	787.7

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