

Cyanide Destruction Column Studies Report

Eagle Gold Project

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Dated this 13th day of March, 2014.



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Attachment A	Ex-situ Chemical Treatment Procedure
Attachment B	In-situ Biological Treatment Procedure

1.0 INTRODUCTION

1.1. Goals and objectives

An environmental column testing program was conducted during 2012 and 2013 to evaluate several objectives regarding cyanide destruction, and to provide input to geochemical source predictions for spent ore associated with Stratagold's proposed Eagle Gold Project heap leach facility (HLF). Kappes, Cassiday & Associates (KCA) in Reno, Nevada, conducted the first phase of the 2012/2013 column testing program, with input from geochemists from SRK, to evaluate the metallurgical testing of individual ore types and also evaluate the leachability of the ores based on the current heap design (i.e., primarily gold recovery). In June 2012, SRK recommended that sufficient information had been gathered for the metallurgical test purposes, and this phase of testing was concluded on June 26, 2012. The same test columns were then prepared by KCA, under the direction of geochemists from Tetra Tech, to evaluate two potential processes for cyanide destruction in the leached ore, including an ex-situ chemical and an in-situ biological treatment process. KCA (2013) prepared a report of the metallurgical test work, while this report summarizes relevant metallurgical test work to this study and focuses on the evaluation of processes for cyanide destruction.

The goals of the environmental column testing program were to:

- assess the relative performance of ex-situ chemical treatment and in-situ biological treatment in destructing cyanide within the heap and heap leachate. The test results characterize the number and concentration of cyanide degradation products (e.g., cyanate, ammonia, and nitrate) that form at various times or steps in the detoxification process;
- assess the duration (time, number of pore volumes exchanged, etc.) of the rinsing process;
- estimate the concentration/mass of cyanide, metals, etc. remaining in the heap at the end of the destruction processes; and,
- provide data and information to be used by others to help estimate the long-term quality of waters that will drain from the heap.

The objectives of the study were to generate data that will:

- Allow for an assessment of the most efficient and cost-effective cyanide destruction process for the heap; and,
- To provide data to others to develop a refined source term for the heap drainage as part of the process to predict post-closure water quality.

1.2. Column Testing History

Previous column tests have been conducted to simulate heap leach characteristics including gold recovery and cyanide destruction. Environmental column tests were conducted by KCA in 1995/1996 (Dublin Gulch – Environmental and Metallurgical Laboratory Report, KCA, April 1997), 2009/2010 (Eagle Gold Project Proposal for Executive Committee Review, Pursuant to the Yukon Environmental and Socio-economic Assessment Act, Stantec, December 2010, specifically Appendix 8: Geochemical Characterization and Water Quality Predictions and Appendix 27: Leach Metallurgy and Neutralization Summary), and most recently in 2011 (KCA, 2012), following metallurgical testing for gold recovery. The 1995/1996 and 2011 environmental testing simulated the process for cyanide conversion to cyanate via the addition of hydrogen peroxide as an oxidant and copper sulphate pentahydrate as a catalyst. Cyanide destruction

continued until Weak Acid Dissociable (WAD) cyanide decreased to less than 0.2 milligrams per liter (mg/L). Column test conditions varied based on variable ore blends, particle size, crush type, and agglomeration as summarized in Table 1.1-1.

Table 1-1: Historical Environmental Column Tests and Conditions

Year	Sample No.	Ore Type	Crush size, mm	Temperature	Treatment
95/96	22652	A	-50	Ambient*	1 kg/MT hydrated lime
95/96	22660	A	-12.5	Ambient*	1 kg/MT hydrated lime
95/96	22685	A	-50	Cold†	1 kg/MT hydrated lime
95/96	22687	A	-12.5	Cold†	1 kg/MT hydrated lime
95/96	22662	B	-12.5	Ambient*	1 kg/MT hydrated lime
95/96	22664	C	-12.5	Ambient*	1 kg/MT hydrated lime
95/96	22666	A,B,C,D	-12.5	Ambient*	1 kg/MT hydrated lime
2010	42979	A,B,C	-5, Conventional P80 = 3.641	Ambient*	2 kg/MT cement
2011	48111	A,B,C	HPGR P80 = 7	Ambient*	3 kg/MT cement
2011	48114	A,B,C	HPGR P80 = 7	Ambient*	3 kg/MT cement

Ore Types as follows: A – weathered granodiorite, B – freshly to weakly altered granodiorite (<20% altered), C – Strongly altered (sericite, chlorite, carbonate) granodiorite, D – fine-grained granodiorite, and E – weathered metasediments.

*20 to 30° C

†-2 to 2° C

Although multiple column studies with ores from the site were conducted prior to the 2012/2013 program (Table 1.1-1), those previous studies were not specifically based on the current heap design, including the final ore blend, crush size and type. Because of potential variations between the historic and current column testing ore preparation methods and because the historical least test column operation did not simulate heap operation through the rinsing stage, the 2012/2013 environmental testing program was initiated to simulate alternative heap leach treatment methodologies including rinsing and cyanide destruction (i.e., in-situ biological detoxification and ex-situ chemical detoxification methods).

2.0 CURRENT TESTING METHODOLOGY

2.1. Metallurgical Testing and Initial Column Conditions

The environmental testing of the columns was initiated immediately following the abbreviated phase of the gold recovery (leach) testing. The metallurgical leaching and subsequent column testing were designed so that the ore placed in the columns (e.g., ore preparation, ore type distribution, concentration and application rate of cyanide solution) would be representative of the conditions proposed for the Eagle Gold Project. Therefore, at the termination of the cyanide leaching period, the leached ore and pore fluids in the columns would be representative of those anticipated to be present in the heap at the start of the cyanide destruction and rinsing stage.

2.2. Column cyanide destruction Testing Methods

A total of eight 40-kg columns [three for each cyanide destruction method to provide statistically viable data sets at room temperature, and an additional column for each method operated at approximately 4° C to simulate site-specific kinetic concerns (seasonal variability)] were prepared for the metallurgical leaching procedure.

The metallurgical phase of the column tests was completed on June 26, 2012. These columns were then re-purposed for cyanide destruction testing. Two approaches were considered as alternatives for cyanide destruction: ex-situ chemical treatment and in-situ biological treatment as described in the following sections.

Leached solutions were sampled and analyzed for pH every one to four days and for WAD CN every five to seven days. Additionally, the leached solutions were sampled and analyzed for a full suite of parameters at three different points during the column test work: at the initiation of the cyanide destruct phase, at the approximate mid-point of the cyanide destruct test phase and at the conclusion of the test.

The parameters that were monitored are listed in Table 2.2-1 below. Analytical results are provided in full in Tables 2.2-2 through 2.2-10 and Figures 2.2-1 through 2.2-4. Detection limits for each parameter are also provided in Tables 2.2-2 through 2.2-10; these were set to ensure that the results were sufficiently sensitive for use in future analyses, modeling and design applications.

Table 2-1: Analytical Suite for Column Testing

pH	Carbonate	Manganese*	Sulphate
Alkalinity	Chloride	Mercury*	Thallium*
Aluminum*	Chromium*	Molybdenum*	Thiocyanate
Ammonia	Cobalt*	Nickel*	TKN
Antimony*	Copper*	Nitrate	Uranium*
Arsenic*	Cyanate	Nitrite	Vanadium*
Barium*	Cyanide, Total	Phosphorus	Zinc*
Beryllium*	Cyanide, WAD	Potassium*	
Bicarbonate	Fluoride	Selenium*	
Boron*	Iron*	Silver*	
Cadmium*	Lead*	Sodium*	
Calcium*	Magnesium*	Strontium*	

*Analyzed in the dissolved form.

2.2.1. Ex-situ Chemical Treatment

Ex-situ chemical treatment was used to provide destruction of cyanide into less toxic degradation products by copper-catalyzed oxidation with hydrogen peroxide. A detailed discussion of this treatment procedure has been provided in Attachment A of this appendix and is summarized below.

Ex-situ treatment was administered in two phases to a total of four columns (IDs 63310, 63313, and 63316 operated at room temperature, and 63322 operated at approximately 4°C). The initial phase was initiated on July 19, 2012 via the application of a chemical treatment process using a single dose of hydrogen peroxide (with copper catalyst) to oxidize cyanide to cyanate in the water circulated through the column. The treated water was recirculated through the column at a rate of approximately one pore volume per week (or as slowly as possible to maintain saturation), flushing additional cyanide from the pore waters until the WAD cyanide concentration in the column drainage decreased to <0.2 mg/L (the target WD CN concentration that was assumed to achieve compliance for free CN ¹).

Prior to treatment, the final barren solution drained from the columns was submitted for analysis of all parameters listed in Table 2.2-1. The analytical results are provided in Table 2.2-2. During the circulation of the copper/hydrogen peroxide treated solution, the effluent was sampled daily for pH, and sampled approximately weekly for WAD cyanide analysis, as summarized in Table 2.2-3 and Figures 2.2-1 and 2.2-2. An additional sample was collected after three weeks of this phase of testing, and that analytical data are provided in Table 2.2-4.

Once the WAD cyanide in the column effluent decreased to < 0.2 mg/L (and additional testing confirmed that free cyanide had decreased to <0.015 mg/L) the hydrogen peroxide treatment process was discontinued. This goal was met on September 24, 2012 in the column operated in cold conditions (ID 63322, approximately 4° C), and on October 2, 2012 for the columns operated at room temperature conditions. Once the target concentrations were met, the columns were gravity drained and the water was tested for the full analytical suite listed in Table 2.2-1. The results of which are provided in Table 2.2-5.

¹ Cyanide may be analyzed for free, WAD (which includes free plus weak complexes), or total (including strongly complexed with iron or cobalt). However, the concentration of free cyanide tends to drop to below the detection limit very rapidly so is not very useful for determining progress of cyanide destruction. Strongly complexed cyanide is not treated with peroxide oxidation, but is also very unreactive and is, therefore, not susceptible to leaching. Therefore, WAD cyanide is the most useful measure of cyanide destruction progress. Although water quality standards are based on free cyanide, the weak complexes of cyanide have the potential to break down to free cyanide so are a more appropriate indicator of compliance with the Water Quality Standards.

Table 2-2: Initial Leachate Water Quality, Pre-cyanide Detoxification, All Columns

Constituent	Unit	63310	63313	63316	63301	63304	63307	63322*	63319*	Average	Median	STD DEV
pH	pH Units	9.36	9.48	9.51	9.51	9.45	9.57	9.81	9.91	9.58	9.51	0.188
Bicarbonate (HCO ₃)	mg/L	540	650	690	460	470	590	330	320	506	505	137
Carbonate (CO ₃)	mg/L	100	140	190	150	130	180	180	220	161	165	38
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	N/A
Total Alkalinity	mg/L as CaCO ₃	620	770	890	620	600	780	560	620	683	620	116
Total Kjeldahl Nitrogen	mg/L	120	110	140	89	120	130	78	70	107	115	25
Total Nitrogen	mg/L	120	120	140	89	120	130	81	180	123	120	31
Total Dissolved Solids (TDS)	mg/L	1900	2200	2300	1700	1800	2100	2000	1300	1913	1950	318
Chloride	mg/L	25	42	30	32	24	28	390	55	78	31	126
Fluoride	mg/L	4.4	4.8	4.4	4.1	4.4	4.7	2.8	3.1	4.1	4.4	0.7
Sulfate	mg/L	290	290	270	210	260	280	260	340	275	275	37
Nitrate Nitrogen	mg/L	0.82	0.87	0.76	0.75	0.71	0.90	2.6	3.3	1.34	0.85	1.01
Nitrite Nitrogen	mg/L											
Aluminum	mg/L	1.4	2.1	2.0	1.8	1.5	1.8	0.71	0.94	1.53	1.65	0.50
Barium	mg/L	0.051	0.100	0.058	0.037	0.033	0.051	0.047	0.059	0.055	0.051	0.021
Beryllium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	N/A
Bismuth	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A
Boron	mg/L	0.11	0.11	0.12	0.16	0.17	0.18	0.24	0.05	0.14	0.14	0.06
Cadmium	mg/L	0.0067	0.0097	0.0055	0.01	0.01	0.01	0.0082	0.0099	0.0088	0.0090	0.0026
Calcium	mg/L	65	240	58	29.00	29.00	57.00	100	120	87	62	69
Chromium	mg/L	0.0053	0.0081	0.0067	0.0053	0.0025	0.0068	0.0095	0.011	0.0069	0.0068	0.0027
Cobalt	mg/L	0.26	0.25	0.27	0.17	0.21	0.21	0.13	0.13	0.20	0.21	0.06
Copper	mg/L	4.0	4.7	3.9	3.2	4.8	5.0	2.2	3	3.9	4.0	1.0
Gallium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A
Iron	mg/L	8.7	7.6	7	11	8.9	12	4.7	3.4	7.9	8.2	2.9
Lithium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A
Magnesium	mg/L	0.25	0.65	0.25	0.25	0.25	0.25	1.7	0.57	0.52	0.25	0.50
Manganese	mg/L	0.022	0.0025	0.032	0.04	0.02	0.04	0.23	0.027	0.052	0.030	0.073
Molybdenum	mg/L	0.15	0.15	0.14	0.09	0.13	0.14	0.08	0.058	0.117	0.135	0.036
Nickel	mg/L	0.029	0.048	0.035	0.030	0.061	0.053	0.056	0.14	0.057	0.051	0.036
Phosphorus	mg/L	0.25	0.98	0.70	0.25	0.25	0.56	1	1	0.52	0.57	0.26

Constituent	Unit	63310	63313	63316	63301	63304	63307	63322*	63319*	Average	Median	STD DEV
Potassium	mg/L	7.6	9.1	12	7.3	8.1	8.2	8.6	6	8.4	8.2	1.7
Scandium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A
Silver	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	N/A
Sodium	mg/L	710	800	840	610	680	760	750	490	705	730	112
Strontium	mg/L	0.99	3.8	0.92	0.45	0.49	0.86	1.8	2.1	1.43	0.96	1.12
Tin	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A
Titanium	mg/L	<0.10	<0.10	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A
Vanadium	mg/L	0.18	0.24	0.23	0.20	0.20	0.22	0.16	0.19	0.20	0.20	0.03
Zinc	mg/L	1.4	2.3	1.2	1.3	4.5	3.7	4.5	3.7	2.8	3.0	1.4
Mercury	mg/L	0.0035	0.0041	0.0041	0.0034	0.0037	0.0037	0.0032	0.0026	0.0035	0.0036	0.0005
Antimony	mg/L	1.4	1.4	1.4	1.2	1.3	1.3	0.63	0.62	1.16	1.30	0.34
Arsenic	mg/L	17	19	17	15	17	17	11	12	16	17	3
Lead	mg/L	0.21	0.32	0.26	0.23	0.18	0.24	0.082	0.17	0.212	0.220	0.070
Selenium	mg/L	0.044	0.052	0.041	0.040	0.048	0.046	0.023	0.031	0.041	0.043	0.009
Thallium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	N/A
Cyanate	mg/L	170	160	220	120	160	180	160	120	161	160	32
Thiocyanate	mg/L	56	55	60	41	54	56	42	37	50	55	9
Ammonia, as Nitrogen	mg/L	29	78	28	71	67	75	74	60	60	69	20
WAD CN**	mg/L	12.37	22.2	23.53	13.56	13.56	8.64	14.62	19.68	16.02	14.09	5.21

* Columns will be refrigerated during detoxification, but have been operated at room temperature to this point.

**All analytes are reported for sampled collected on or about June 30, 2012. WAD CN analysis was performed on a sample collected the first day of detoxification on July 13, 2012.

Text in **RED** is reported at one-half of the detection limit to allow for calculation of average, mean, and standard deviation. For analytes where all analyses were below laboratory detection limits, the concentration, average, and mean were reported as less than the method detection limit.

Table 2-3: Ex-situ Chemical Detoxification Data Summary, pH and WAD CN

Detox Days	pH				WAD CN, mg/L			
	63310	63313	63316	63322*	63310	63313	63316	63322*
0	9.8	9.9	9.9	10.0	13.56	13.56	8.64	14.62
1	9.5	9.7	9.5	10.2	--	--	--	--
4	9.5	9.6	9.7	10.0	--	--	--	--
5	9.4	9.6	9.7	10.0	--	--	--	--
6	9.6	9.7	9.7	10.0	--	--	--	--
7	9.3	9.4	9.5	9.7	0.80	2.26	1.60	9.57
8	9.3	9.3	9.6	9.8	--	--	--	--
10	9.1	9.2	9.8	9.7	--	--	--	--
11	9.4	9.5	9.5	9.8	--	--	--	--
12	9.4	9.5	9.5	9.7	--	--	--	--
13	9.1	9.3	9.4	9.5	1.33	0.53	0.93	9.04
14	9.0	9.2	9.3	9.5	--	--	--	--
17	8.9	9.1	9.1	9.5	--	--	--	--
18	9.0	9.1	9.0	9.5	--	--	--	--
19	8.9	8.9	9.0	9.3	--	--	--	--
20	8.9	9.0	9.0	9.3	0.83	0.31	0.31	7.34
21	8.8	8.9	9.0	9.3	--	--	--	--
24	9.0	9.1	9.0	9.3	--	--	--	--
25	8.8	8.8	8.9	9.4	--	--	--	--
26	8.8	8.9	8.9	9.3	--	--	--	--
27	8.9	9.0	9.1	9.3	0.47	0.31	0.26	6.4
28	8.9	9.0	9.1	9.3	--	--	--	--
31	9.0	9.1	9.1	9.2	--	--	--	--
32	8.9	8.9	9.0	9.2	--	--	--	--
33	8.9	8.9	8.9	9.2	--	--	--	--
34	8.9	8.9	8.9	9.1	0.42	0.31	0.36	5.83
35	8.8	8.9	8.9	9.1	--	--	--	--

Detox Days	pH				WAD CN, mg/L			
	63310	63313	63316	63322*	63310	63313	63316	63322*
38	8.9	9.0	9.0	9.1	--	--	--	--
39	8.9	9.0	9.1	9.2	--	--	--	--
40	8.8	8.8	9.0	9.0	0.31	0.26	0.31	2.13
42	8.9	9.0	9.1	9.2	--	--	--	--
46	9.0	9.1	9.2	9.1	--	--	--	--
48	8.8	8.9	8.9	9.0	0.26	0.26	0.26	1.04
52	9.0	9.0	9.1	9.0	--	--	--	--
54	8.9	9.0	9.0	9.0	0.21	0.26	0.26	0.88
56	8.8	8.9	8.9	8.9	--	--	--	--
59	9.0	9.1	9.1	9.0	0.24	0.26	0.24	0.73
61	8.9	9.0	9.0	9.0	--	--	--	--
63	9.0	9.0	9.0	9.0	--	--	0.26	--
66	9.0	9.1	9.0	9.0	0.26	0.21	--	0.16
68	8.9	9.0	9.1	8.9	--	--	<0.10	--
74	9.0	9.2	--	8.9	0.16	0.10	0.16	0.16
80	--	--	--	--	<0.10	<0.10	--	--

*Operated at 4° C.

Table 2-4: Mid-Point Leachate Water Quality, Ex-Situ Chemical Detoxification Columns

Constituent	Unit	63310	63313	63316	Average	Median	STD DEV	63322*	% Difference From Room Temp. Columns
pH	pH Units	9.1	9.3	9.4	9.3	9.3	0.2	9.5	2.15
Total Kjeldahl Nitrogen	mg/L	100	100	100	100	100	0	85	-15.00
Total Nitrogen	mg/L	140	140	150	143	140	6	130	-7.14
Nitrate Nitrogen	mg/L	32	33	41	35	33	5	36	9.09
Nitrite Nitrogen	mg/L	3.1	1.9	2.0	2.3	2.0	0.7	4.1	105.00
Aluminum	mg/L	5.6	5.9	5.5	5.7	5.6	0.2	1.4	-75.00
Barium	mg/L	0.068	0.078	0.079	0.075	0.078	0.006	0.025	-67.95
Beryllium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	N/A	<0.0010	0
Bismuth	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Boron	mg/L	0.19	0.17	0.15	0.17	0.17	0.02	0.22	29.41
Cadmium	mg/L	0.0012	0.0021	0.0015	0.0016	0.0015	0.0005	0.0005	-66.67
Calcium	mg/L	17	16	16	16	16	1	11	-31.25
Chromium	mg/L	0.0093	0.010	0.010	0.010	0.010	0.000	0.0055	-45.00
Cobalt	mg/L	0.41	0.42	0.40	0.41	0.41	0.01	0.18	-56.10
Copper	mg/L	0.15	0.18	0.23	0.19	0.18	0.04	7.0	3788.89
Gallium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Iron	mg/L	3.5	4.6	3.9	4.0	3.9	0.6	1.2	-69.23
Lithium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	0.12	140.00
Magnesium	mg/L	0.55	0.62	1.25	0.81	0.62	0.39	0.58	-6.45
Manganese	mg/L	0.065	0.085	0.068	0.073	0.068	0.011	0.016	-76.47
Molybdenum	mg/L	0.18	0.20	0.18	0.19	0.18	0.01	0.10	-44.44
Nickel	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	N/A	0.18	3500.00
Phosphorus	mg/L	0.52	0.66	0.70	0.63	0.66	0.09	0.56	-15.15
Potassium	mg/L	7.2	9.6	12	10	10	2	9.3	-3.12
Scandium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Silver	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	N/A	0.0053	112.00
Sodium	mg/L	780	890	880	850	880	61	860	-2.27
Strontium	mg/L	0.25	0.25	0.26	0.25	0.25	0.01	0.20	-20.00
Tin	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Titanium	mg/L	0.25	0.26	0.27	0.26	0.26	0.01	<0.10	-80.77

Constituent	Unit	63310	63313	63316	Average	Median	STD DEV	63322*	% Difference From Room Temp. Columns
Vanadium	mg/L	0.065	0.083	0.096	0.081	0.083	0.016	0.058	-30.12
Zinc	mg/L	0.093	0.14	0.13	0.12	0.13	0.02	0.067	-48.46
Mercury	mg/L	0.010	0.0095	0.0090	0.0095	0.0095	0.0005	0.0073	-23.16
Antimony	mg/L	1.9	2.0	2.0	2.0	2.0	0.1	0.74	-63.00
Arsenic	mg/L	18	20	19	19	19	1	11	-42.11
Lead	mg/L	0.61	0.62	0.57	0.60	0.61	0.03	0.19	-68.85
Selenium	mg/L	0.063	0.067	0.062	0.064	0.063	0.003	0.045	-28.57
Thallium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	N/A	<0.010	0
Cyanate	mg/L	140	140	170	150	140	17	170	21.43
Thiocyanate	mg/L	70	68	66	68	68	2	82	20.59
Ammonia, as Nitrogen	mg/L	99	81	91	90	91	9	81	-10.99
WAD CN	mg/L	1.33	0.53	0.93	0.93	0.93	0.40	9.04	872.04

Data collected 8/2/2012

* Operated at 4° C.

Text in **RED** is reported at one-half of the detection limit to allow for calculation of average, mean, and standard deviation. For analytes where all analyses were below laboratory detection limits, the concentration, average, and mean were reported as less than the method detection limit.

Table 2-5: Final Detoxification Leachate Water Quality, Ex-Situ Chemical Detoxification Columns

Constituent	Unit	63310	63313	63316	Average	Median	STD DEV	63322*	% Difference from Room Temp. Columns
pH	pH Units	8.85	9.12	8.96	8.98	8.96	0.14	8.80	-1.79
Acidity (Titrimetric)	mg/L as CaCO ₃	-1.4	--	-111	-56.2	-56.2	77.5	--	N/A
Bicarbonate (HCO ₃)	mg/L	690	710	640	680	690	36	590	-14.49
Carbonate (CO ₃)	mg/L	58	110	69	79	69	27	32	-53.62
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	N/A	<1.0	0
Total Alkalinity	mg/L as CaCO ₃	660	770	640	690	660	70	540	-18.18
Redox Potential	mV	250	--	--	250	250	0	--	N/A
Total Kjeldahl Nitrogen	mg/L	23	--	36	29.5	29.5	9.2	100	238.98
Total Nitrogen	mg/L	260	--	--	260	260	0	310	19.23
Total Dissolved Solids (TDS)	mg/L	4100	--	3900	4000	4000	141	3500	-12.50
Electrical Conductivity	µmhos/cm	5600	7600	5800	6333	5800	1102	--	N/A
Chloride	mg/L	45	90	58	64	58	23	560	865.52
Fluoride	mg/L	3.6	3.6	4.3	3.8	3.6	0.4	1.8	-50.00
Sulfate	mg/L	1000	1400	1200	1200	1200	200	470	-60.83
Nitrate Nitrogen	mg/L	250	350	300	300	300	50	--	N/A
Nitrite Nitrogen	mg/L	4	0.61	5.1	3.2	4.0	2.3	--	N/A
Aluminum	mg/L	1.3	0.93	0.75	0.99	0.93	0.28	0.15	-83.87
Barium	mg/L	0.038	0.053	0.027	0.039	0.038	0.013	0.022	-42.11
Beryllium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	N/A	<0.0010	0
Bismuth	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Boron	mg/L	0.18	0.19	0.16	0.18	0.18	0.02	0.25	38.89
Cadmium	mg/L	<0.0010	--	<0.0010	<0.0010	<0.0010	N/A	<0.0010	0
Calcium	mg/L	14	14	7.2	12	14	4	11	-21.43
Chromium	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	N/A	<0.0050	0
Cobalt	mg/L	0.57	0.66	0.48	0.57	0.57	0.09	0.19	-66.67
Copper	mg/L	0.09	0.09	0.071	0.08	0.09	0.01	0.078	-13.33
Gallium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Iron	mg/L	0.48	0.49	0.43	0.47	0.48	0.03	0.16	-66.67
Lithium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	0.22	340.00
Magnesium	mg/L	2	--	1.6	1.8	1.8	0.3	3.7	105.56
Manganese	mg/L	0.017	0.015	0.011	0.014	0.015	0.003	<0.0050	-83.33

Constituent	Unit	63310	63313	63316	Average	Median	STD DEV	63322*	% Difference from Room Temp. Columns
Molybdenum	mg/L	0.27	0.32	0.24	0.28	0.27	0.04	0.12	-55.56
Nickel	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	N/A	<0.010	0
Phosphorus	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	N/A	<0.50	0
Potassium	mg/L	14	21	17	17	17	4	16	-5.88
Scandium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Silver	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	N/A	<0.0050	0
Sodium	mg/L	1200	1800	1300	1433	1300	321	1500	15.38
Strontium	mg/L	0.46	0.63	0.34	0.48	0.46	0.15	0.40	-13.04
Tin	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Titanium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Vanadium	mg/L	0.024	0.024	0.029	0.026	0.024	0.003	0.016	-33.33
Zinc	mg/L	0.026	0.031	0.017	0.025	0.026	0.007	<0.010	-80.77
Mercury	mg/L	0.0057	0.004	0.0041	0.0046	0.0041	0.0010	0.0023	-43.90
Antimony	mg/L	1.6	2	1.7	1.8	1.7	0.2	0.63	-62.94
Arsenic	mg/L	5.4	4.7	5.1	5.1	5.1	0.4	2.7	-47.06
Lead	mg/L	0.13	0.081	0.054	0.088	0.081	0.039	0.018	-77.78
Selenium	mg/L	0.039	0.044	0.038	0.040	0.039	0.003	<0.0050	-93.59
Thallium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	N/A	<0.0010	0
Cyanate	mg/L	19	11	31	20	19	10	170	794.74
Thiocyanate	mg/L	69	93	59	74	69	17	45	-34.78
Ammonia, as Nitrogen	mg/L	26	12	29	22	26	9	97	273.08
WAD CN	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	0.16	68.75

Data collected 11/11/2012

* Operated at 4° C.

Text in **RED** is reported at one-half of the detection limit to allow for calculation of average, mean, and standard deviation. For analytes where all analyses were below laboratory detection limits, the concentration, average, and mean were reported as less than the method detection limit.

The second phase involved the addition of simulated rinse water to further flush metals and other compounds from the columns. After the columns had been drained following the first phase of treatment, two mock rinse solutions were used to compare their rinse effectiveness.

Two columns (ID 63310 and 63313) were subjected to rinsate solution consisting of deionized water. The rinsing phase was initiated immediately after the initial treatment solutions were drained and completed. The other two columns (ID 63316 and 63322) were subjected to a mock rinse solution consisting of various major ions as listed in Table 2.2-6 as a surrogate for water available at the site.

Rinsing was continuous until a target WAD cyanide concentration of <0.1 mg/L and a target ammonia concentration of <10 mg/L were attained. At that time, the columns were again drained and the rinsate solution tested for the full analytical suite as listed in Table 2.1-2, the results of which are provided in Table 2.2-7.

Table 2-6: Mock MWTP Effluent Rinse Solution

Constituent	Concentration in mg/L
Cl ⁻	100
SO ₄ ²⁻	1300
Ca ²⁺	20
Na ⁺	930
HCO ₃ ⁻	700

In a full scale application, excess water would be drained from the heap and treated as described above as the rinse water is added to the top of the heap.

Table 2-7: Rinsate Water Quality, Chemical Detoxification Columns

Constituent	Unit	Distilled Water Rinse		Mock Rinse Solution	
		63310	63313	63316	63322*
pH	pH Units	8.56	8.80	8.68	8.77
Acidity (Titrimetric)	mg/L as CaCO ₃	-188	-135	-158	-179
Bicarbonate (HCO ₃)	mg/L	550	530	680	740
Carbonate (CO ₃)	mg/L	14	33	36	50
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	<1.0
Total Alkalinity	mg/L as CaCO ₃	470	490	620	690
Redox Potential	mV	280	280	300	250
Total Kjeldahl Nitrogen	mg/L	13	24	30	29
Total Nitrogen	mg/L	130	110	31	31
Total Dissolved Solids (TDS)	mg/L	1600	1500	2800	2900
Electrical Conductivity	µmhos/cm	2400	2400	4200	4500
Chloride	mg/L	9.1	17	79	160
Fluoride	mg/L	2.1	3.1	2.2	1.5
Sulfate	mg/L	220	310	1000	1000
Nitrate Nitrogen	mg/L	110	84	58	33
Nitrite Nitrogen	mg/L			1.8	1.8
Aluminum	mg/L	0.74	0.88	1.7	0.94
Barium	mg/L	0.016	0.014	0.040	0.035
Beryllium	mg/L	<0.0010	<0.0010	<0.0004	<0.0004
Bismuth	mg/L	<0.10	<0.10	<0.075	<0.075
Boron	mg/L	0.11	0.11	0.11	0.20

Constituent	Unit	Distilled Water Rinse		Mock Rinse Solution	
		63310	63313	63316	63322*
Cadmium	mg/L	<0.0010	<0.0010	<0.0002	<0.0002
Calcium	mg/L	6.7	3.7	24	31
Chromium	mg/L	<0.0050	<0.0050	0.0026	0.0030
Cobalt	mg/L	0.10	0.13	0.095	0.043
Copper	mg/L	0.54	0.84	23	1.3
Gallium	mg/L	<0.10	<0.10	<0.020	<0.020
Iron	mg/L	0.36	0.51	0.92	0.78
Lithium	mg/L	<0.10	<0.10	0.02	0.19
Magnesium	mg/L	0.72	<0.50	1.2	3.6
Manganese	mg/L	0.0093	0.011	0.028	0.030
Molybdenum	mg/L	0.059	0.071	0.068	0.024
Nickel	mg/L	<0.010	<0.010	0.004	0.009
Phosphorus	mg/L	<0.50	<0.50	0.57	0.32
Potassium	mg/L	5.8	5.9	12	12
Scandium	mg/L	<0.10	<0.10	0.0010	<0.0010
Silver	mg/L	<0.0050	<0.0050	0.0008	0.0027
Sodium	mg/L	500	480	1000	1000
Strontium	mg/L	0.15	<0.10	0.43	0.57
Tin	mg/L	<0.10	<0.10	<0.010	<0.010
Titanium	mg/L	<0.10	<0.10	0.04	0.02
Vanadium	mg/L	0.011	0.026	0.034	0.021
Zinc	mg/L	0.050	0.027	0.087	0.075
Mercury	mg/L	0.0016	<0.0010	<0.0007	<0.0007
Antimony	mg/L	0.87	0.91	0.99	0.47
Arsenic	mg/L	4.1	5.2	7.3	3.3
Lead	mg/L	0.064	0.073	0.18	0.090
Selenium	mg/L	0.0085	0.020	0.019	0.010
Thallium	mg/L	<0.0010	<0.0010	<0.0002	<0.0002
Cyanate	mg/L	7.1	4.9	2.5	28
Thiocyanate	mg/L	17	20	18	9.0
Ammonia, as Nitrogen	mg/L	0.95	3.7	13	13
Cyanide, Total	mg/L	0.38	1.1	0.60	0.34
Cyanide, WAD	mg/L	0.047	<0.025	0.040	0.090
Silicon	mg/L	—	—	17	16
Uranium	mg/L	—	—	0.24	0.17
Total Organic Carbon	mg/L	13.0	15.0	—	—

Data collected 12/12/2012 after approximately 30 days of rinsing.

*Operated at 4° C.

2.2.2. In-situ Biological Treatment

The objective of in-situ biological treatment is the destruction of cyanide into less toxic degradation products, using microbially mediated processes. A detailed discussion of this treatment procedure has been provided in Attachment B of this appendix and is summarized below.

In-situ treatment uses a biologically mediated process in which a supplemental reduced carbon syrup is added to the heap to degrade cyanide and to generate microbial growth within the heap. The reduced carbon promotes a direct consumption of free cyanide and some weak

cyanide complexes by the formation of non-toxic cyanohydrins. Subsequent degradation of the cyanohydrins and other nitrogen forms is supported by excess carbon (over what is required to react with free and weak complexes of cyanide) because the additional carbon generates a fine biofilm on the heap particles that incorporates the reduced nitrogen compounds (cyanohydrins, ammonia). Reduction in metal concentrations is also commonly observed as a result of the reducing conditions established during microbial metabolic processes, because many metals are less soluble in a reduced state (chromium, copper, selenium, uranium, for instance). Other metals that preferentially sorb to iron or manganese oxides in a more neutral pH range created during the cyanide destruction process will generally decrease, including trace metals such as arsenic and antimony.

A total of four columns were treated biologically (IDs 63301, 63304, and 63307 were operated at room temperature; ID 63319 was operated at approximately 4°C). The material in the columns used for biological treatment were sampled prior to initiating the test phase and the sample subjected to a hot water rinse which was analyzed for initial quantities of total nitrogen and metals compounds. The results of the initial sampling event are provided in Table 2.2-2. The biological process was initiated on July 13, 2012 by the addition of 24.25 g of the reduced carbon syrup (as GWS-BCY3 syrup, a blend of molasses, fructose, ethanol, methanol, and trace phosphorous) at the end of the leaching cycle. The flow rate in the column was no greater than one pore volume exchanged per week, to allow for consumption of the supplemental carbon within the column. During the circulation of the solution, the effluent was sampled typically daily for pH, and sampled approximately weekly for WAD cyanide analysis, as summarized in Table 2.2-8 and Figures 2.2-3 and 2.2-4.

Table 2-8: In-Situ Biological Detoxification Data Summary, pH and WAD Cyanide

Detox Days	pH				WAD CN, mg/L			
	63301	63304	63307	63319*	63301	63304	63307	63319*
0	9.9	9.9	9.9	10.1	12.37	22.2	23.53	19.68
3	9.8	9.3	9.4	10.1	--	--	--	--
4	9.5	9.3	9.5	9.9	--	--	--	--
5	9.5	9.4	9.5	10.0	--	--	--	--
6	9.6	9.4	9.6	9.9	--	--	--	--
7	9.5	9.2	9.5	10.0	--	--	--	--
10	9.4	9.1	9.3	9.8	--	--	--	--
11	9.5	9.3	9.6	9.7	--	--	--	--
12	9.8	9.6	9.8	10.0	--	--	--	--
13	9.4	9.3	9.4	9.8	--	--	--	--
14	9.4	9.3	9.4	9.7	--	--	--	--
17	9.4	9.3	9.4	9.4	2.66	2.66	2.13	9.31
18	9.2	9.3	9.4	9.4	--	--	--	--
19	9.0	9.1	9.2	9.4	--	--	--	--
20	9.0	9.1	9.2	9.3	--	--	--	--
21	9.1	9.2	9.3	9.3	--	--	--	--
24	9.2	9.2	9.2	9.4	--	--	--	--
25	9.2	9.2	9.2	9.3	--	--	--	--
26	9.1	9.1	9.2	9.1	--	--	--	--
27	9.0	9.1	9.2	9.1	--	--	--	--
28	9.0	9.1	9.1	9.0	--	--	--	--
31	9.1	9.1	9.2	9.1	--	--	--	--
32	9.0	9.1	9.2	9.1	--	--	--	--
33	9.0	9.1	9.2	9.0	--	--	--	--
34	9.1	9.2	9.2	9.1	--	--	--	--
35	9.0	9.0	9.2	9.1	--	--	--	--
38	9.1	9.2	9.2	9.1	0.88	0.73	2.26	2.86
39	9.1	9.1	9.2	9.1	--	--	--	--
40	9.0	9.1	9.2	9.0	--	--	--	--
41	9.0	9.1	9.2	9.1	--	--	--	--
42	9.0	9.1	9.2	9.1	--	--	--	--
45	9.1	9.1	9.3	9.2	0.57	0.62	0.73	2.71
46	9.1	9.1	9.2	9.2	--	--	--	--
47	8.9	9.0	9.0	9.0	--	--	--	--
49	9.1	9.1	9.2	9.1	--	--	--	--
53	8.8	9.2	9.3	9.2	--	--	--	--
55	9.0	9.1	9.1	9.1	0.57	0.31	0.52	1.20
59	9.1	9.1	9.3	9.1	--	--	--	--
61	9.2	9.2	9.2	9.1	0.57	0.73	1.14	2.03
63	8.9	9.1	9.2	9.0	--	--	--	--
66	9.0	8.9	9.3	9.1	0.48	0.66	0.73	1.73
68	9.1	9.1	9.3	9.1	--	--	--	--
73	9.0	9.3	9.3	9.2	0.78	0.62	0.62	0.42
75	9.1	8.8	9.3	9.2	--	--	--	--
80	9.3	9.1	9.3	9.0	0.68	0.52	0.42	0.31
84	9.3	9.1	9.3	9.1	--	--	--	--
87	--	9.2	9.3	8.8	0.52	0.42	0.42	0.31

Detox Days	pH				WAD CN, mg/L			
	63301	63304	63307	63319*	63301	63304	63307	63319*
102	--	--	--	--	1.3	0.62	0.84	0.26
143	--	--	--	--	0.24	0.25	0.32	0.1
181	--	--	--	--	--	0.14	0.14	0.24
188	--	--	--	--	--	0.43	0.62	0.24
193	--	--	--	--	--	0.08	0.068	0.032
202	--	--	--	--	--	0.26	0.32	0.065
210	--	--	--	--	--	0.33	1.1	0.47
218	--	--	--	--	--	0.345	--	--

* Operated at 4° C.

Because target WAD CN concentrations were not attained after approximately four months of column operation, a second dose of supplemental carbon was added to each of the columns on November 15, 2012 to provide additional metabolites to the microbial population and further reduce the WAD CN concentration to <0.2 mg/L as follows:

- ID 63301 – 17 mLs
- ID 63304 – 22 mLs
- ID 63307 – 25 mLs
- ID 63319 – 7 mLs

Due to time constraints, one of the columns (ID 63301) was drained and submitted for humidity cell testing on December 3, 2012 prior to reaching the target WAD CN concentration. Column 63301 contained 0.26 mg/L WAD CN at the time the column was drained. The remaining two room temperature columns (IDs 63304 and 63307) and the cold temperature column (ID 63319) continued to operate. An additional sample was collected for analysis, as provided in Table 2.2-9.

Table 2-9: Mid-Point Detoxification Water Quality, In-Situ Biological Detoxification Columns

Constituent	Unit	63301	63304	63307	Average	Median	STD DEV	63319*	% Difference from Room Temp. Columns
pH	pH Units	8.8	8.66	8.71	8.72	8.71	0.07	8.77	0.69
Acidity (Titrimetric)	mg/L as CaCO ₃	-163	--	--	-163	-163	N/A	--	N/A
Bicarbonate (HCO ₃)	mg/L	1200	1100	1500	1267	1200	208	910	-24.17
Carbonate (CO ₃)	mg/L	65	47	69	60	65	12	47	-27.69
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	N/A	<1.0	0
Total Alkalinity	mg/L as CaCO ₃	1100	1000	1300	1133	1100	153	820	-25.45
Redox Potential	mV	230	240	210	227	230	0	140	-39.13
Total Kjeldahl Nitrogen	mg/L	0.15	7.6	15	7.6	7.6	7.4	7.1	-6.58
Total Nitrogen	mg/L	0.15	9	17	9	9	0	0.76	-91.56
Total Dissolved Solids (TDS)	mg/L	2600	2500	2800	2633	2600	153	2000	-23.08
Electrical Conductivity	µmhos/cm	4100	4100	4400	4200	4100	173	3700	-9.76
Chloride	mg/L	27	22	26	25	26	3	650	2400.00
Fluoride	mg/L	1.6	2.1	2.3	2.0	2.1	0.4	1.8	-14.29
Sulfate	mg/L	950	1100	1000	1017	1000	76	190	-81.00
Nitrate Nitrogen	mg/L	0.5	0.5	2.1	1.0	0.5	0.9	0.5	0
Nitrite Nitrogen	mg/L	0.125	9	0.29	3.1	0.3	5.1	0.76	162.07
Aluminum	mg/L	0.7	1.1	0.73	0.84	0.73	0.22	0.23	-68.49
Barium	mg/L	0.031	0.036	0.031	0.033	0.031	0.003	0.016	-48.39
Beryllium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	N/A	<0.0010	0
Bismuth	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Boron	mg/L	0.12	0.15	--	0.14	0.135	0.02	0.53	292.59
Cadmium	mg/L	<0.0010	<0.0010	<0.001	<0.0010	<0.0010	N/A	<0.0010	0
Calcium	mg/L	17	17	15	16	17	1	8.2	-51.76
Chromium	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	N/A	<0.0050	0
Cobalt	mg/L	0.17	0.23	0.22	0.21	0.22	0.03	0.092	-58.18
Copper	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	N/A	<0.050	0
Gallium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Iron	mg/L	3.6	3.2	5.3	4.03	3.6	1.12	0.77	-78.61
Lithium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	0.32	540.00
Magnesium	mg/L	3.3	3.2	3.4	3.3	3.3	0.1	2.3	-30.30
Manganese	mg/L	0.036	0.068	0.044	0.049	0.044	0.017	0.011	-94.32

Constituent	Unit	63301	63304	63307	Average	Median	STD DEV	63319*	% Difference from Room Temp. Columns
Molybdenum	mg/L	0.11	0.12	0.13	0.12	0.12	0.01	<0.10	-97.92
Nickel	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	N/A	<0.010	0
Phosphorus	mg/L	<0.50	0.53	0.65	<0.50	<0.50	N/A	0.71	184.0
Potassium	mg/L	13	12	12	12	12	1	11	-8.33
Scandium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Silver	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	N/A	<0.0050	0
Sodium	mg/L	960	1000	1200	1053	1000	129	830	-17.00
Strontium	mg/L	0.44	0.48	0.44	0.45	0.44	0.02	0.25	-43.18
Tin	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0
Titanium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	<1.0	0
Vanadium	mg/L	0.019	0.021	0.027	0.022	0.021	0.004	0.027	28.57
Zinc	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	N/A	<0.010	0
Mercury	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	N/A	<0.010	0
Antimony	mg/L	1.3	1.3	1.3	1.3	1.3	0.0	0.68	-47.69
Arsenic	mg/L	2.2	3	3.9	3.0	3	0.9	5.5	83.33
Lead	mg/L	0.057	0.09	0.059	0.069	0.059	0.019	0.028	-52.54
Selenium	mg/L	0.016	0.02	0.019	0.018	0.019	0.002	<0.050	-86.84
Thallium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	N/A	<0.0010	0
Cyanate	mg/L	5.3	5.5	3.8	5	5.3	1	2.7	-49.06
Thiocyanate	mg/L	2.2	2.7	4.4	3	2.7	1	12	344.44

Data collected 12/3/2012

* Operated at 4° C.

Text in RED is reported at one-half of the detection limit to allow for calculation of average, mean, and standard deviation.

After several additional months of cycling, the columns had not yet attained the target WAD CN concentration. A third and final dose (65 g) of carbon syrup was added to each of the remaining three columns on March 7, 2013. The target WAD CN concentrations were attained on March 15, 2013 and the columns were immediately drained. A post-treatment rinsing phase was not required for the biological columns. Effluent solutions were submitted for final analysis of an abbreviated list of parameters due to available sample volume, as presented in Table 2.2-10.

Table 2-10: Final Detoxification Water Quality, In-Situ Biological Detoxification Columns

Constituent*	Unit	Blended Final Solution
pH	pH Units	--
Acidity (Titrimetric)	mg/L as CaCO ₃	--
Bicarbonate (HCO ₃)	mg/L	--
Carbonate (CO ₃)	mg/L	--
Hydroxide (OH)	mg/L	--
Total Alkalinity	mg/L as CaCO ₃	--
Redox Potential	mV	--
Total Kjeldahl Nitrogen	mg/L	--
Total Nitrogen	mg/L	--
Total Dissolved Solids (TDS)	mg/L	--
Electrical Conductivity	µmhos/cm	--
Chloride	mg/L	99
Fluoride	mg/L	1.9
Sulfate	mg/L	1000
Nitrate Nitrogen	mg/L	0.30
Nitrite Nitrogen	mg/L	--
Aluminum	mg/L	--
Barium	mg/L	--
Beryllium	mg/L	--
Bismuth	mg/L	--
Boron	mg/L	--
Cadmium	mg/L	<0.0009
Calcium	mg/L	--
Chromium	mg/L	0.0085
Cobalt	mg/L	--
Copper	mg/L	0.089
Gallium	mg/L	--
Iron	mg/L	2.9
Lithium	mg/L	--
Magnesium	mg/L	--
Manganese	mg/L	--
Molybdenum	mg/L	0.14

Constituent*	Unit	Blended Final Solution
Nickel	mg/L	0.033
Phosphorus	mg/L	--
Potassium	mg/L	--
Scandium	mg/L	--
Silver	mg/L	<0.0015
Sodium	mg/L	--
Strontium	mg/L	--
Tin	mg/L	--
Titanium	mg/L	--
Vanadium	mg/L	--
Zinc	mg/L	0.12
Mercury	mg/L	<0.0010
Antimony	mg/L	0.68
Arsenic	mg/L	2.6
Lead	mg/L	0.53
Selenium	mg/L	0.013
Thallium	mg/L	<0.0004
Uranium	mg/L	0.52
Cyanate	mg/L	1.6
Thiocyanate	mg/L	0.79
Ammonia, as Nitrogen	mg/L	<0.050

* Insufficient volume from columns to do individual samples, limited analyte list
Data collected 3/20/2013

2.3. Closure (Long-Term Seepage) Phase

Upon completion of the cyanide destruction test work, four columns from the ex-situ treatment (IDs 63310, 63313, 63316, and 63322) and one column from the in-situ treatment (ID 63301) were repurposed to serve as a humidity test cell (HTC) for long-term kinetic testing. The results of the HTC test work are summarized in SRK (2014). The remaining columns were sealed and refrigerated for potential future study purposes. After the HTCs were initiated, operation of two columns (IDs 63310 and 63313) were suspended until further notice due to redundancies with other columns selected for testing.

2.4. Data Analyses

The results of the column tests were evaluated with respect to the goals of the environmental testing summarized below:

- To assess the relative performance of ex-situ chemical treatment and in-situ biological treatment in destructing cyanide within the heap and heap leachate, including the number and concentration of cyanide degradation products (e.g., cyanate, ammonia, and nitrate) that form at various times or steps in the detoxification process.

- To assess the duration (time, number of pore volumes exchanged, etc.) of the rinsing and cyanide destruction process.
- To estimate the concentration/mass of cyanide, metals, etc. remaining in the heap at the end of the detoxification processes.
- To provide data to help estimate the long-term quality of waters that will drain from the heap.

2.4.1. Ex-Situ Chemical Treatment Procedure

Data indicate that on day 0 the WAD Cyanide concentrations in the columns to be treated with the ex-situ chemical treatment procedure ranged from 8.64 mg/L to 14.62 mg/L, with an average of 12.60 mg/L. Almost 98% removal of WAD CN was attained in the first 48 days of treatment, reaching the target WAD CN concentration of <0.2 mg/L after 74 days of treatment in the three room temperature columns and after 68 days in the cold temperature column (ID 63322). These results suggest that the kinetics of the cyanide destruction using the ex-situ chemical procedure do not have a significant temperature dependence. Other species of concern, such as ammonia and cyanate, had 63% and 87% reductions in concentration, respectively. Nitrate in particular increased almost 300 fold during the test work as the nitrogen component of the cyanate, cyanide, and TKN (organic nitrogen and ammonia) was oxidized. A summary of results is presented in Table 2.4-1 and Figure 2.4-1.

In addition to the monitored decreases in WAD CN concentrations, the concentrations of the majority of other aqueous species also decreased during this testing phase as shown in Table 2.4-1. For example, concentration of As decreased by an average of 68% in the four columns. Other species of concern, such as cadmium, chromium, copper, iron, manganese, nickel, strontium, vanadium, zinc, and lead, had similar reductions in concentration. A few species, including selenium, thallium, and titanium, remained relatively constant. A limited number of species (including cobalt, magnesium, molybdenum, and sulfate) exhibited greater than two-fold increases in concentration.

Variations in solution composition due to temperature were limited to a few select species. The percent difference between the average room temperature water quality and the low temperature water quality is calculated in Tables 2.2-4 and 2.2-5. Concentrations of sulfate roughly doubled in the low temperature column, but increased three- or four-fold in the room temperature columns. Contrary to observations in the room temperature columns, concentrations of cyanate did not decrease while selenium concentrations decreased by at least a factor of four in the low temperature columns. However, the vast majority of aqueous species behaved similarly in the low temperature as in the room temperature columns.

The second phase of the testing procedure required that the columns be drained of the reactive cyanide destruction solution and rinsed with either DI or mock rinsate solution. Table 2.4-1 provides a comparison of the average room temperature final detoxification solution with the rinsate solution from column 63316. The concentrations of a majority of the aqueous species decreased during the rinsing phase, as was expected. It is worth noting, however, that concentrations of several elements of concern (such as arsenic, copper, lead, and zinc) increased during the rinsing process, possibly indicating the presence of a continuing source of metals in the column.

Table 2-11: Comparison of Average Column Values, Room Temperature Ex-Situ Chemical Detoxification Columns

Constituent	Unit	Pre-Detox	Mid-Point	Final Detox	Mock Effluent Rinse, Column 63316 only	% Difference Pre-Detox to Final	% Difference Final to Rinse
pH	pH Units	9.58	9.27	8.98	8.68	-6%	-3%
Acidity (Titrimetric)	mg/L as CaCO ₃	--	--	-56	-158	N/A	181%
Bicarbonate (HCO ₃)	mg/L	506	--	680	680	34%	0%
Carbonate (CO ₃)	mg/L	161	--	79	36	-51%	-54%
Hydroxide (OH)	mg/L	0.5	--	0.5	0.5	0%	0%
Total Alkalinity	mg/L as CaCO ₃	683	--	690	620	1%	-10%
Redox Potential	mV	--	--	250	300	N/A	20%
Total Kjeldahl Nitrogen	mg/L	107	100	30	30	-72%	2%
Total Nitrogen	mg/L	123	143	260	31	112%	-88%
Total Dissolved Solids (TDS)	mg/L	1913	--	4000	2800	109%	-30%
Electrical Conductivity	µmhos/cm	--	--	6333	4200	N/A	-34%
Chloride	mg/L	78	--	64	79	-18%	23%
Fluoride	mg/L	4	--	3.8	2.2	-6%	-43%
Sulfate	mg/L	275	--	1200	1000	336%	-17%
Nitrate Nitrogen	mg/L	1.3	35.3	300	58	22309%	-81%
Nitrite Nitrogen	mg/L	--	2.3	3.2	1.8	39%	-44%
Aluminum	mg/L	1.5	5.67	0.99	1.7	-35%	71%
Barium	mg/L	0.05	0.075	0.039	0.04	-28%	2%
Beryllium	mg/L	0.0005	0.0005	0.0005	0.0002	0%	0%
Bismuth	mg/L	0.05	0.05	0.05	0.0375	0%	0%
Boron	mg/L	0.143	0.17	0.18	0.11	24%	-38%
Cadmium	mg/L	0.0088	0.0016	0.0005	0.0001	-94%	-80%
Calcium	mg/L	87	16	12	24	-87%	105%
Chromium	mg/L	0.01	0.0098	0.0025	0.0026	-64%	4%
Cobalt	mg/L	0.20375	0.410	0.570	0.095	180%	-83%
Copper	mg/L	3.85	0.19	0.08	23	-98%	27390%
Gallium	mg/L	0.05	0.05	0.05	0.01	0%	-80%
Iron	mg/L	7.91	4	0.47	0.92	-94%	97%
Lithium	mg/L	0.05	0.05	0.05	0.02	0%	-60%
Magnesium	mg/L	0.52	0.81	1.8	1.2	245%	-33%
Manganese	mg/L	0.06	0.073	0.014	0.028	-76%	95%
Molybdenum	mg/L	0.12	0.187	0.277	0.068	136%	-75%
Nickel	mg/L	0.06	0.005	0.005	0.004	-91%	-20%
Phosphorus	mg/L	0.613	0.63	0.25	0.57	-59%	128%
Potassium	mg/L	8.363	9.6	17	12	107%	-31%
Scandium	mg/L	0.05	0.05	0.05	0.001	0%	-98%

Constituent	Unit	Pre-Detox	Mid-Point	Final Detox	Mock Effluent Rinse, Column 63316 only	% Difference Pre-Detox to Final	% Difference Final to Rinse
Silver	mg/L	0.0025	0.0025	0.0025	0.0008	0%	-68%
Sodium	mg/L	705	850	1433	1000	103%	-30%
Strontium	mg/L	1.43	0.25	0.48	0.43	-67%	-10%
Tin	mg/L	0.05	0.05	0.05	0.005	0%	0%
Titanium	mg/L	0.05	0.26	0.05	0.04	0%	-20%
Vanadium	mg/L	0.20	0.081	0.026	0.034	-87%	32%
Zinc	mg/L	2.825	0.121	0.025	0.087	-99%	253%
Mercury	mg/L	0.00	0.0095	0.0046	0.00035	30%	-92%
Antimony	mg/L	1.156	1.97	1.77	0.99	53%	-44%
Arsenic	mg/L	16	19	5.1	7.3	-68%	44%
Lead	mg/L	0.21	0.60	0.09	0.18	-58%	104%
Selenium	mg/L	0.04	0.064	0.040	0.019	-1%	-53%
Thallium	mg/L	0.0005	0.005	0.0005	0.0001	0%	0%
Cyanate	mg/L	161.3	150	20.3	2.5	-87%	-88%
Thiocyanate	mg/L	50.1	68	74	18	47%	-76%
Ammonia, as Nitrogen	mg/L	60.3	90	22	13	-63%	-42%
WAD CN	mg/L	16.0	0.93	0.05	0.04	-100%	-20%

Text in RED is reported at one-half of the detection limit to allow for calculation of average, mean, and standard deviation.

Text in GREEN indicates a decrease in the total concentration.

2.4.2. In-Situ Biological Detoxification Procedure

Data indicate that the day 0 WAD Cyanide concentrations in all columns treated with the biological detoxification method ranged from 12.37 mg/L to 23.53 mg/L, with an average of 19.45 mg/L. Approximately 97% of the initial WAD CN was removed in the first 55 days of treatment. However, the degradation of WAD CN slowed significantly after 55 days, remaining above the target of 0.2 mg/L for over 100 days of additional cycling as illustrated in Figure 4. At that time, an analysis of the leachate solution indicated that the degradation process had stalled (Table 2.2-8). A second dose of the carbon syrup solution was added, and the columns placed in a dark room to prevent possible degradation of strong-acid dissociable and other CN-complexes, which may serve as a continuing source of WAD CN. After the third dose of the carbon syrup was applied at day 239, the leachate concentration of WAD CN decreased to below the target concentration and the columns were drained. A data review conducted by Dr. Jim Harrington (Access Consulting) suggested that the degradation of CN was limited by the availability of the reduced carbon substrate and that additional amendments earlier in the cyanide destruction process would expedite degradation rates. In addition, he proposed that exposure to ambient UV light in the laboratory may have generated a continuing source of WAD CN via the degradation of strong-acid dissociable CN complexes. Both hypotheses would be corrected in a field scale setting due to the constant monitoring of the recirculated solutions and the size of the heap.

In addition to the monitored decreases in WAD CN concentrations, the concentrations of other nitrogen species decreased during the cyanide destruction process as shown in Table 2.4-2 and

Figure 2.4-2. Concentrations of thiocyanate and ammonia were reduced by 97% and 99%, respectively, from the pre-treatment to the final solution.

Concentrations of the majority of other aqueous species also decreased during the testing process as shown in Table 2.4-2. For example, the concentration of As decreased by an average of 83%. Other species of concern, such as cadmium, copper, iron, nickel, zinc, mercury, antimony, and selenium had similar reductions in concentration. A limited number of species (including chromium, molybdenum, lead, and sulfate) had increases in concentration. Due to the limited amount of solution available for analysis, a limited selection of analytes was requested; therefore a discussion regarding other analytes not listed in Table 2.4-2 is not possible.

Also, because of the limited solution available, the cold temperature column solution was blended with the room temperature solutions after the final column drain-down. Consequently, a comparison of temperature effects is not possible with the final biological columns. However, samples analyzed at the midpoint of the testing process were collected discretely and are the focus of this discussion. Unlike the ex-site chemically treated columns, variations in solution composition due to temperature were observed to some degree in all species. Table 2.2-9 provides a calculation of the percent difference between the cold temperature column and the average of the room temperature columns. Concentrations of arsenic, chloride, boron, lithium, and thiocyanate were elevated a minimum of 83% in the low temperature column compared to the room temperature columns. The elevation of arsenic at low temperatures warrants additional monitoring in the field setting due to implications of arsenic treatment requirements. The remaining aqueous species were present at lower concentrations in the low temperature column than the room temperature columns.

The data presented in Table 2.4-2 are representative of anticipated concentrations of all analytes remaining in the pore water within the heap at the end of the in-situ biological treatment process. The results of subsequent humidity cell testing performed on the columns after the cyanide destruction phase of testing is described and summarized in SRK (2014).

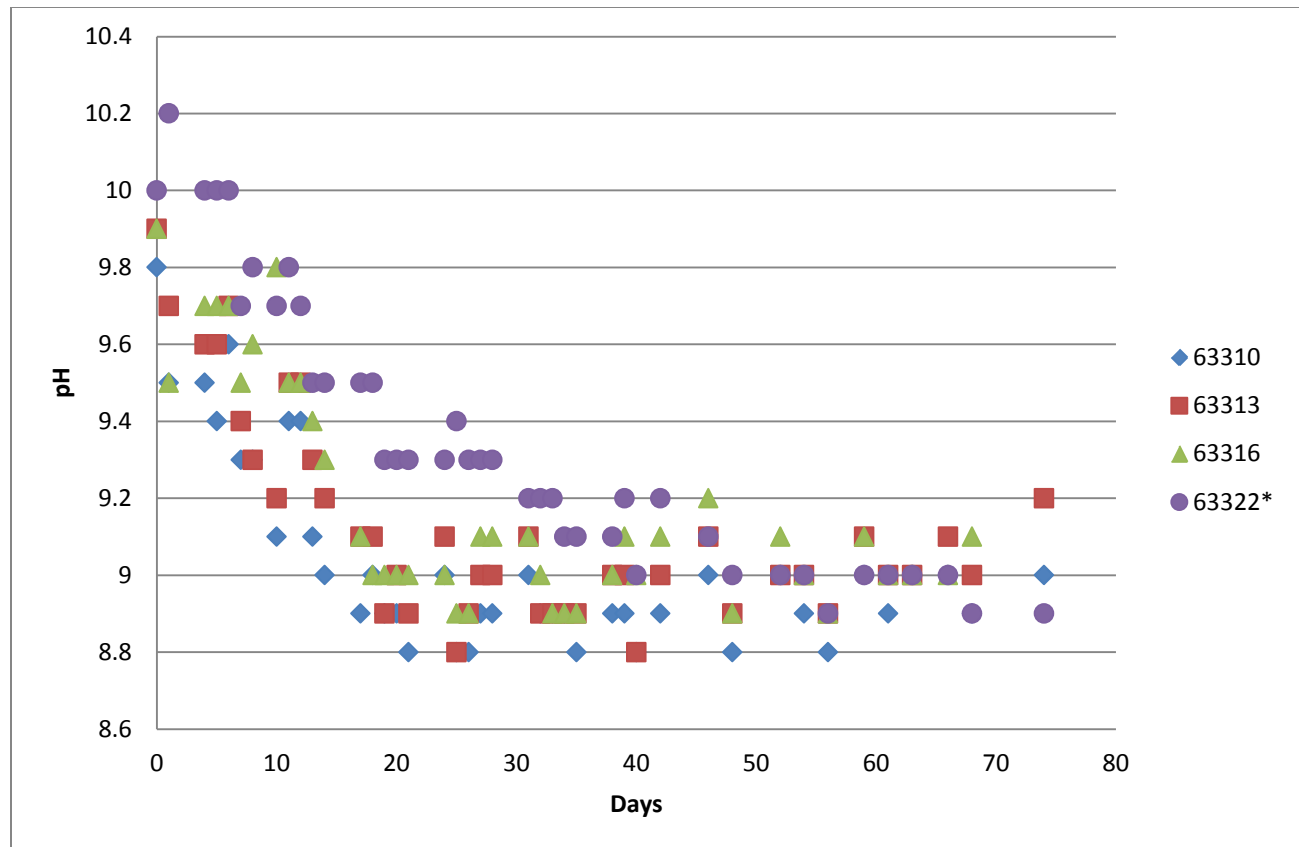
Table 2-12: Comparison of Average Column Values, Room Temperature In-Situ Biological Detoxification Columns

Constituent	Unit	Pre-Detox	Mid-Point	Blended Final Solution	% Difference Pre-Detox to Final
pH	pH Units	9.58	8.72	--	N/A
Acidity (Titrimetric)	mg/L as CaCO ₃	--	-163	--	N/A
Bicarbonate (HCO ₃)	mg/L	506	1267	--	N/A
Carbonate (CO ₃)	mg/L	161	60	--	N/A
Hydroxide (OH)	mg/L	0.5	0.5	--	N/A
Total Alkalinity	mg/L as CaCO ₃	683	1133	--	N/A
Redox Potential	mV	--	227	--	N/A
Total Kjeldahl Nitrogen	mg/L	107	8	--	N/A
Total Nitrogen	mg/L	123	9	--	N/A
Total Dissolved Solids (TDS)	mg/L	1913	2633	--	N/A
Electrical Conductivity	µmhos/cm	--	4200	--	N/A
Chloride	mg/L	78	25	99	27%
Fluoride	mg/L	4	2	1.9	-54%
Sulfate	mg/L	275	1017	1000	264%
Nitrate Nitrogen	mg/L	1.3	1.0	0.30	-78%
Nitrite Nitrogen	mg/L	--	3.1	--	N/A

Constituent	Unit	Pre-Detox	Mid-Point	Blended Final Solution	% Difference Pre-Detox to Final
Aluminum	mg/L	1.5	0.84	--	N/A
Barium	mg/L	0.05	0.03	--	N/A
Beryllium	mg/L	0.0005	0.0005	--	N/A
Bismuth	mg/L	0.05	0.05	--	N/A
Boron	mg/L	0.143	0.135	--	N/A
Cadmium	mg/L	0.0088	0.0005	0.00045	-95%
Calcium	mg/L	87	16	--	N/A
Chromium	mg/L	0.01	0.0025	0.0085	23%
Cobalt	mg/L	0.20375	0.207	--	N/A
Copper	mg/L	3.85	0.025	0.089	-98%
Gallium	mg/L	0.05	0.05	--	N/A
Iron	mg/L	7.91	4.03	2.9	-63%
Lithium	mg/L	0.05	0.05	--	N/A
Magnesium	mg/L	0.52	3.30	--	N/A
Manganese	mg/L	0.06	0.049	--	N/A
Molybdenum	mg/L	0.12	0.120	0.14	19%
Nickel	mg/L	0.06	0.005	0.033	-42%
Phosphorus	mg/L	0.613	0.25	--	N/A
Potassium	mg/L	8.363	12	--	N/A
Scandium	mg/L	0.05	0.05	--	N/A
Silver	mg/L	0.0025	0.0025	0.00075	0%
Sodium	mg/L	705	1053	--	N/A
Strontium	mg/L	1.43	0.45	--	N/A
Tin	mg/L	0.05	0.05	--	N/A
Titanium	mg/L	0.05	0.05	--	N/A
Vanadium	mg/L	0.20	0.022	--	N/A
Zinc	mg/L	2.825	0.005	0.12	-96%
Mercury	mg/L	0.0035	0.0005	0.0005	-86%
Antimony	mg/L	1.156	1.30	0.68	-41%
Arsenic	mg/L	16	3.0	2.6	-83%
Lead	mg/L	0.21	0.07	0.53	151%
Selenium	mg/L	0.04	0.018	0.013	-68%
Thallium	mg/L	0.0005	0.0005	0.0002	0%
Cyanate	mg/L	161.3	4.9	--	N/A
Thiocyanate	mg/L	50.1	3.1	1.6	-97%
Ammonia, as Nitrogen	mg/L	60.3	--	0.79	-99%
WAD CN	mg/L	16.0	--	0.025	-100%

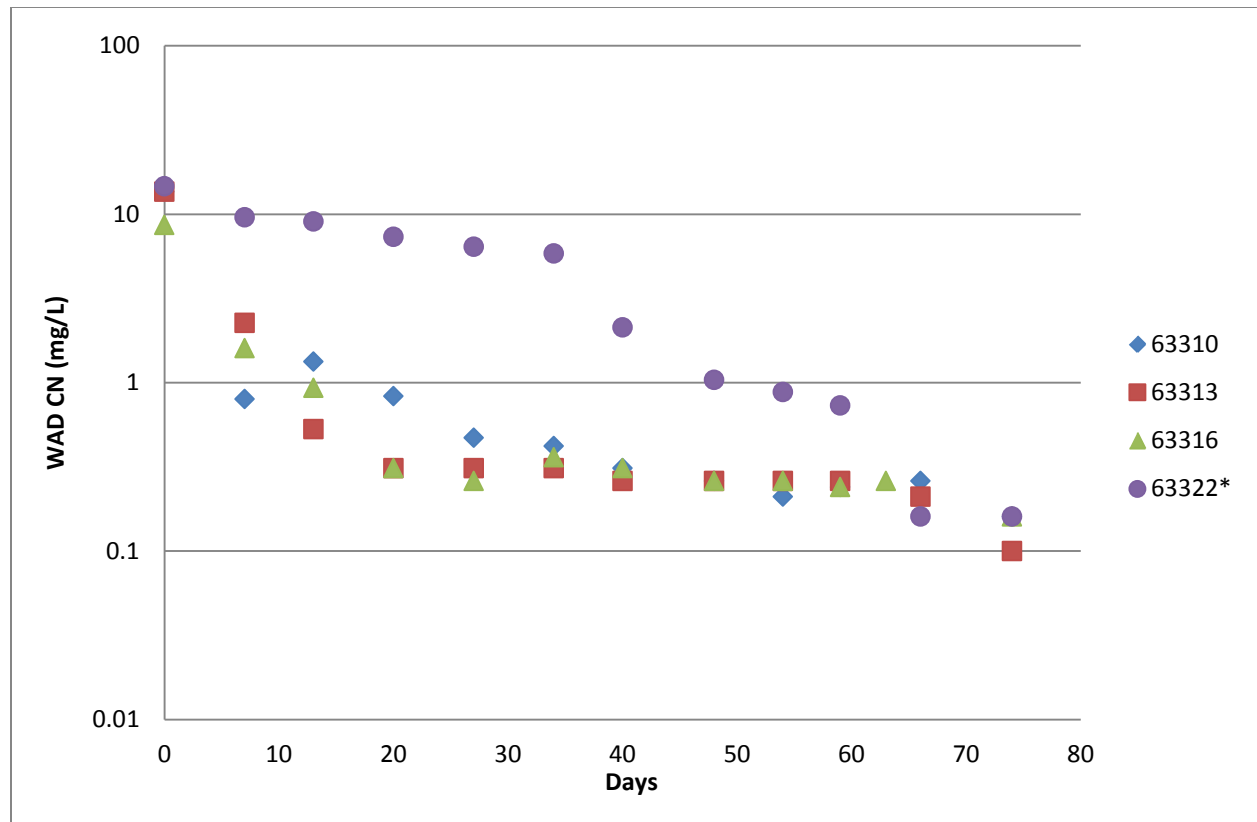
Text in RED is reported at one-half of the detection limit to allow for calculation of average, mean, and standard deviation.

Text in GREEN indicates a decrease in the total concentration.



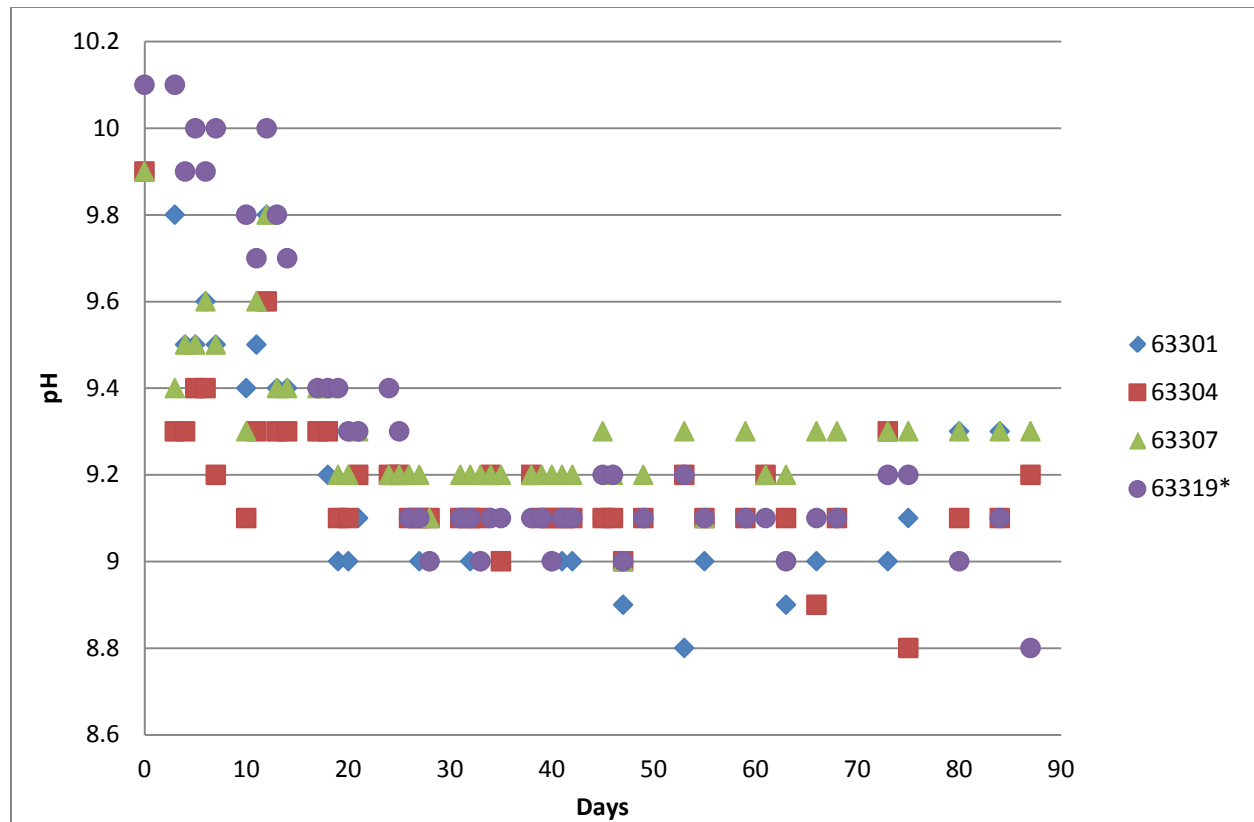
* Operated at 4 ° C.

Figure 2-1: Ex-Situ Chemical Treatment pH vs. Time



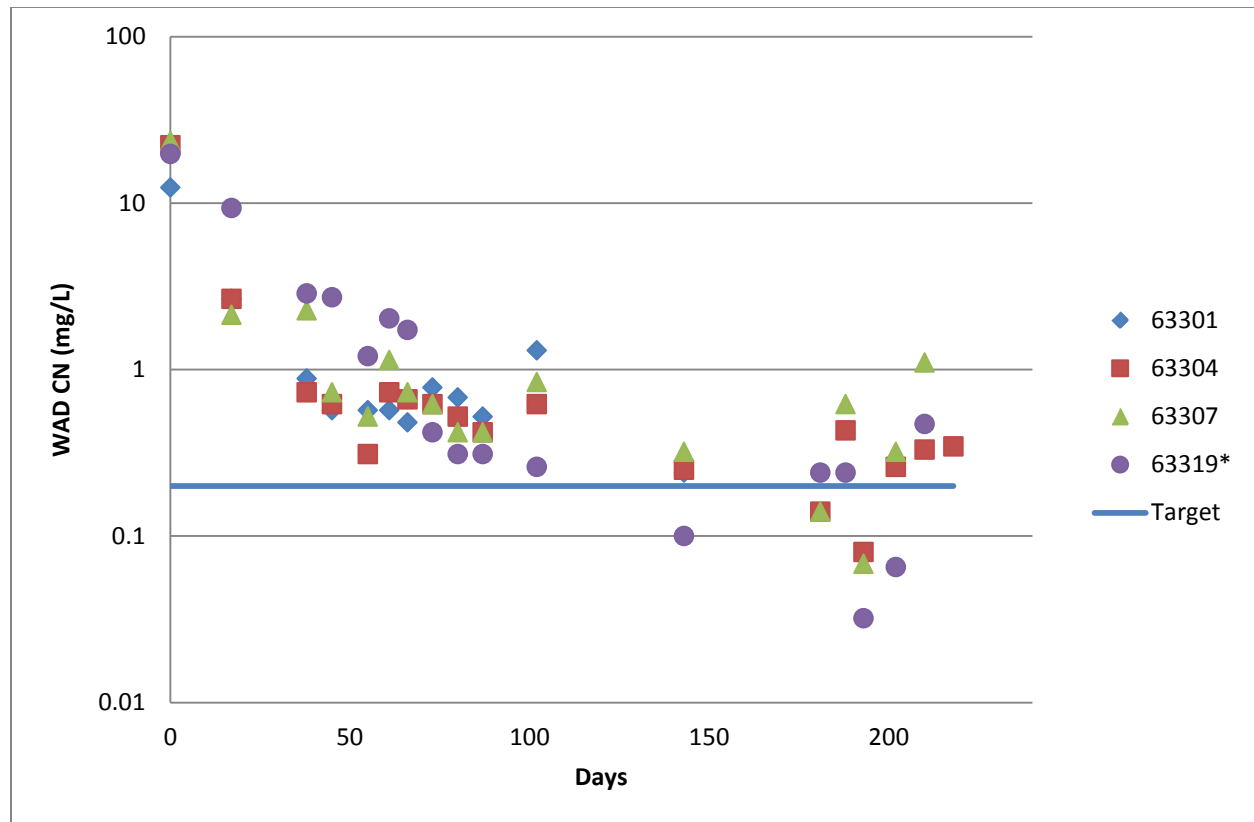
* Operated at 4° C.

Figure 2-2: Ex-Situ Chemical Treatment WAD CN vs. Time



* Operated at 4° C.

Figure 2-3: In-Situ Biological Treatment pH vs. Time



Additional doses of carbon added at days 143 and 239. * Operated at 4° C.

Figure 2-4: In-Situ Biological Treatment WAD CN vs. Time

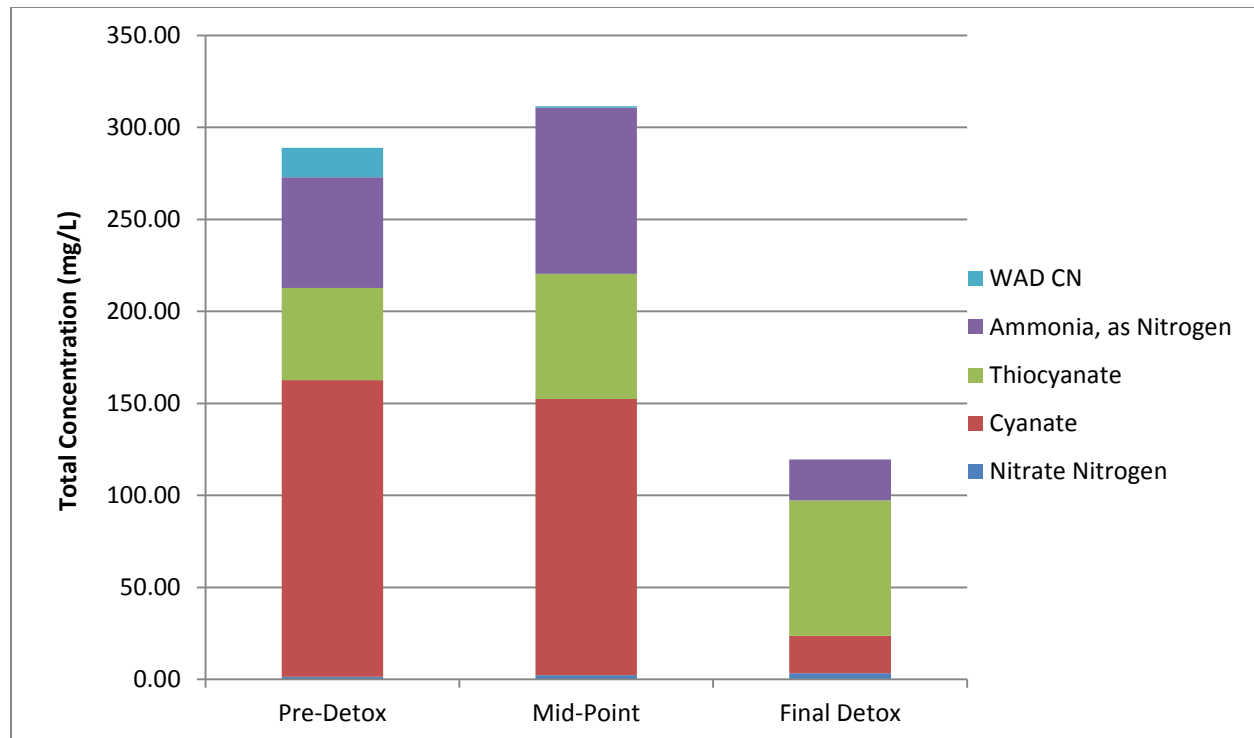


Figure 2-5: Ex-Situ Chemical Treatment Nitrogen Species Evolution

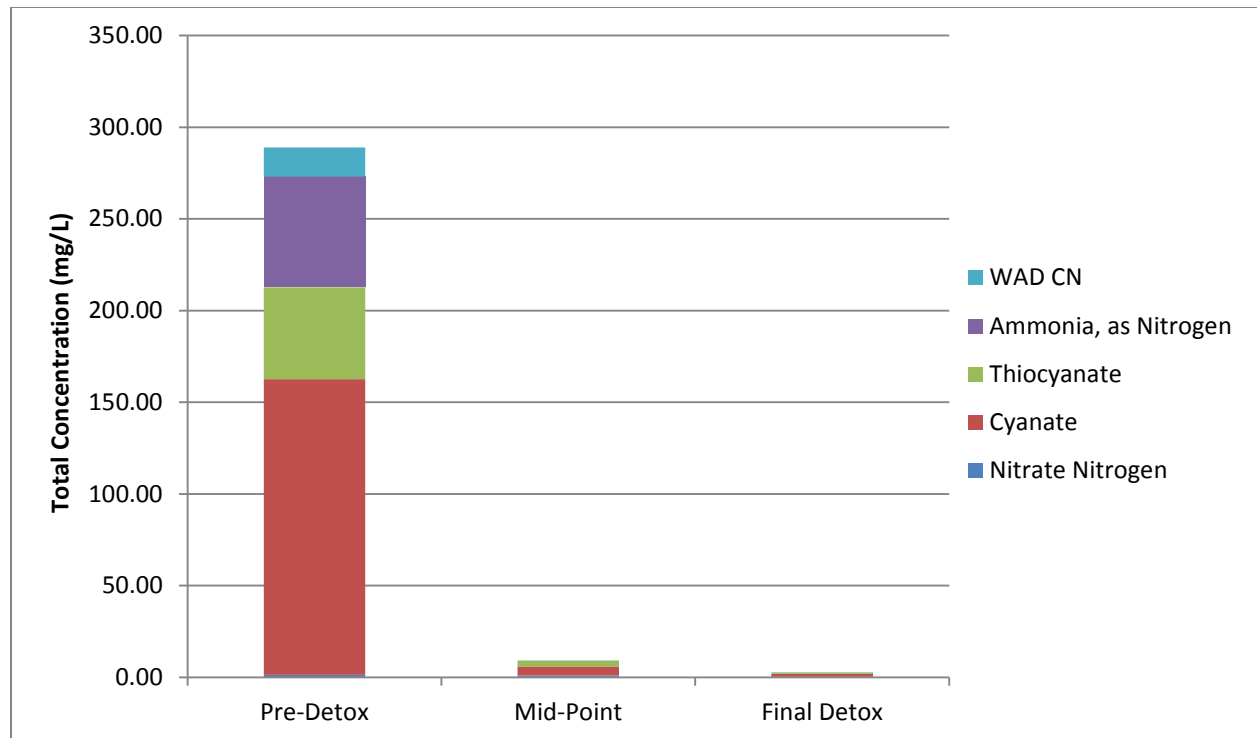


Figure 2-6: In-Situ Biological Treatment Nitrogen Species Evolution

3.0 CONCLUSIONS AND RECOMMENDATIONS

Both cyanide destruction procedures attained the target WAD CN concentration of <0.2 mg/L during the column test, provided sufficient reactive solution was applied to the columns as needed. However, the final leachate water quality produced from the two methodologies present different water treatment challenges for any mine water treatment plant design. Table 3-1 and Figures 3-1 and 3-2 summarize the percent differences in final leachate water quality between the ex-situ chemical treatment and the in-situ biological treatment options.

Although the ex-situ chemical treatment method effectively removed the WAD CN in a relatively short time, the degradation of CN was incomplete. Instead of innocuous end-products, a build-up of cyanate, thiocyanate, ammonia, and nitrate was observed. These nitrogen species would require additional water treatment to produce effluent compliant with discharge standards.

The biological detox method reduced concentrations of all nitrogen species, including cyanate, thiocyanate, ammonia, and nitrate, to levels that would likely be managed via blending with other site waters. The removal of environmentally-significant metals such as lead, zinc, iron, nickel, and chromium is less efficient in the bacterial treatment process, however these metals are typically readily removed by standard mine water treatment technologies. Due to the limited volume of the final solution, a complete chemical analysis was not possible.

Based on the above-described test work, in-situ biological treatment is the preferred method to achieve cyanide destruction within the heap. The chemical treatment method would be needed to provide an efficient CN-destruction technology for handling such events. Bench scale studies would be necessary to optimize the treatment of the excess heap solution during operations using the ex-situ chemical treatment methodology.

The final detox solution analytical results are available to use as a refined source term for the heap drainage in the post-closure water quality and geochemical model, as appropriate.

Table 3-1: Comparison of Final Treatment Solution Compositions

Constituent	Unit	Average Room Temperature Final Ex-Situ Chemical Detox Solution	Blended Room Temperature Final In-Situ Biological Detox Solution	% Difference of In-situ Compared to Ex-Situ
pH	pH Units	8.98	--	N/A
Acidity (Titrimetric)	mg/L as CaCO ₃	-56.2	--	N/A
Bicarbonate (HCO ₃)	mg/L	680	--	N/A
Carbonate (CO ₃)	mg/L	79	--	N/A
Hydroxide (OH)	mg/L	<1.0	--	N/A
Total Alkalinity	mg/L as CaCO ₃	690	--	N/A
Redox Potential	mV	250	--	N/A
Total Kjeldahl Nitrogen	mg/L	29.5	--	N/A
Total Nitrogen	mg/L	260	--	N/A
Total Dissolved Solids (TDS)	mg/L	4000	--	N/A
Electrical Conductivity	µmhos/cm	6333	--	N/A
Chloride	mg/L	64	99	54%
Fluoride	mg/L	3.8	1.9	-50%
Sulfate	mg/L	1200	1000	-17%

Constituent	Unit	Average Room Temperature Final Ex-Situ Chemical Detox Solution	Blended Room Temperature Final In-Situ Biological Detox Solution	% Difference of In-situ Compared to Ex-Situ
Nitrate Nitrogen	mg/L	300	0.30	-100%
Nitrite Nitrogen	mg/L	3.2	--	N/A
Aluminum	mg/L	0.99	--	N/A
Barium	mg/L	0.039	--	N/A
Beryllium	mg/L	<0.0010	--	N/A
Bismuth	mg/L	<0.10	--	N/A
Boron	mg/L	0.18	--	N/A
Cadmium	mg/L	0.0005	0.00045	-10%
Calcium	mg/L	12	--	N/A
Chromium	mg/L	0.0025	0.0085	240%
Cobalt	mg/L	0.57	--	N/A
Copper	mg/L	0.08	0.089	6%
Gallium	mg/L	<0.10	--	N/A
Iron	mg/L	0.47	2.9	521%
Lithium	mg/L	<0.10	--	N/A
Magnesium	mg/L	1.8	--	N/A
Manganese	mg/L	0.014	--	N/A
Molybdenum	mg/L	0.28	0.14	-49%
Nickel	mg/L	0.005	0.033	560%
Phosphorus	mg/L	<0.50	--	N/A
Potassium	mg/L	17	--	N/A
Scandium	mg/L	<0.10	--	N/A
Silver	mg/L	0.0025	0.00075	-70%
Sodium	mg/L	1433	--	N/A
Strontium	mg/L	0.48	--	N/A
Tin	mg/L	<0.10	--	N/A
Titanium	mg/L	<0.10	--	N/A
Vanadium	mg/L	0.026	--	N/A
Zinc	mg/L	0.025	0.12	386%
Mercury	mg/L	0.0046	0.0005	-89%
Antimony	mg/L	1.8	0.68	-62%
Arsenic	mg/L	5.1	2.6	-49%
Lead	mg/L	0.088	0.53	500%
Selenium	mg/L	0.040	0.013	-68%
Thallium	mg/L	0.0005	0.0002	-60%
Cyanate	mg/L	20	--	N/A
Thiocyanate	mg/L	74	1.6	-98%
Ammonia, as Nitrogen	mg/L	22	0.79	-96%
WAD CN	mg/L	0.05	0.025	-50%

Text in RED is reported at one-half of the detection limit to allow for calculation of average, mean, and standard deviation.

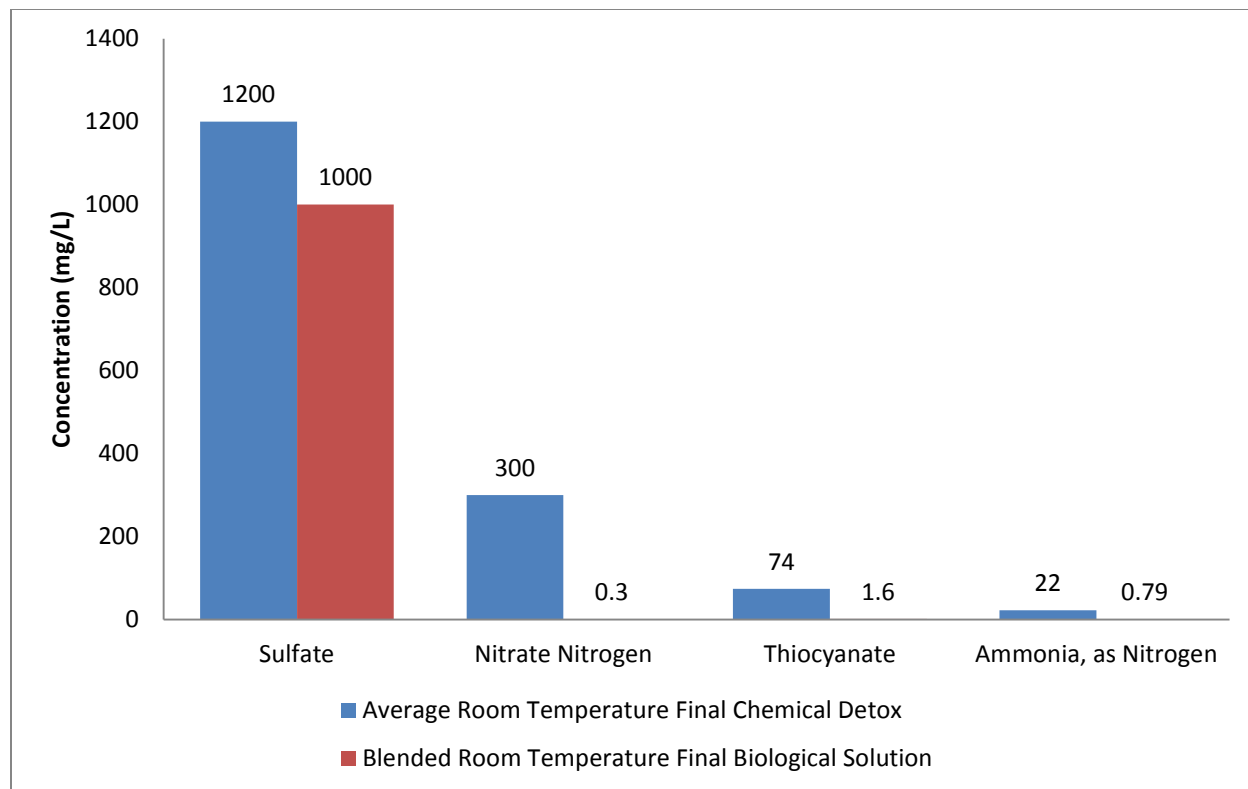


Figure 3-1: Selected Anion Comparisons between the Ex-situ Chemical and In-situ Biological Treatment Methods

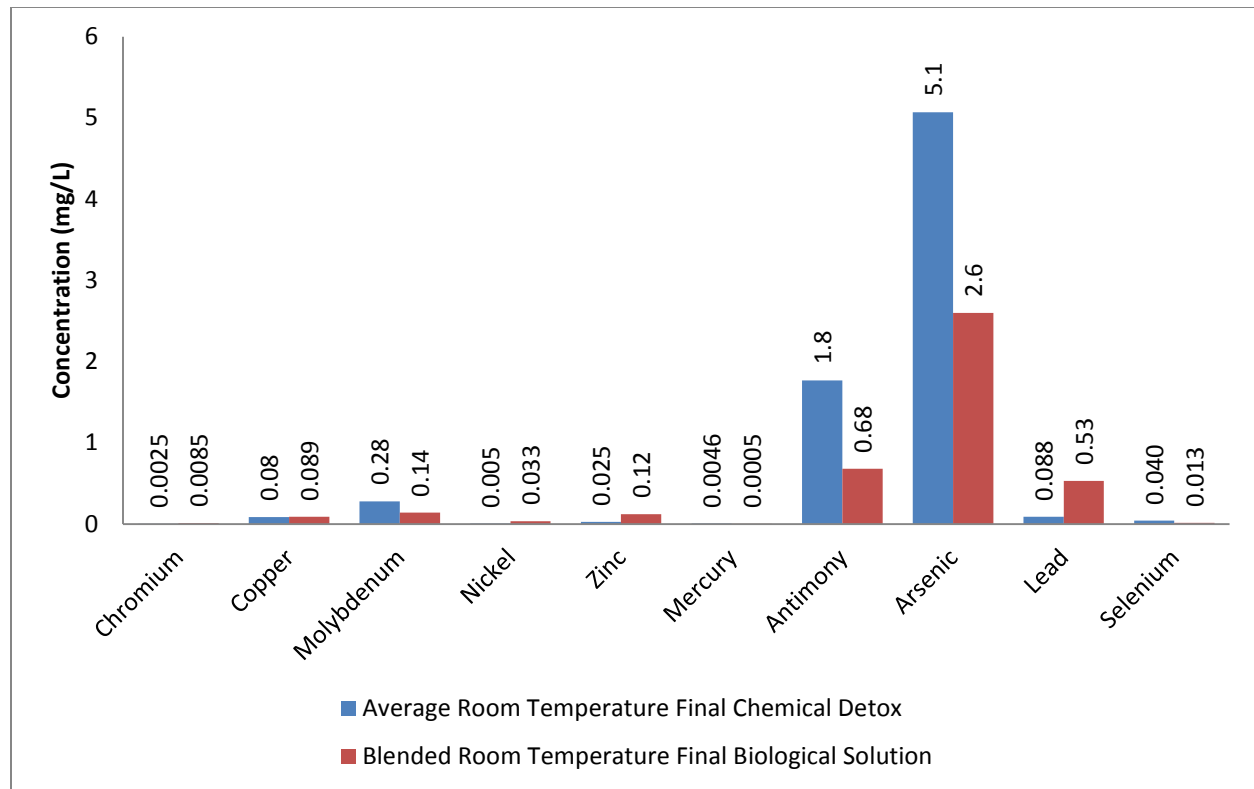


Figure 3-2: Selected Metal Comparisons between the Ex-situ Chemical and In-situ Biological Treatment Methods

4.0 REFERENCES

KCA 2012. Eagle Gold Project, Report of Metallurgical Test Work October 2012; prepared by Kappes Cassiday & Associates (Reno, Nevada) for Stratagold Corporation (Vancouver, BC).

KCA 2014. Eagle Gold Project, Report of Metallurgical Test Work January 2014; prepared by Kappes Cassiday & Associates (Reno, Nevada) for Stratagold Corporation (Vancouver, BC).

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ATTACHMENT A

Ex-situ Chemical Treatment Procedure

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Column Testing for Ex-situ Chemical Treatment for Cyanide Destruction

Ex-situ treatment applied a chemical dosage of hydrogen peroxide (with copper catalyst) to oxidize cyanide to cyanate in the water circulated through the column. The following provides a step-wise Standard Operating Procedure for the ex-situ chemical treatment process:

1. Upon conclusion of the metallurgical testing, analyze the final metallurgical test solution for all parameters listed in Table 2.2-1 including total and weak acid dissociable (WAD) cyanide. Immediately prepare the 40-kg columns for cyanide detoxification testing.
2. Convert the total cyanide concentration to total cyanide by mass and calculate the approximate quantity of peroxide required for treatment. Total oxidation requires 1.26 kg peroxide per kilogram cyanide and a concentration of 5 to 50 mg/L soluble copper (as copper nitrate)².
3. Prepare the treatment solution of 10% peroxide (or a minimum stoichiometric excess of 20%) in a 10 mg/L copper nitrate solution, adjusted to a pH greater than 9 to prevent the formation of hydrogen cyanide gas (HCN).
4. Add the treatment solution to the column effluent, which will be recirculated to the top of the column at a rate equivalent to the infiltration/drainage rate so as to maintain saturation and constant peroxide and copper dosages.
5. Collect and sample the effluent solution for WAD cyanide every pore volume for the first five cycles, with decreased sampled frequency depending on the results of the initial analysis³.
6. Repeat steps 2-5 as needed until the WAD cyanide in the column effluent has decreased to <0.2 mg/L and additional testing has confirmed that free cyanide has decreased to < 0.005 mg/L.
7. Sample and submit the leachate for all parameters listed in Table 2.2-1.
8. Once the WAD and free cyanide concentrations have reached <0.2 mg/L and <0.005 mg/L, respectively, allow the columns to gravity drain and replace the full volume of the rinsate solution with RO water or mock rinsate solution (as described in Table 2.2-6) to begin rinsing metals and other non-cyanide compounds from the heap. Note: heap leachate chemistry is expected to change over time due to continued recycling through the system. However, the primary purpose of this column test is to evaluate the changes in cyanide concentration over time with rinsing. Resulting changes in other water quality parameters are not expected to change significantly over the time frame considered during this short-term column test and will, therefore, not be considered.
9. Sample leachate and submit the leachate for all parameters listed in Table 2.2-1.
10. Continue rinsing with the serial dilutions until the WAD cyanide concentration decreases to <0.1 mg/L and ammonia concentration is <10 mg/L.

² U.S. Patent No. 3,510,424 and U.S. Patent No. 3,617,567.

³ Cyanide may be analyzed for free, WAD (which includes free plus weak complexes), or total (including strongly complexed with iron or cobalt). However, the concentration of free cyanide tends to drop to below the detection limit very rapidly so is not very useful for determining progress of cyanide destruction. Strongly complexed cyanide is not treated with peroxide oxidation, but is also very unreactive and is, therefore, not susceptible to leaching. Therefore, WAD cyanide is the most useful measure of cyanide destruction progress. Although water quality standards are based on free cyanide, the weak complexes of cyanide have the potential to break down to free cyanide so are a more appropriate indicator of compliance with the Water Quality Standards.

ATTACHMENT B

In-situ Biological Treatment Procedure

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Column Testing for In-Situ Biological Treatment for Cyanide Destruction and Metals Reduction

In situ microbial treatment is accomplished in two phases, a rapid reaction of sugars with free or weakly complexed cyanide, and the slower reaction of microbes that are naturally present in the ore materials growing up and utilizing cyanide as a nitrogen source, or destroying cyanide to render the pore water environment more benign from a microbial perspective. Microbial growth is stimulated by the addition of a carbon source at a typical molar ratio of 0.5:1 sugars to cyanide (i.e., 4:1 C:N ratio). In prior cyanide destruction experience with a heap, this ratio has been highly variable, and other nitrogen species (nitrate/nitrite or ammonia) can be a bigger control on carbon demand; however, in a test column the WAD and free cyanide are typically the driver of a carbon demand.

In order to calculate specific ranges of reagents that will be required, previous columns' water quality results (specifically cyanide-related concentrations) were evaluated for planning purposes. For purposes of this discussion, barren solution is assumed to have cyanide at a concentration of 0.33 g/L based on prior KCA test columns. However, as in situ biological treatment will improve water quality with respect to metals and other anions that affect water quality, the columns will be operated to optimize the extent of biological treatment to minimize metals loading.

Based on the initial concentration of CN, 457 mg total organic carbon (TOC) as sugars will be added per liter to the barren solution (in practice this would also include the volume contained in the barren solution reservoir as well as in the pore spaces of the heap materials). Columns will be recirculated at a rate half as fast as was used for leaching the ore, or a rate targeted to exchange a column pore volume no faster than once every 3.5 days. This slower rate is more conducive to enhancement of microbial growth and supporting biological mechanisms.

The following steps comprise the Standard Operating Procedure for testing microbial destruction of cyanide and other constituents that affect water quality:

1. Ensure that a complete water quality assay is completed for barren leach solution with respect to cyanide forms (free, WAD, and total cyanide), related nitrogen forms (ammonia, cyanate, thiocyanate, nitrate, and nitrite), and project-specific anions, metals, and metalloids of concerns as listed in Table 2.2-1. (If column solids will be tested afterwards, a sample of column solids should be removed before the biological treatment to provide a comparison sample.)
2. Amend barren leach solution (total volume includes the calculated saturated porosity) with sugar solution to achieve 0.5:1 molar ratio of glucose/glucose equivalents to total CN in solution. Estimated volume in prior KCA column test was approximately 12.7 liters, including the volume held in the column and the reservoir. At 12.7 liters and that dosage rate, approximately 5.83 grams TOC or 14.57 grams sugars will be added to the barren leach solution reservoir. Review the final metallurgical column analytical data and perform this calculation to confirm the actual dose used in the test column operation.
3. Mix the barren leach solution with the organic carbon dosage, and let react at room temperature for 1 hour. At the end of one hour, sample for WAD CN, total CN, and nitrogen species (ammonia, nitrate, nitrite). This test determines the extent of abiotic reaction of the sugars with the free and WAD CN.

4. Recirculate at a rate equivalent to half of what was used to leach the columns to facilitate microbial growth in the columns (no faster than a column porosity exchange once every 3.5 days or as slow as possible given the porosity of the column).
5. Sample and analyze the column effluent twice weekly for WAD CN and total CN.
6. Sample column effluent weekly for nitrogen species listed above and TOC.
7. At the end of 3 weeks, amend barren leach solution with alcohol (methanol/ethanol mix) with up to 100 mg/L TOC in the overall solution volume in the reservoir + column porosity to enhance further biological treatment for metals in column pore waters.
8. At the end of 6-8 weeks, repeat complete water quality assay as performed in step 1 (time dependent on the rate of sugar degradation in the first 4 weeks results).
9. Continue circulation until the results of the complete water quality assay as performed in Step 1 has been received.