Operational Prediction of the ARD and Metal Leaching Potential of a Strongly Oxidized, Low NP Waste Rock

Scott R. Frostad[1,2]

[1] Cogema Resources Inc., McClean Lake Operation, PO Box 9204, Saskatoon, SK S7K 3X5 (306) 633-2177 Ext. 409 Scott.Frostad@cogema.ca; [2] Formerly with Kemess Mines Ltd., Smithers, BC.

Abstract

Based on elemental and ABA analysis, a significant portion of a waste rock with low levels of sulphide-S and neutralization potential (NP) was predicted to potentially generate acid rock drainage (ARD). Mineralogical work included optical and scanning electron microscopy, electron-probe microanalysis, and quantitative X-ray powder diffraction. Post-blast grab samples were sieved into various size fractions and each fraction was analyzed to determine the relative contribution of acid potential (AP) and NP. Kinetic testing included field test pads, laboratory cells comparing drip-leach and flood leach, and re-circulating columns. Interpreting the results of the kinetic tests was aided with pre and post-test shake flask data.

Results of the study indicated that much of the sulphides are encapsulated within quartz, insoluble sulphate was a minor but potentially significant constituent of the measured AP, and sulphides preferentially report to the fine fraction of the post-blast material. Molar ratios of calcium and magnesium to sulphate for leachate from the field test pads were used in combination with laboratory sulphate production rates to assess the ARD potential. Selenium, the primary element of concern, returned concentrations from the field tests an order of magnitude greater than returned from the laboratory re-circulating columns and waste dump seeps of the same material.

Introduction

Acid base accounting analyses and kinetic testing are routinely used to determine the potential of a waste rock to generate acid rock drainage (ARD). Segregation and mitigation of potentially problematic material can be very expensive. Furthermore, the prediction of the ARD and metal leaching (ML) potential of waste rock with low levels of sulphide-S and neutralization potential (NP) is hampered by the small concentrations involved and the differences between an actual dump and kinetic test conditions. Accurately measuring the acid potential (AP) of waste rock having a low sulphide content may require an estimate of exposed (available) sulphide in the waste dump (Lapakko, 1994; Price and Kwong, 1997) and insoluble sulphate (Price, 1997). Predictions based on low NP concentrations should consider the dependence of available NP on grain size (White et al., 1998; Scharer et al., 2000) and the possibility of limited buffering due to the presence of precipitates (Frostad et al, 2000a; Scharer et al., 2000). Laboratory kinetic tests can overestimate NP depletion rates for materials with low sulphide contents since carbonate dissolution can be controlled by rinse volumes rather than acid generation (Frostad et al., 2000a; Li 2000).

Field kinetic tests are operated to incorporate site-specific conditions that are difficult to account for in laboratory kinetic tests such as particle size distribution, flush volumes, and temperature. However, making short-term predictions using field test data is difficult since the drainage chemistry will typically develop slowly (Frostad et al., 2000b) and if test piles become frozen, the leachate chemistry may not be in equilibrium with conditions in the pile (Bennett et al., 2000).

Objectives

The objective of the current study was to improve the ML/ARD prediction of the Kemess South leach cap waste rock and thereby lessen handling and mitigation costs by: (1) determining the source of the measured AP and NP, and their distribution in relation to particle size; and (2) conducting a variety of field and laboratory kinetic tests.

Materials and Methods

The Kemess South gold-copper orebody, located in north-central British Columbia, is associated with a porphyritic quartz monzodiorite intrusion. Oxidation and subsequent leaching of the upper portion of the orebody, the 'leach cap' material, has removed most of the sulphides, copper and NP. The net potential ratio (NPR) of leach cap material, calculated by dividing the Sobek-NP (Sobek et al., 1975) by the AP, is currently used for ARD classification. The AP has units of kg $CaCO_3$/tonne and is obtained by multiplying sulphide-S (%) by 31.25. Leach cap material is currently deemed to be potentially ARD generating (PAG) if the NPR is <= 2, and not potentially ARD generating (NPAG) if NPR is >2.

Static Tests

Ongoing characterization of leach cap material includes sampling of pre-blast rotary drill hole cuttings and post-blast grab samples. The post-blast samples are sieved into >25 mm, 2.36-25 mm (coarse) and <2.36 mm (fine) size fractions and weighed. The coarse and fine fractions are submitted for acid base accounting (ABA) and inductively coupled plasma atomic emission spectroscopy (ICP-AES).

Petrographic examination of twenty-two leach cap samples (twelve pre-blast and ten post-blast) was conducted by Harris Exploration Services, Vancouver, BC with the objective of determining the presence and mode of occurrence of the sulphides, carbonates and barite. The samples were screened to a size range of 0.5-2.36 mm before being briquetted in epoxy and prepared as polished thin sections.

Scanning electron microscopy/energy-dispersion spectrometry (SEM/EDS), quantitative X-ray powder diffraction (XRD) and electron-probe microanalysis (EPMA) was used to analyze nine powdered samples (<50 um fines) and eight corresponding polished thin sections by the University of British Columbia (Raudsepp and Pani, 2000). The primary purpose of the study was to determine the percentage of Ba that occurs as barite ($BaSO_4$) since barite is non-acid leachable and therefore reports as sulphide-S in an ABA analysis. The powdered samples analyzed by SEM/EDS were examined using backscattered electron (BSE) imaging. XRD data was analyzed using the Rietveld method, a crystal structure refinement method. The barium concentrations of these samples were determined by both aqua regia digestion (ICP analyses) and by X-ray fluorescence (XRF) using a lithium borate fusion. The sulphate-S concentrations were determined using HCl extractions and then again using a hot Na_2CO_3 leach that is considered to attack barite.

A sulphide-S distribution study was conducted on six post-blast samples to determine the relationship between particle size and sulphide-S. Each sample had the <2.36 mm fraction separated by dry sieving. One split of the <2.36 mm fraction was sampled and analyzed for total and sulphate-S (for mass balance purposes) then the <75 µm size fraction was separated by dry sieving and also analyzed for sulphur. The other <2.36 mm split was weighed, wet sieved using 425 and 75 µm screens, then the size fractions >75 µm were dried, weighed and analyzed for sulphur species. The calculated mass of the <75 µm size fraction was assigned the total and sulphate-S values obtained from dry sieving.

Shake flask testing of kinetic test samples LTP-2, 5 and 6, pre and post-testing, were conducted to aid in the interpretation of the kinetic tests results. The shake flask procedure requires a flask containing a 250 g sample of particle size <2 mm and 750 mL of de-ionized water to be gently agitated with a bench-top orbital shaker for 24 hours. The sample is left to stand for a minimum of three hours to allow suspended materials to settle then the supernatant is decanted and analyzed for pH, conductivity, sulphate and dissolved metals.

Kinetic Test Type and Operation

The kinetic test program for the leach cap material included two humidity cells, five laboratory leach columns, three field tests, and two re-circulating leach columns.

Humidity cell testing of sample LC-1, created from the <6.35 mm size fraction of post-blast material, was conducted in duplicate at BC Research Inc., Vancouver, BC. The humidity

cell cycle included 3 days of dry air, 3 days of wet air, and 1-day flood leach. The leach used 500 mL of de-ionized water and the cell contents were stirred gently and allowed to stand for two hours before being drained. The two humidity cells were operated for a total of 46 weeks.

Leach cell testing of three samples using two separate leach methods was conducted at the Environmental Laboratory of Kemess Mine. The purpose of the testing was to validate the humidity cell rates of weathering and to help establish a relationship between laboratory and field test results. Three cells (LTP 2A, 5A and 6) received weekly 500-mL drip leaches and two duplicate cells (LTP-2B and 5B) received weekly 500-mL 1-hour flood leaches. All three samples were subjected to a shake flask analysis before and after testing. To aid interpretation of field metal leaching rates, the drip-leach cells were initially leached with small volumes of water. The dry sample was slowly saturated and the first 50 mL of leachate collected became the first leach and the second, third, fourth and fifth leaches were 50 mL, 100 mL, 150 mL and 150 mL volumes, respectively. These small volume leaches, totaling 500 mL of leachate, were conducted during the first week and were followed by the standard 500 mL weekly leaches.

The field experiments were constructed to assist in the prediction of ARD/ML. The LTP-2 field test began operation during June 1999 and, due to anomalous selenium concentrations in the leachate, two other field tests (LTP-5 and 6) were built and began operation during July 2000. The pads are 2.26 x 2.26 metres, constructed of planking with crib walls 16 cm in height, and have a plywood base covered by an impervious liner. Each test pad was filled with approximately 3.5 tonnes of material and leachate is sampled when the 75-L collection bucket approaches capacity. Sulphate production rates and NP depletion rates are calculated using the measured volumes of leachate released and precipitation data.

Re-circulation leach column testing was conducted to predict the saturation concentration of selenium in drainage from the leach cap waste dump. Leach Column-1 consisted of five stacked cells connected by tubing with each cell holding a 2-kg charge. De-ionized water was dripped into the column until the 10-kg sample became saturated and 1000 mL of leachate had been collected. A 10-mL sample of the leachate was diluted with 90 mL of de-ionized water to provide adequate sample volume and analyzed for dissolved Se. The remaining leachate was brought up to a volume of 1000 mL using de-ionized water, then dripped back into the column. The leachate was collected, sampled and re-circulated ten times. The sample was replaced with 10 kg of fresh, dry material two times, each time being leached with the previously described procedure. The second re-circulation test, Leach Column-2, only used one 2-kg cell. The sample was saturated with de-ionized water, an additional 500 mL of water was added, then the recovered leachate was dripped back through the cell a total of five times before being analyzed for Se. Replacement of the sample was conducted seven times and each time the sample was saturated with distilled water then leached five times with re-circulated leachate.

Results and Discussion

The leach cap samples were determined to have a fairly consistent mineralogy (XRD) containing muscovite (25-35%), illite (6-10%), quartz (47-55%), hematite (4-9%), and kaolinite (3-9%). The statistical median of ABA results for the pre-blast cuttings and the post-blast grab samples, both coarse and fine fraction are found in Table 1.

Sulphides

For PAG samples, the analytical sulphide-S median for pre-blast drill hole cuttings was similar to the post-blast coarse fraction median at 0.07%. The post-blast fine fraction returned a higher sulphide-S median than the coarse fraction at 0.10%. Sulphides preferentially reported to the fine fraction of post-blast samples for 63% of the samples. PAG and NPAG post-blast fines both returned maximum sulphide-S contents of 0.14%.

Extremely rare traces of pyrite (and occasional chalcopyrite) were found in 11 of the 12

petrographic slides. All sulphides observed in the fine fraction of both pre- and post-blast samples occurred as minute specks, typically ranging in size from 5 – 50 μm, and were encapsulated in fragments of quartz or, more rarely, hematite. Encapsulation of the acid generating sulphides is consistent with the expected destruction of exposed sulphides by oxidation within the leach cap material.

The sulphide-S distribution study was undertaken since the petrographic examinations did not examine the <500 μm size fraction. For the six post-blast samples studied, the <2.36 mm size fraction comprised an average of 25% (weight percent), and the sulphide-S content of these fines was 0.02 to 0.12%. The proportion of sulphide-S in the <425 μm fraction ranged from 18 to 43%. Assuming all the sulphide-S in the <500 μm size fraction is available for oxidation, and using the sulphide-S upper range of 0.14%, the maximum amount of available sulphide-S in a PAG sample is 0.02%.

Insoluble Sulphate (Barite-S)

Barite was detected in all the samples using SEM/EDS but was only found in 4 of the 12 petrographic slides. The BSE examination showed barite to generally occur as grains <5 μm in size but it was not practically possible to quantitatively measure its abundance using this technique. The EPMA analysis of muscovite and illite found these minerals to contain 0.18-0.30 wt.% Ba with none of the kaolinite containing Ba above the detection limit of 0.07%. If it is assumed that the only significant sources of barium are barite and muscovite/illite, 29-53% of the barium (in the <50 μm size fraction) is hosted by barite.

Barium concentrations (ICP) ranged from 0.024-0.428% and the median Ba concentrations for the coarse and fine post-blast samples are 0.107% and 0.126%, respectively. Conservatively assuming 25% of the Ba occurs as barite, the median value of barite-S for the fine post-blast samples is 0.007%. The comparison of ICP versus XRF showed ICP to be underestimating the barium concentrations by approximately 15%. The hot Na_2CO_3 leach returned sulphate-S concentrations equal to, or greater than, the HCl extractions (median difference of 0.01%) and is therefore assumed to be correctly accounting for barite. Subtracting 0.01% barite-S from the % sulphide-S of PAG post-blast fines does not result in any samples being reclassified as NPAG.

Neutralization Potential

Leach cap material generally returns a PAG classification due to an absence of neutralizing potential rather than an increase in sulphide percentage (Table 1). The PAG post-blast fines returned carbonate NP (Carb-NP) values that were greater than Sobek-NP values for 61% samples suggesting the presence of Fe carbonates and that NPR values are appropriately calculated from Sobek-NP (Frostad et al., 2003). The NP is similar to the sulphides in that it preferentially reports to the fine fraction of the post-blast samples.

Rare fragments of sparry carbonate were found in 6 of the 12 pre-blast samples and estimated to represent an overall carbonate content in the order of 0.3%. Unlike the sulphides, carbonate fragments in this size range (0.5-2.36 mm) are exposed and, therefore, available to neutralize acidity. The analytical results for these samples closely reflected the estimates made from optical observations (i.e. Carb-NP of 3 equates to 0.3% $CaCO_3$ in the sample). The analysis of the XRD data using the Rietveld method did not report carbonate for any of the samples.

ARD Potential

A summary of ABA results for the kinetic test samples is presented in Table 1. The highest sulphide-S content was returned from LTP-6 at 0.06% while samples LC-1 and LTP-5 only reported 0.01% sulphide-S. Both samples LTP-2 and LTP-6 returned less than the detection limit for carbon indicating no carbonate neutralization potential. A summary of the laboratory and field results is provided in Table 2.

The pre and post-test shake flask analyses indicate that the kinetic tests were measuring production rates rather than release rates for most metals. No significant differences in the shake flask analyses were noted between drip

and flood leached laboratory cells. For LTP-2, 5, and 6, initial sulphate concentrations ranged from 10 to 13 mg/L SO_4 while post laboratory and field-test results were lower ranging from 3 to 9 mg/L SO_4. Field test LTP-5 showed an increase of calcium, from 5 to 24 mg/L, suggesting that the field NP depletion rate may be slightly underestimated.

The pH, sulphate and alkalinity concentrations of the field cells for the last 5 available cycles of testing are greater than the comparable laboratory samples. The high water to solid ratio for the laboratory cells would have removed readily soluble sulphate and metals more quickly than the field tests. For all the laboratory cells, the sulphate production rates were very low at 1.5 mg/kg/wk or less and appeared stable when testing was terminated. For the field cells, the sulphate production rates still appear to be decreasing while alkalinity has become relatively steady.

The molar ratio of calcium and magnesium to sulphate, referred to as the 'carbonate molar ratio', allows NP depletion rates to be based on field test results. The high molar ratios of the laboratory cells, 4.9 to 61.7, are thought to reflect carbonate dissolution in response to rinse volumes. The molar ratios of the field cells, 1.8 to 2.6, are considered to better represent NP depletion in relation to sulphide oxidation but are still likely an overestimation due to the high volume of rainfall that rinses the small test piles. Using the stable sulphide production rates obtained from the laboratory in combination with field test molar ratios provides NP depletion rates of 1.4 to 3.2 mg/kg/wk. The rate of NP depletion would be further reduced by the physical characteristics of the leach cap material. The blasted rock is very fine grained with a high holding capacity for rainwater (as determined by field-test water balance calculations) and slow pore water flushing would enhance the distribution of carbonate NP while saturation of the fines would inhibit oxidation of exposed pyrite.

Based on the results of this study, the potential of any leach cap material to generate ARD is considered to be extremely low. The petrographic study indicated that carbonate in the fine fraction (<2.36 mm) can be regarded as available NP and that sulphides in the >500 μm size fraction are not available for oxidation. Conservatively assuming all the sulphides in the <500 μm size fraction are available for oxidation, and using the calculated percent of sulphide occurring in this size fraction (50%), then 50% of the PAG material is reclassified as NPAG. A less conservative assumption, 50% sulphides in the <500 μm fraction are exposed, reclassifies all PAG material to NPAG.

Metal Leaching Potential

Selenium was first identified as an element of concern from field test results. Leachate collected from the LTP-2 field test returned Se concentrations up to 1600 μg/L in comparison to the BC Water Quality Objective for Se of 1.0 μg/L. The Se concentration from the LTP-2 field test remained above 500 mg/L for the first year and dropped to 220 μg/L by the end of the second year (Figure 1). The laboratory leach cell containing LTP-2 material returned 1560 μg/L Se for the initial 50-mL leach, and the average for the last 5 cycles of testing was 97 μg/L Se. Both the field test and laboratory leach cell indicated that selenium release from leach cap material had potential to be a concern in the short-term.

The two re-circulation leach columns, Column-1 and 2, returned average selenium concentrations for the last 5 cycles of testing of 106 and 109 μg/L, respectively (Figure 2). The leach cap waste dump drainage returned similar selenium concentrations with an average of 131 μg/L Se for its first year of existence. The initial field test results dramatically overestimated the selenium concentrations that would be experienced from the leach cap waste dump. It is considered that the high volume of rainwater that continually rinsed the small 3.5 tonne field test allowed the leachate to become super-saturated with selenium in the short term. The Column-2 procedure of predicting field concentrations for metals of concern is recommended since it is a fast, relatively simple method that uses a small apparatus.

Conclusions

An extensive characterization study has been conducted to determine the ARD/ML potential of a strongly oxidized, low NP waste rock. All the material is considered to have an extremely low potential to generate acidic water since:

- available sulphide-S is estimated to be less than 0.02%,
- the ratio of available NP to available sulphide-S is estimated to be at least twice as high than is indicated by the NPR,
- the only potential source for ARD is highly reactive sulphides occurring in the fine fraction, therefore, any acid generation would be short-lived, and
- carbonate dissolution rates, based on kinetic testing and physical characteristics of the material, would be slow enough to neutralize potential acidity.

Selenium was shown to be an element of concern from field-testing, however, seeps from the leach cap waste rock dump have returned Se concentrations an order of magnitude lower than the field test results. For predicting metal leaching rates, the re-circulation leach column-2 methodology outlined in this paper is considered to provide a fast and reliable result.

To minimize the potential loading of selenium to the local environment, efforts have been made to hydrologically isolate the leach cap waste dump. The waste rock dump was constructed on a pad of inert Tertiary sediments (>2 metres thick) to prevent the leaching of selenium from material located at the bottom of the dump by overland flow. Building the waste rock dump upwards rather than outwards has reduced surficial area, and sloping and compacting the upper surface has promoted runoff. Recently, the leach cap waste dump was capped with 2 metres of Tertiary sediments to further restrict water infiltration.

Since leach cap material with an NPR <=2 has an extremely low ARD potential, and subaqueous disposal may create a liability due to uncontrolled selenium loadings, the leach cap waste dump is considered to be the safest destination for all leach cap waste rock.

Acknowledgements

The author would like to thank Bill Price (CANMET, formerly with British Columbia Ministry of Energy and Mines) for his valuable input throughout this study, Harold Bent (Northgate Exploration Ltd.) for reviewing this paper, and Northgate for permission to publish the data presented here.

References

Bennett, J.W., Comarmond, M.J. and Jeffery, J.J. 2000. Comparison of sulfidic oxidation rates measured in the laboratory and the field. P171-180. *In* Proceedings of the fifth International Conference on Acid Rock Drainage, Denver, Colorado.

Frostad, S.R., Price, W.A. and Bent, H.G. 2003. "Operational NP determination - Accounting for iron manganese carbonates and developing a site-specific fizz rating. *In* Proceedings of the Sudbury 2003 Mining and the Environment Conference, Sudbury, Ontario (these proceedings).

Frostad, S.R., Klein B. and Lawrence R.W. 2000a. Kinetic testing 1. Effects of protocol variable on rates of weathering. P641-649. *In* Proceedings of the fifth International Conference on Acid Rock Drainage, Denver, Colorado.

Frostad S.R., Klein B. and Lawrence R.W. 2000b. Kinetic testing 2. Scaling up laboratory data to predict field rates of weathering. P651-659. *In* Proceedings of the fifth International Conference on Acid Rock Drainage, Denver, Colorado.

Lapakko, K.A. 1994. Comparison of Duluth Complex rock dissolution in the laboratory and field. P419-428. *In* Proceedings of the International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage, Pittsburgh, Pennsylvania.

Li, M. 2000. Acid rock drainage prediction for low-sulphide, low-neutralization potential mine wastes. P567-580. *In* Proceedings of the fifth International Conference on Acid Rock Drainage, Denver, Colorado.

Price W.A. 1997. Guidelines and recommended methods for the prediction of metal leaching and acid rock drainage at mine sites in British Columbia, draft report. 159P. Reclamation Section, Energy and Minerals Div, Ministry of Employment and Investment, Smithers, BC.

Price, W.A. and Kwong, Y.T.J. 1997. Waste rock weathering, sampling and analysis: Observations from the British Columbia Ministry of Employment and Investment database. P15-29. *In* Proceedings of the fourth International Conference on Acid Rock Drainage, Vancouver, BC.

Raudsepp, M. and Pani, E. 2000. Examination of barium-bearing minerals in rock samples from the leached cap zone, Kemess Mine, using scanning electron microscopy, electron-probe microanalysis and quantitative x-ray powder diffraction. Report for Kemess Mines Ltd. November 14, 2000.

Scharer, J.M., Bolduc, L., Pettit, C.M. and Halbert, B.E. 2000. Limitations of acid-base accounting for predicting acid rock drainage. P591-601. *In* Proceedings of the fifth International Conference on Acid Rock Drainage, Denver, Colorado.

White, W.W. III, Lapakko, K.A. and Cox, R.L. 1998. Effects of protocol variables and sample mineralogy on static-test NP. P187-233. *In* Proceedings of the eleventh Annual Conference of the Society of Mineral Analysts, Elko, Nevada.

Table 1: Summary of Median ABA Results for Pre and Post-blast Samples and Kinetic Test Samples of Leach Cap Waste Rock

	NPAG - Median			PAG - Median			Kinetic Test Samples			
ABA Parameter	Pre-blast	>2.36 mm	<2.36 mm	Pre-blast	>2.36 mm	<2.36 mm	LC-1	LTP-2	LTP-5	LTP-6
No. of Samples	280	202	198	46	24	28	1	1	1	1
Sulphate-S (%)	0.02	0.01	0.02	0.01	0.02	0.03	<0.01	0.01	<0.01	0.04
Sulphide-S (%)	0.03	0.03	0.03	0.07	0.07	0.10	0.01	0.04	0.01	0.06
AP	0.9	0.9	0.9	2.2	2.2	3.1	0.3	1.3	0.3	1.9
Sobek-NP	10	23	25	3	3	3	44	6	27	6
Carb-NP	7	20	23	2	3	4	34	0	23	0
NPR	11	26	28	1.4	1.4	1.0	147	4.6	90	3.2

Note: Units for AP and NP are kg $CaCO_3$/tonne

Table 2: Summary of Kinetic Test Results for Leach Cap Waste Rock

Kinetic Test Type	**Humidity Cells**		**Leach Cells**					**Field Tests**		
Leach Protocol	Flooded + Stirred		Drip	Flooded	Drip	Flooded	Drip	Precipitation		
Sample	LC-1A	LC-1B	LTP-2A	LTP-2B	LTP-5A	LTP-5B	LTP-6	LTP-2	LTP-5	LTP-6
Weeks of Operation	39	39	16	16	16	16	16	104	47	47
pH	8.2	8.1	7.7	7.4	7.6	7.7	7.4	8.1	8.1	8
Cond. (µmhos/cm)	77	69	61	35	45	64	30	150	391	237
Acidity (mg $CaCO_3$/L)	2	3	2	3	1	1	1	1	2	2
Alkalinity (mg $CaCO_3$/L)	54	33	23	15	20	28	10	55	112	83
Sulphate (mg/L)	2	1	3	2	1	1	2	11	26	24
SO_4 Prod'n Rate	0.50	0.25	1.5	0.95	0.56	0.64	0.75	0.12	0.22	0.19
Carb-NP Dep'n Rate	17.9	17.8	10.4	4.8	3.1	4.6	3.7	0.32	0.44	0.34
[Ca+Mg] / [SO_4]	35.7	61.7	7.9	4.9	5.7	8.2	4.9	2.6	2.3	1.8
[Ca] / [SO_4]	33.8	57.7	7.6	4.6	5.3	7.8	4.1	2.5	2.2	1.6
Sulphur Dep'd (%)	22.8	20.2	2.7	1.7	5.3	7.2	0.57	0.97	4.5	0.35
NP Dep'd (%)	1.9	2.0	3.3	1.7	0.18	0.26	1.2	0.69	0.10	0.36

Notes: Units for sulphate production rate and carbonate NP depletion rate are mg/kg/wk.
All results are an average of the last 5 available cycles of testing.

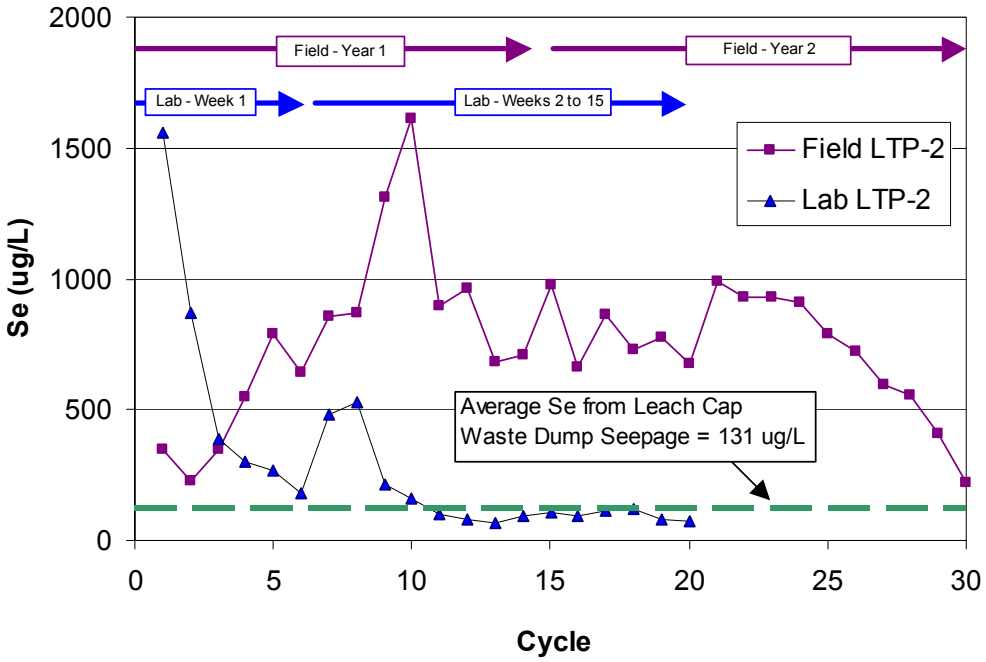

Figure 1. Comparison of Selenium Concentrations from Laboratory Leach Cell Versus Field Cell for Leach Cap Sample LTP-2.

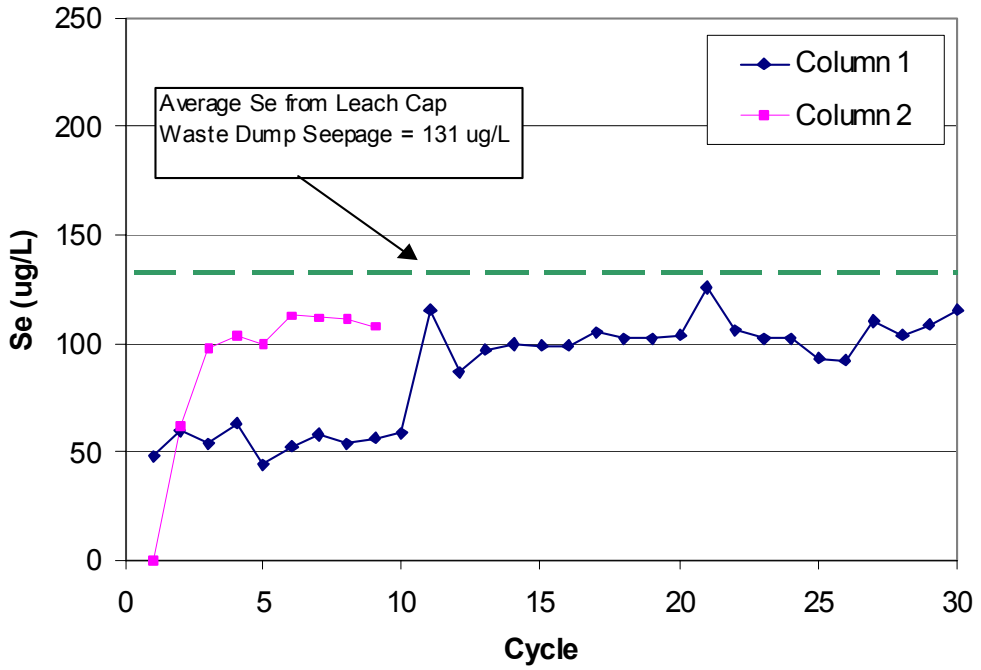

Figure 2. Comparison of Selenium Concentrations from Leach Columns Versus Average of Leach Cap Waste Dump Seepage.