Testing the Solid Waste Leachate and Water Quality of the Norske Skog Pulp and Paper Mill in Kawerau, New Zealand to Investigate Industrial Contamination of the Surrounding Surface Water and Groundwater

Alana Dingman
Frontiers Abroad 2012
Final Report
13 June, 2012

Abstract

The Norske Skog Tasman Pulp and Paper Mill in Kawerau, New Zealand has been producing newsprint since its inception in 1955. The production process inevitably produces solid and liquid waste. This waste is contaminated with various chemicals added to the pulp during production. The waste was originally dumped directly into the Tarawera River. After the Tasman Pulp and Paper Enabling Act was passed in 1964, the company began using land from the local Iwi as a dump site, and created a landfill beginning in 1971. This landfill is still in use today, and has changed the local landscape in several ways. The site is of concern because of the potential safety hazard of chemicals leaching from the solid waste into the local water systems. Tests have been conducted to determine what inorganic contaminants are present, and to what concentration. The inorganic cations and anions found indicate the necessary level of concern for the land. Results show that with no variables, the concentrations of chemicals fluctuate temporally and spatially. This data in addition to previously conducted analysis reaffirms the presence of contaminants in this landfill. Future tests will need to be conducted to make further comparisons and conclusions.

1. Introduction

Industrial processes inevitably impact the environment on varying scales. Solid waste leachate analysis and water quality testing are two ways to monitor the condition of the environment. Many industrial processes produce solid waste that carries pollutants, including heavy metals, organic material, and suspended solid (Buyukkamaci and Koken, 2010). These pollutants can be leached out of the waste through natural processes such as precipitation events. The leachate can then infiltrate the ground into the surrounding water systems. This process introduces concentrations of soluble metals in the local water system. Both surface water and groundwater systems are easily affected by their surrounding environment, and can undergo physical and chemical changes as a result of industry. Some of these changes will not reach concentration levels toxic to the population, but nevertheless land and water quality are compromised. As industry grows, so does land use and water quality concern. Leachate and water should continue to be tested, especially near waste dump sites, for the well-being of our future and ability to continue using our natural resources.

It is important to test the chemical properties solid waste for comparison with the chemistry of associated water across spatial and temporal scales. This process can help determine the source of the physical and chemical changes in water. It can also determine the concentration of pollutants and their toxicity. These factors are important to know for the health and safety of the population. Previous work has been conducted by the Ministry for the

Environment to develop standards for certain levels of contaminants that are acceptable in landfills (Ministry for Environment 2003). The method for testing used by the Ministry for the Environment is taken from the United States Environmental Protection Agency (USEPA), and is known at the Toxicity Characteristic Leaching Procedure (TCLP).

Environmental impacts must be assessed at the Tasman Mill operated by Norske Skog in Kawerau New Zealand. This mill is a major operation, producing 315,000 tonnes of paper for newsprint in 2011 (Norske Skog 2011) and is economically valuable, as it contributes heavily to the GDP of New Zealand. It has been in operation since 1955 (Norske Skog) and has been using the same waste site for landfill since 1971. It is known that this company creates tonnes of waste and dumps it on this nearby site. To date, over 600,000 cubic meters have been dumped on this land. Throughout its use as a waste dump site, it has been transformed from a body of water to a solid landfill. It is also known through previous testing that this solid waste leaches contaminants into the surrounding bodies of water and groundwater (Hikuroa and Slade, 2011). Past testing of solid waste and water quality have been conducted to measure which contaminants are present and their concentrations (Howell, 2011). It is important to continually monitor this site to ensure acceptable levels of pollutants. The pollutants in the water eventually flow down gradient into the Tarawera river, which increases the scale and potential severity of this issue.

2. Background

The Tasman Pulp and Paper company built a mill outside Kawerau in 1952, and is the main industry that helped build the town. Kawerau is in the Bay of Plenty region of the north island, New Zealand.

A Map of Kawerau, New Zealand taken from KEA http://www.e-c.co.nz/kea/where-we-are.asp

Now the Norske Skog pulp and paper mill, it has been burying hazardous waste on the nearby Maori land (Te Kete Poutama). Initially, waste was directly dumped into the Tarawera river. Currently, the mill is polluting the surrounding water and soil in the Lake Rotoitipaku area.

Map of Waste Dump Site and Adjacent Ponds, taken from Angela Slade

The unaffected water in this area includes a spring and the affected area includes two ponds down gradient of the spring. Today, over 20m of waste covers the lake area and geothermal features. The lake no longer exists, and the geothermal resource is rendered useless. The site is situated on permeable pumiceous rock, and the area has known faults active as recently as 1987. It is also as close as 100m to the Tarawera river and has a shallow water table. Some efforts have been made to ameliorate environmental impacts. A containment pond was constructed on site, but has failed three times and has allowed for groundwater and soil contamination, proving it ineffective. The current proposed solution is to cap the waste site with semi-permeable material, and to top that with native flora (Hikuroa and Slade 2011).

The methods used for this project involve lab work and data analysis. The solid waste samples and water samples were collected from different locations on site. The solid waste samples were taken from various locations on the dump site in three transects. The first transect has 9 samples, the second has 3, and the third has 9, and were labeled accordingly. The water samples were taken from a spring stream up gradient of the site, and two ponds down gradient.

The objective of this project is to use new and existing data to provide an analysis of the Norske Skog mill waste site. The overall goal is to test the effects the solid waste could have on surrounding bodies of water, including surrounding ponds and the Tarawera River. This is achieved through chemical testing of collected water samples and leachate samples from the solid waste of the landfill. The testing conducted will be through the use of Atomic Absorption Spectrometry (AAS) to determine cation (Ca, Mg and Na) concentrations, and by Ion Chromatography (IC) to determine anion (chloride, sulphate, nitrate, and phosphate) concentrations in the water and leachate samples. This work is done by machines in a laboratory.

This data will be compared to several other sets of data. This analysis will be compared to data collected in the same location one year ago by a former Frontiers Abroad student, Cailly Howell (Howell 2011). This comparison will help to determine if similar conclusions can be drawn. The water chemistry will also be compared to the leachate chemistry to observe if the two have similar characteristics and are therefore both affected by the mill waste. The analysis also serves to compare the chemistry of unaffected and affected water systems.

I hypothesized that the data trend this year will be similar to previous years because the mill has been continuing to dump waste on the same site. There may be some variation in data

due to physical variability such as amount of recent precipitation, and pH of rainwater. Precipitation levels can affect pollutant concentrations. The more rain, the more likely contaminants have already been leached. pH can affect how much the soil has been broken down, and influences the waste chemistry (Howell 2011). There will also be temporal variability in the time that solid waste has been present in the system. The longer the waste has been present, the more likely is has been leaching pollutants. This may influence concentrations in the data set.

3. Methods and Materials

3.1 Sample collection

The freshwater samples were collected and tested for physical characteristics on site on February 10, 2012. Each water sample was collected in separate clean bottles. The first sample was taken from the spring, the second from the first pond, and the third from the second pond. After initial collection, each sample was tested for pH, temperature, conductivity, and dissolved oxygen (DO). After testing, each sample was transferred to a second bottle through a filtered (.45micrometer membrane) syringe. The filter served to collect all solid suspended sediment. The solid samples were collected in transects directly on the waste site. The first transect was located on the east bank of the large pond, and continued east for roughly 50m in a vegetated area. The second transect was located further north along a dirt road, and continued east to west for about 10m. The third transect was located about 30m north of the second transect, and continued south to north on the waste site in an area without vegetation. Exact GPS measurements were not recorded. The samples were shoveled from the surface and placed in labeled plastic bags. They vary in consistency and appearance.

3.2 Sample Preparation

For testing, the samples needed to undergo preparation in the water chemistry lab at The University of Auckland. This preparation work was done in the second week of May 2012. Two sample sets were made using the twenty one total soil samples and three water samples classified as "A" and "B" respectively. First, the water samples needed to be moved from their original containers to 50mL centrifuge tubes. At each collection site, two bottles of water were collected.
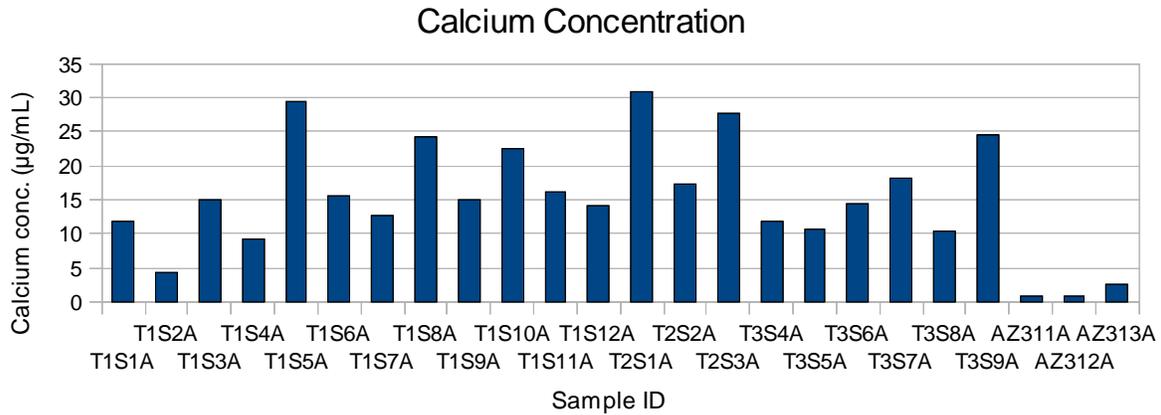
One bottle provided the water for anion testing, while the other was used for cation testing. Using plastic droppers, 40mL of water was transferred from the original bottles to the centrifuge tubes. The solid sample preparation required mixing of 4g of solid waste with 40mL of DI water in a 50mL centrifuge tube, which was then shaken for 5 minutes, and set aside to settle and undergo further mixing for 4 hours at room temperature. After 4 hours, the mixed liquid was transferred into a new centrifuge tube after filtration through a .45 micrometer filter.
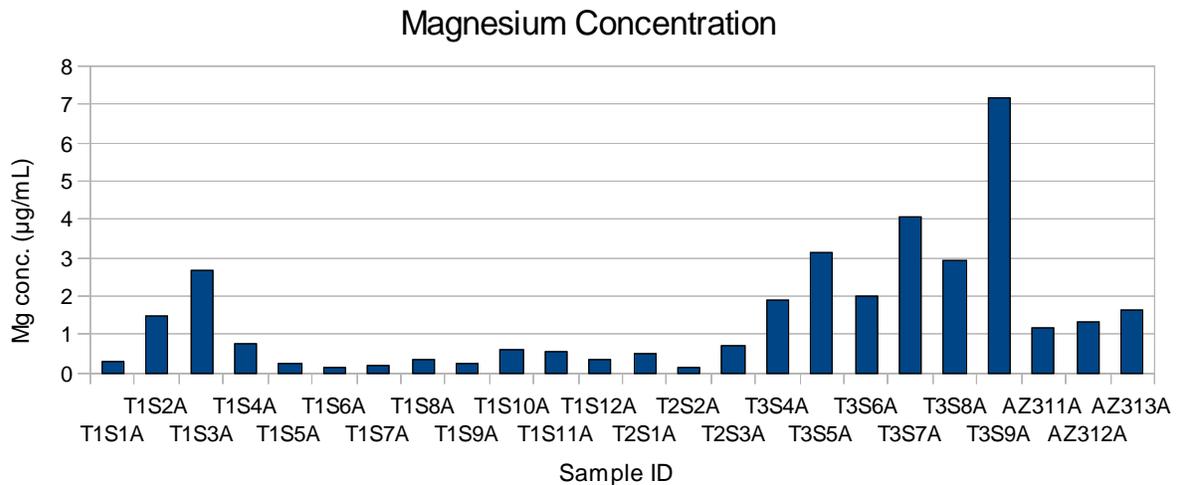
3.3 Sample Testing

Both the water and leachate samples were tested for anion and cation content and concentration. Each sample set, A and B, both had 6 water samples and 21 leachate samples. Three of the water samples were tested for cations, and three for anions, one for each site. All 21 leachate samples were tested for anions and cations. The testing was conducted in the Geology Chemistry Lab in the Human Sciences Building at the University of Auckland between 17 May and 22 May 2012. The testing was conducted by Atomic Absorption Spectrometry (AAS) to determine the Cation concentrations, and by Ion Chromatography (IC) to determine the Anion concentrations. The Cations tested were Sodium, Magnesium and Calcium. Some samples had high concentrations of cations and needed to be diluted using DI water. The Na samples were all diluted by 1/10 because of high concentration which prevented accurate testing. The tabulated values have been adjusted to compensate for this. Potassium would have been tested if not for broken lab equipment. The anions tested were chloride, sulphate, nitrate, and phosphate. The results were recorded on the computer software connected to the AAS and IC machines.
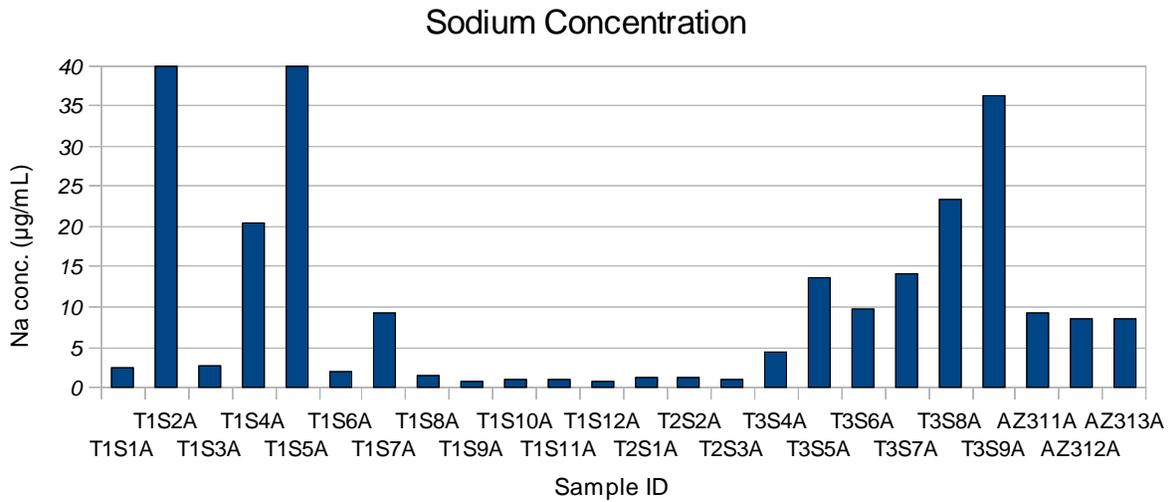
4. Results

The experiment conducted measured the cation and anion concentrations in 21 solid waste samples, labeled by transect number (Tn), sample number (Sn) and by set (A or B). The Water samples are labeled according to location, as AZ311, AZ312, and AZ313, and by set as well (A or B). The table below shows the cation concentrations of Calcium, Magnesium, and Sodium in µg/mL:

Calcium Concentration

Calcium conc. (µg/mL) — y-axis: 0, 5, 10, 15, 20, 25, 30, 35

Sample ID (x-axis): T1S1A, T1S2A, T1S3A, T1S4A, T1S5A, T1S6A, T1S7A, T1S8A, T1S9A, T1S10A, T1S11A, T1S12A, T2S1A, T2S2A, T2S3A, T3S4A, T3S5A, T3S6A, T3S7A, T3S8A, T3S9A, AZ311A, AZ312A, AZ313A

Above, Calcium concentrations do not appear to show a trend by transect. There are also no extreme outliers. It is worth noting that the concentrations are significantly lower in the water samples. This may be due to the way Calcium behaves in water, and more readily dissolves and becomes diluted in water than in solid matter.

Magnesium Concentration

Mg conc. (µg/mL) — y-axis: 0, 1, 2, 3, 4, 5, 6, 7, 8

Sample ID (x-axis): T1S1A, T1S2A, T1S3A, T1S4A, T1S5A, T1S6A, T1S7A, T1S8A, T1S9A, T1S10A, T1S11A, T1S12A, T2S1A, T2S2A, T2S3A, T3S4A, T3S5A, T3S6A, T3S7A, T3S8A, T3S9A, AZ311A, AZ312A, AZ313A
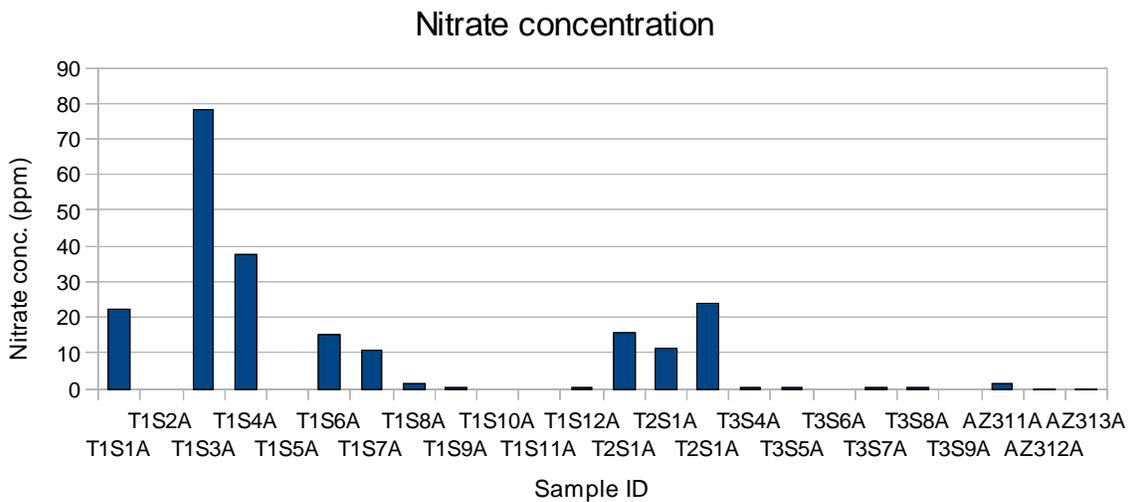
In the graph of Magnesium concentrations, there are no strong trends among transects one and two. However there is a spike in concentration at the beginning of transect 1. This may be due to the proximity to a pond, as transect 1 started close to a pond and each sample moved further from this feature. These values in T1S2A, T1S3A and T1S4A are similar to the concentrations in the three water samples. The water samples are all at similar concentrations, which may be due to the ease with which cations travel through water systems. They also slightly increase with each sample. The values also spike at T3, most likely because it was more recently produced at is leaching at higher rates than solids that have been in the landfill for a longer period.

Sodium Concentration

Na conc. (µg/mL)

40
35
30
25
20
15
10
5
0

T1S1A T1S2A T1S3A T1S4A T1S5A T1S6A T1S7A T1S8A T1S9A T1S10A T1S11A T1S12A T2S1A T2S2A T2S3A T3S4A T3S5A T3S6A T3S7A T3S8A T3S9A AZ311A AZ312A AZ313A

Sample ID

The Sodium concentrations varied the most of all the cations tested. T1S2A and T1S5A were extreme outliers and had concentrations of 363µg/mL and 501µg/mL respectively. These values were most likely subject to contamination. This graph shows a similar trend in T3 and the water to the Magnesium data, although at a higher concentration. This reinforces the idea that the temporal variation is a major factor in leaching rates.

No values of Ca or Mg were too high, but when Na cations were tested it was found that T1S2A and T1S5A were still too concentrated after initial dilution, and were then diluted by 20 times and 30 times respectively. The values in table 1 have also been adjusted for this.

The following graphs show Nitrate, Chloride, and Sulfate concentrations of solid and

Nitrate concentration

Nitrate conc. (ppm)

90
80
70
60
50
40
30
20
10
0

T1S1A T1S2A T1S3A T1S4A T1S5A T1S6A T1S7A T1S8A T1S9A T1S10A T1S11A T1S12A T2S1A T2S1A T2S1A T3S4A T3S5A T3S6A T3S7A T3S8A T3S9A AZ311A AZ312A AZ313A
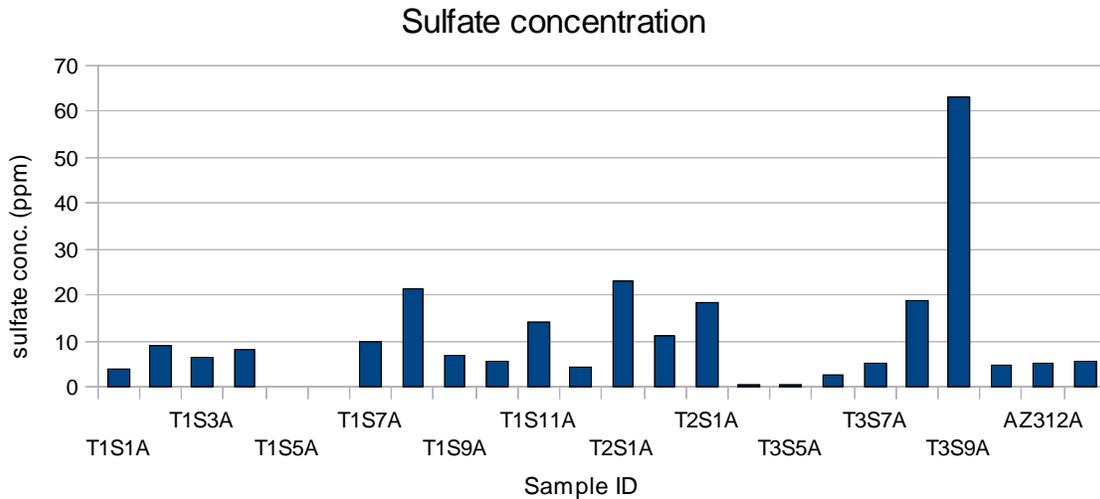
Sample ID

water samples in ppm:

The Nitrate data is incomplete and this anion was not detected in every sample. There is

Chloride concentration
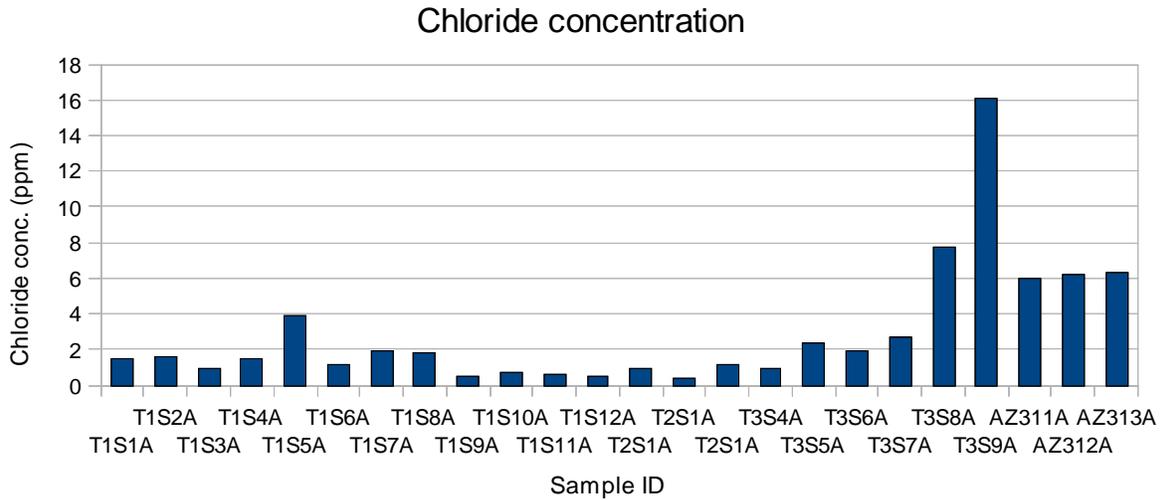
no definite trend in this data.

Chloride was found in every sample. This also has the same trend as Calcium and Magnesium in T3. The water samples are also consistent and are relatively similar. Otherwise, the concentrations of chloride are low in T1 and T2, the older samples.

Sulfate concentration

The Sulfate data set was also incomplete. This showed an unusual spike in T3S9A, similar to the other chemical tests. Transect 3 also rapidly increases in concentration spatially. The concentrations remained constant in the water samples.

The phosphate data was not significant enough to graph, as only data for two locations were detected.

5. Discussion

The results show that high concentrations of cations and anions are present, and therefore the landfill is contaminated from the pulp and paper mill waste. The results vary spatially and temporally. This is evident in the differences in concentrations between transects and water samples.

The concentrations between water and leachate samples differed for several reasons. The water results also remained relatively constant across all 3 samples which shows they are connected systems, or have similar exposure to pollutants. The variances in leachate results may be due to environmental conditions such as level of precipitation at the time of sample collection. If the time of collection was during drought, there may be potential for higher concentrations of cations and anions due to a lack of leaching.

Another reason for variance in leachate results may be temporal. Solid waste collected from T1 was older than solid waste from T2 and T3, which had been dumped most recently. This could explain why T3S9A showed higher concentrations of contaminants overall. This sample most likely held more contaminants than those from T1 because it was not exposed to the elements as long, and did not have time to leach as many chemicals.

A third difference explaining differences in results may be due to flow rates of water. It is known that the landfill is above porous rock, but the surface waste is sitting on 20m of solid waste, which may have a different porosity. This will affect the flow rate of water through the system, and will affect how quickly the contaminants will be carried away, and the amount of time that solid waste is mixing with water.

A fourth reason for variance in results is due to the heterogeneous nature of the solid waste. Each transect had different physical characteristics, and may therefore contain different concentrations of contaminants. There may also be a variety of contaminants present in each transect. The first transect was taken from a vegetated location, and soil samples were darker in color, and contained biological material such as roots. Transect two was finer grained, dark in color, and had no visible biological material. Transect three samples were taken from an area of recently produced waste. This waste was made of gray clumps of paper pulp, and showed no signs of biological activity on site. These transects have different physical characteristics which reflect upon their chemical differences.

A fifth reason for variance is potential human and lab error, which may have caused contamination of samples. The sodium outliers for example were yellow in color, unlike the other samples. It was determined that the discoloration was due to contamination between sample collection and sample preparation. To eliminate bias, it would have been ideal to collect samples of leachate in the field, rather than creating the leachate in the lab.

Cailly's research proved difficult to compare to, and further reinforces that more extensive testing is necessary. She used varying pH, amounts of solid waste, and temporal exposure. These characteristics are important to account for environmental variability. Her research shows how leachate may contain different concentrations of contaminants. This is relevant to the Tasman landfill because it has been in use for over 40 years, and has had much environmental exposure. Her 4g of solid samples were compared to the averages and standard deviations of the Ca and Mg samples. As shown in Figure 1 (see appendix), her values with 4g of solid at a pH of 3.23 for Ca and Mg were 11.710µg/mL and 6.123µg/mL. Her values at a pH of 5.53 were 0.960µg/mL (Ca) and 1.283µg/mL (Mg). The average we found for the same elements were 16.98µg/mL and 1.44µg/mL with standard deviations of 7.05 and 1.64. The Calcium is therefore comparable, but the Magnesium is not at a lower pH while the opposite is true at a higher pH. However, this comparison is between individual values and averages of several values. This comparison should be further investigated for correlation.

Due to time constraints, full analysis was not possible, but provides an opportunity for further work to be done. If time permitted, the Potassium concentration could have been tested. Further testing with more variables could have been performed as well. Similar to Cailly's report, we could have expanded the parameters of this experiment.

6. Conclusion

The presence of tested cations and anions suggests contamination. Future testing would be necessary to make a more definite conclusion. This includes testing for associated chemicals such as organics and heavy metals. Groundwater should also be tested for health and safety purposes.

To put this in perspective, it is important to consider receiving environment. It is important to recognize nearby water resources, and how deep the water table is. The local

geology is useful to know to help analyze where the leachate may flow, and at what rate. Not only is knowledge of the landscape important, but so is knowledge of the local population. In addition to this scientific work, population density should be taken into account. Further testing of the Tarawera river will prove if the water is diluted enough to acceptable concentrations.

TCLP testing should also be done in the landfill to test for acceptable levels of contaminants in the landfill. This testing uses acetic acid with a pH of 5 over 24 hours and is used by the Ministry for the Environment. According to the US EPA there are no TCLP limits on organic pollutants, but there are for inorganics (Ministry for the Environment, 2003). It may also be useful to test organics and volatiles to further understand the broader scope of environmental contamination at this site. This would involve different methods of testing.

In conclusion, this testing for cations and anions confirmed pollution in the landfill from the Tasman Mill. This supports a need for reproducing and expanding upon the experiment, as well as looking into further detail of what the implications of pollution are at this location.

Acknowledgments

Thank you to Dan Hikuroa, Angela Slade for field and project guidance, Russell Clarke for laboratory help, and the FA Earth Systems '12 students for their sample collections and support.

References

Buyukkamaci, Nurdan, Emre Koken (2010). Economic Evaluation of Alternative Wastewater Treatment Plant Options for Pulp and Paper Industry. *Science of the Total Environment*, 408: 6070-6078.

Joblin, Mark Hugh (2012). Environmental Assessment of the Effects of Leachate Irrigation and Seepage from the Paokahu Landfill, Gisborne, New Zealand. Research Commons at the University of Waikato. <http://researchcommons.waikato.ac.nz/handle/10289/4801>

Hikuroa, D., Slade, A., & Gravley, D., (2011). Implementing Maori indigenous knowledge (matauranga) in a Scientific Paradigm: Restoring the Mauri to Te Kete Poutama. *MAI Review*, 3: 1-9.

Howell, Cailly (2011) Determining the concentration of calcium, potassium, magnesium, and zinc cations leached from solid waste generated by the Norske Skog Tasman Pulp and Paper Mill under varying pH conditions. *Frontiers Abroad 2011*: 1-23.

IFC: World Bank Group (1998) Pulp and Paper Mills. Pollution Prevention and Abatement Handbook. <www.ifc.org/ifcext/enviro.nsf/.../gui_pulp_wb/.../pulp_ppah.pdf>

Loser, Chrsitian, Andreas Zehnsdorf, Kati Gorsch, Heinz Seidel (2006) Remediation of heavy metal polluted sediment in the solid bed: Comparison of abiotic and microbial leaching. *Chemosphere*, 65: 9-16.

Ministry for the Environment (2003) Waste Acceptance Criteria for Class A Landfills, *URS*
     <http://www.mfe.govt.nz/publications/waste/waste-acceptence-criteria-sep03.pdf >

Norske Skog (2011) Annual Report 2011 Norske Skog: Norwegian Paper Tradition.

Norske Skog, Everything We Do Counts: Notes on Sustainability and the paper you print on.
     <www.norskeskog.com/Admin/Public/DWSDownload.aspx>

"Norske Skog Tasman." *Norske Skog Tasman*. Norske Skog.
     <http://www.norskeskog.com/Business-units/Australasia/Norske-Skog-Tasman.aspx>.

Appendix

Sample	Ca (µg/ml)	Mg (µg/ml)	Na (µg/ml)
T1S1A	11.92	0.29	2.43
T1S2A	4.43	1.48	364.92
T1S3A	14.89	2.66	2.82
T1S4A	9.33	0.77	20.47
T1S5A	29.46	0.25	503.22
T1S6A	15.65	0.12	1.91
T1S7A	12.8	0.18	9.2
T1S8A	24.29	0.32	1.55
T1S9A	15.08	0.24	0.76
T1S10A	22.41	0.62	1.02
T1S11A	16.28	0.55	1
T1S12A	14.18	0.35	0.72
T2S1A	30.79	0.49	1.28
T2S2A	17.24	0.14	1.33
T2S3A	27.62	0.72	1.02
T3S4A	11.96	1.88	4.44
T3S5A	10.55	3.13	13.62
T3S6A	14.52	2.01	9.71
T3S7A	18.14	4.07	14.21
T3S8A	10.45	2.96	23.3
T3S9A	24.64	7.18	36.35
AZ311A	0.8	1.19	9.27
AZ312A	0.86	1.34	8.47
AZ313A	2.57	1.61	8.65
Average:	15.03	1.44	43.4
Std. Dev.	8.43	1.64	122.35

Table 1. Raw Data Cation of Concentrations, Averages, and Standard Deviation

Sample	Nitrate(ppm)	Chloride(ppm)	Sulfate(ppm)	Phosphate(ppm)
T1S1A	22.3	1.45	4.08	
T1S2A		1.57	9.17	
T1S3A	78.14	0.93	6.5	
T1S4A	37.6	1.51	8.13	53.92
T1S5A		3.93		
T1S6A	15.03	1.14		
T1S7A	10.97	1.95	9.96	15.44
T1S8A	1.71	1.85	21.43	
T1S9A	0.41	0.53	6.94	
T1S10A		0.77	5.78	
T1S11A		0.67	14.08	
T1S12A	0.38	0.57	4.22	
T2S1A	15.92	0.95	23.13	
T2S1A	11.37	0.44	10.96	
T2S1A	24.12	1.19	18.51	
T3S4A	0.51	0.96	0.47	
T3S5A	0.48	2.35	0.32	
T3S6A		1.98	2.47	
T3S7A	0.19	2.68	5.35	
T3S8A	0.37	7.77	18.85	
T3S9A		16.05	63.2	
AZ311A	1.33	6.05	4.84	
AZ312A	0.03	6.22	5.31	
AZ313A	0.03	6.3	5.42	
Average	12.27	2.91	11.32	34.68
Std. Dev	19.74	3.51	13.29	27.21

Table 2. Raw Anion Data of Concentrations, Averages, and Standard Deviations

Table 4. Varying Amount of Solid Experiments: Cation Concentrations.

Sample ID	[Ca] µg/mL	[Mg] µg/mL	[K] µg/mL	[Zn] µg/mL
CH23 (2g)	2.768	1.912	3.162	0.007
CH25 (4g)	11.710	6.123	4.877	0.016
CH27 (8g)	12.859	5.264	4.140	0.004
CH24 (2g)	-0.889	0.569	2.127	0.009
CH26 (4g)	0.960	1.283	2.379	0.011
CH28 (8g)	50.205	HIGH	11.173	0.006

Note: Two different pH levels were used, 3.23 and 5.53. The first three listed samples, CH23, 25, 27 were at pH 3.23 and samples CH 24, 26, 28 were at pH 5.53.

Figure 1. Cailly's results of varying amount of solids in different pH environments