EPA/600/R-05/002
November 2004

Mine Waste Technology Program

Remediation Technology Evaluation at the Gilt Edge Mine, South Dakota

by

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Contract No. DE-AC09-96EW96405
EPA IAG No. DW89938870-01-1

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This study was conducted in cooperation with
U.S. Department of Energy
Savannah River Operations Office
Aiken, South Carolina 29802

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Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Notice

The U.S. Environmental Protection Agency through its Office of Research and Development funded the research described here under IAG DW89938870-01-0 through the U.S. Department of Energy (DOE) Contract DE-AC22-96EW96405. It has been subjected to the Agency's peer and administrative review and has been cleared for publication as an EPA document. The views and opinions of authors expressed herein do not necessarily state or reflect those of the EPA or DOE, or any agency thereof. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Foreword

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The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments, and groundwater; prevention and control of indoor air pollution; and restoration of ecosystems. The NRMRL collaborates with both public and private-sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

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Lawrence W. Reiter, Acting Director
National Risk Management Research Laboratory

Abstract

This document reports the findings of the Mine Waste Technology Program's Activity III, Project 29, The Remediation Technology Evaluation Project at the Gilt Edge Mine, South Dakota. This project consisted of evaluating three emerging acidic waste rock stabilization technologies and comparing those technologies to lime treatment of acidic waste rock. The three new technologies tested were the Silica Micro Encapsulation (SME) Technology from Klean Earth Environmental Company (KEECO), the Passivation Technology from the University of Nevada-Reno (UNR), and the Envirobond Technology from Metals Treatment Technologies (MT^2). Performance of the technologies was evaluated as a pilot-scale demonstration by placing treated waste rock into isolated cells at the Gilt Edge Mine and monitoring the leachate collected from the representative cells. The objective of the treatments was to reduce the contaminants of concern by at least 90% or to South Dakota water discharge limits. The three technology vendors also provided a cost estimate to treat a hypothetical 500,000-cubic yard waste rock pile at the Gilt Edge Mine using the pilot-scale data as a guideline.

The leachate results revealed that UNR's Passivation technology and the lime treatment reduced more contaminants of concern to the project objectives than the KEECO and MT^2 technologies.

Appendices A through D are available upon request from the MSE MWTP Program Manager. Please refer to document number MWTP-235. Email: mse-ta@mse-ta.com, Phone (406) 494-7100.

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Appendices are available upon request at Email: mse-ta@mse-ta.com or Phone (406)494-7100. Document # MWTP-235.

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Acronyms and Abbreviations

ABA	acid-base accounting
ARD	acid rock drainage
CaO	lime (dry)
$CACO_3$	calcium carbonate (limestone)
CDM	CDM Federal Inc.
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	foot
KEECO	Kleen Earth Environmental Company
L	liter
mg	milligram
MS	matrix spike
MSD	matrix spike duplicate
MSE	MSE Technology Applications, Inc.
MT^2	Metals Treatment Technologies
MWTP	Mine Waste Technology Program
PR	presumptive remedy
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
ROD	Record of Decision
SAP	sampling and analysis plan
SD AWQC	South Dakota Applicable Water Quality Criteria
SME	silica microencapsulation
TDS	total dissolved solids
µg	microgram
UNR	University of Nevada-Reno
yd^3	cubic yard

Acknowledgment

This document was prepared by MSE Technology Applications, Inc. (MSE) for the U.S. Environmental Protection Agency's (EPA) Mine Waste Technology Program (MWTP) and the U.S. Department of Energy's (DOE) National Energy Technology Laboratory. Ms. Diana Bless is EPA's MWTP Project Officer, while Mr. Gene Ashby is DOE's Technical Program Officer. Ms. Helen Joyce is MSE's MWTP Program Manager.

Executive Summary

The Mine Waste Technology Program (MWTP) Activity III, Project 29, Remediation Technology Evaluation Project was a collaboration between the U.S. Environmental Protection Agency (EPA) Office of Research and Development and EPA Region VIII. The Remediation Technology Evaluation Project consisted of evaluating three emerging acidic waste rock stabilization technologies and comparing those technologies to the presumptive remedy (PR) of lime treatment. The objective of EPA Region VIII was to conduct a treatability study as part of the remedial investigation/feasibility study process for the Gilt Edge Mine near Lead, South Dakota, providing data to help in the decision-making process supporting the Record of Decision for the site. The objective of the MWTP was to evaluate promising new technologies for preventing the oxidation of sulfide waste rock, which may be applicable to a large number of mine waste sites.

The three new technologies tested were the Silica Micro Encapsulation (SME) Technology from Klean Earth Environmental Company (KEECO), the Passivation Technology from the University of Nevada-Reno (UNR), and the Envirobond Technology from Metals Treatment Technologies (MT^2). Performance of the technologies was evaluated as a pilot-scale demonstration by placing treated waste rock into isolated cells at the Gilt Edge Mine and monitoring the leachate collected from the representative cells. The leachate was monitored from the spring of 2001 to the fall of 2002. The objective of the treatments was to reduce the contaminants of concern by at least 90% or to South Dakota water discharge limits.

The three technology vendors also provided a cost estimate to treat a hypothetical 500,000-cubic yard (yd^3) waste rock pile at the Gilt Edge Mine using the pilot-scale data as a guideline.

By evaluating the leachate parameters of pH, total dissolved solids (TDS), dissolved arsenic, aluminum, iron, zinc, and sulfate, it was possible to ascertain if the technologies were able to achieve a 90% reduction or the South Dakota discharge limits. Table ES-1 summarizes the results.

Table ES-1. Technology Performance Summary

Technology	Achieve 90% reduction?			Achieve SD Discharge Limits?				Cost to treat 500,000 yd^3 of Waste Rock	Comments
	Al	Fe	Sulfate	pH	TDS	As	Zn		
PR	Yes	Yes	Yes	No	Yes	Yes	Yes	$4,774,438	Effective, but pH was elevated above 8.8 and will fail once lime is exhausted
MT^2	Yes	Yes	No	Yes	No	No	Yes	$4,034,750	Actually increased TDS, sulfate, and arsenic concentrations
UNR	Yes	Yes	No	Yes	Yes	Yes	Yes	$3,241,408	Effective and has longer life than lime treatment
KEECO	No	Yes	No	No	No	No	No	$12,682,998	Expensive and failed during second field season

By looking at the summary, it is evident that for this technology demonstration the UNR and PR technologies were able to achieve seven of the eight objectives. However, the PR of lime treatment will be exhausted over time because the lime is soluble and will eventually dissolve.

The KEECO and MT^2 technologies may be able to produce favorable results by making dosage adjustments and/or using different treatments; however, additional treatment past the second field season was beyond the scope of this technology demonstration. To confirm if the modified KEECO and MT^2 treatments would be effective, another technology demonstration would need to be performed.

1. Introduction

This document is the final report for the Mine Waste Technology Program (MWTP), Activity III, Project 29, *Remediation Technology Evaluation (Gilt Edge Mine)*. This project was funded by the U.S. Environmental Protection Agency (EPA) and jointly administered by the EPA and the U.S. Department of Energy (DOE) through an Interagency Agreement. This project was selected from several potential projects presented by MSE Technology Applications, Inc. (MSE), private industry, various government entities, and EPA regional offices to the Technical Integration Committee for the MWTP in April 2000.

This project was a collaboration between EPA Region VIII and the MWTP. EPA Region VIII's project objective was to conduct a treatability study (Ref. 1) as part of the remedial investigation/ feasibility study process for the Gilt Edge Mine near Lead, South Dakota, to provide data to help in the decision-making process supporting the Record of Decision (ROD) for the site. The objective of the MWTP was to evaluate promising new technologies for preventing the oxidation of sulfide waste rock, which may be applicable to a large number of mine waste sites. The new technologies were compared to the presumptive remedy of lime treatment as well as to controls in which no treatment was performed. The technical and economic information from the technology evaluation are summarized in this final report, which represents the end product of the project.

1.1 Project Description

The Remediation Technology Evaluation project was conducted at the Gilt Edge Mine, which is a 270-acre open-pit cyanide heap leach gold mine located approximately 5 miles southeast of Lead, South Dakota. The immediate area was the site of sporadic mining activity for over 100 years. The Gilt Edge Mine was operated by Brohm Mining Corporation, a wholly owned subsidiary of Dakota Mining Cooperation from February 1986 until July 1999. Brohm's activities included developing several open pits, crushing and placing of the ore on a heap leach pad for gold leaching by cyanidation, and conducting Merrill-Crowe gold recovery in an on-site mill. In July 1999, the Dakota Mining Corporation declared bankruptcy, resulting in the Gilt Edge site being returned to the State of South Dakota for management. After incurring significant costs for water treatment to ensure no discharge of acidic mine water to the environment occurred, the State of South Dakota requested that EPA Region VIII take over the site and list it on the National Priorities List as a Superfund site. As a result, the Gilt Edge Mine is now a Superfund site and is managed by CDM Federal Inc. (CDM) under contract to EPA Region VIII. The collaboration between the MWTP and EPA Region VIII presented an opportunity to evaluate emerging acid rock drainage (ARD) treatment technologies while gathering data leading to an ROD for the site. As the MWTP administrator, MSE managed the project for the EPA National Risk Management Research Laboratory. As EPA Region VIII's Remedial Action contractor, CDM managed the project for EPA Region VIII.

MSE's responsibilities for the project included:

- providing technology vendor subcontracts;
- supporting test cell loading and treatment;
- sampling the test cells with and without CDM personnel being present;
- providing health and safety oversight;
- supporting data evaluation; and
- writing a final report.

CDM's responsibilities as EPA Region VIII's remedial action contractor included:

- writing a sampling and analysis plan (SAP) that included a quality assurance/quality control (QA/QC) plan;
- constructing and loading the test cells;
- monitoring the test cells;
- sampling the test cells with and without MSE personnel being present;

– analyzing all samples;
– collecting and validating all the monitoring data;
– provide data evaluation and interpretation; and
– writing an interim status report after the first year of operation.

1.2 Technology Descriptions

The companies that provided new emerging ARD waste stabilization technologies to be evaluated for this project were:

- Klean Earth Environmental Company (KEECO)
- Metals Treatment Technologies (MT^2)
- Mackay School of Mines, University of Nevada-Reno (UNR)

KEECO has developed a technology for the treatment and prevention of metals-contaminated waters, soils, and possibly sulfidic waste rock called silica microencapsulation (SME). This technology encapsulates metals in an impervious microscopic silica matrix, which essentially locks them up in very small sand-like particles and prevents the metals from leaching and migrating.

MT^2 developed an ARD waste stabilization technology called Envirobond that stabilizes sulfidic waste rock using phosphate stabilization chemistry. This technology has been applied at mining sites, firing ranges, sediment removal sites, and others to produce a solid treatment material meeting EPA's Toxicity Characteristic Leaching Procedure criteria.

UNR provided a technology known as Permanganate Passivation. This process essentially creates an inert layer on the sulfide phase that prevents contact with atmospheric oxygen during weathering of the sulfide rock, thus preventing sulfuric acid generation.

Each treatment technology was compared to the presumptive remedy (PR), which was adding lime (CaO) to the sulfidic waste rock. Lime addition buffers the ARD produced by the sulfidic waste rock and ties up the sulfate as gypsum, which prevents the further production of acid and leaching of metals. However, the disadvantage of lime is that it is soluble and will be dissolved and leached from the waste rock over time whether or not acid is produced.

The advantage of the Permanganate Passivation, SME, and Envirobond technologies is that they all treat the ARD-producing waste rock by sulfide or metals stabilization, which requires only one treatment and should last indefinitely.

2. Technology Evaluation

2.1 Technology Evaluation Process

The technology evaluation process involved loading waste rock from the Gilt Edge site into cells built on the mine property, treating the waste rock, and then testing leachate infiltrating through the waste rock in the cells. A total of 12 cells were constructed and loaded during September and October 2000. Each cell was 40 feet (ft) long, 10 ft wide, and 5 ft high at the front and 20 ft high at the back; constructed of wood framing and plywood sheeting; and lined with a polyvinyl chloride (PVC) liner (see Figure 2-1). A leachate collection system consisting of screened PVC covered with sand was installed in the bottom of each cell to facilitate sampling of ambient water infiltrating through the waste rock. Only ambient water was used for this demonstration. KEECO, UNR, and MT^2 were each assigned two cells to treat, while the PR and control cells each had three cells. The cells were loaded in a series of 1-ft-thick lifts for a total of 125 cubic yards (yd^3) of waste rock. After each lift was placed, the technology provider would treat the waste rock of their assigned cell. Table 2-1 is a plan view of the project test cells.

Effluent from the leachate collection system was collected and sampled on a regular basis for metals, total dissolved solids (TDS), pH, and several other parameters (see Appendices A and B). The cells were monitored from March 2001 to October 2002 with the cells not being sampled during the winter months due to the cells being frozen. Additionally, not all cells were sampled every sampling event because of the lack of effluent in the leachate collection system at certain times.

According to the project SAP (Ref. 1), the primary objective of the project was to ascertain if the treatment technologies could:

- reduce the contaminants of concern by 90% when compared to the control cells; or
- reduce the contaminants of concern to or below the South Dakota Applicable Water Quality Criteria (SD AWQC).

Many different parameters were analyzed for and used to evaluate the treatment performances. However, to illustrate the performance of the treatment technologies for this report, values of dissolved arsenic, dissolved zinc, TDS, and pH from the treatment technologies were compared to the control cells and the SD AWQC over time. Table 2-2 outlines the SD AWQC limits applicable to this report. The SD AWQC limits are presented in Appendix C. In addition, the unregulated parameters of dissolved iron, dissolved aluminum, and sulfate were also compared to the control cells by calculating the percent reduction of contaminants for each sampling event. The percent reduction was calculated for each sampling event by comparing the average of the respective treatment technology's cells against the average of the control cells. A statistical evaluation was conducted for the percent reduction values to determine if the overall mean of each treatment technology was at least 90%. All the values that were flagged with a qualifier in the raw data set (Appendix A) were used as reported. In some cases, samples were not submitted to the laboratory due to the lack of effluent from the cells; therefore, some percent reductions were impossible to calculate.

Figure 2-1. Project test cells 7-12 – view from the North (Gilt Edge Mine).

Table 2-1. Cell Assignment of the Project Test Cells

Cell 1 - KEECO	Cell 7 - PR
Cell 2 - Control	Cell 8 - UNR
Cell 3 - UNR	Cell 9 KEECO
Cell 4 - PR	Cell 10 - Control
Cell 5 – MT^2	Cell 11 – MT^2
Cell 6 - Control	Cell 12 - PR

Table 2-2. SD AWQC for the Gilt Edge Site

Parameter	SD AWQC Discharge Limit
PH	Between 6.5 and 8.8
Dissolved Arsenic	190 micrograms per liter (µg/L) (chronic)
Dissolved Zinc	338 µg/L (chronic)
TDS	2,500 milligrams per liter (mg/L) (30-day average)

3. Waste Rock Results

Multiple waste-rock samples were collected from each cell (two to four samples per cell) while the cells were being filled and analyzed for acid-base accounting (ABA) parameters (Appendix D). Five field duplicates were collected from the waste rock as well. The ABA results show that the acid/base potential (tons calcium carbonate (limestone)/ 1,000 tons of waste rock) ranges from -21 to -130 with an average of -48, and the paste pH of all the waste rock samples ranged from 2.1 to 5.3 with an average of 2.75. Waste rock with an acid/base potential of less than -20 is considered to be acid producing; therefore, the waste rock used for this technology demonstration is considered acid producing.

4. Presumptive Remedy Performance

The waste rock in the PR cells was treated with CaO. Prior to loading the waste rock in the cells, it was piled and mixed with CaO by a front-end loader according to the dosage rates in Table 4-1. The dosage rates were determine by CDM engineers and were based on the ABA results of the waste rock. Once the waste rock and CaO were mixed, the material was loaded into the cells with an excavator as nine separate, 1-ft-thick lifts for a total of 125 yd^3.

Tables 4-2 to 4-4 illustrate the performance of the PR with dissolved aluminum, dissolved iron, and sulfate. When compared to the control cells, the PR did achieve at least a 90% reduction for dissolved aluminum and iron for all the sampling events. The mean percent reduction for dissolved aluminum and iron was 99.96% and 100.00% respectively. The PR did achieve at least a 90% sulfate reduction for all the sampling events except the April 25, 2001, event, which was 74.14%. The mean percent reduction for sulfate was 95.32%.

Figures 4-1 to 4-4 compare the PR values of pH, TDS, dissolved arsenic, and dissolved zinc to the control cells and the SD AWQC over time. Figure 4-1 shows the PR pH ranged from 3.40 to 12.74 and the control cells ranged from 1.81 to 6.65. This shows the PR did generally increase the pH; however, the pH was above the upper discharge limit of 8.8 for most cases. This may be due to an overdose of the CaO.

Figures 4-2 to 4-4 show that the PR did achieve a reduction for TDS, dissolved arsenic, and dissolved zinc to below the discharge limits of 2,500 mg/L, 190 μg/L, and 338 μg/L respectively for the whole duration of the demonstration.

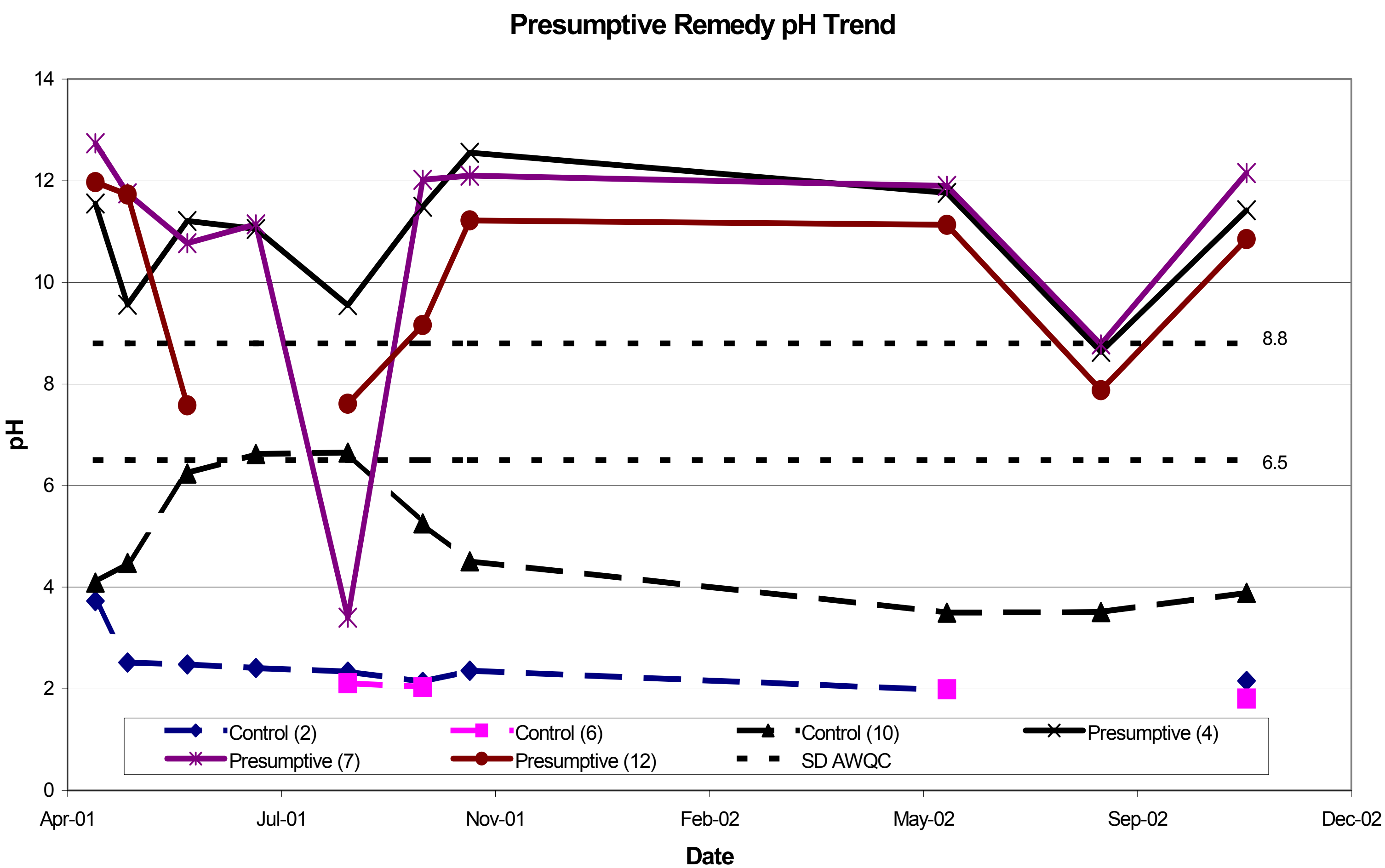

Figure 4-1. PR pH trend.

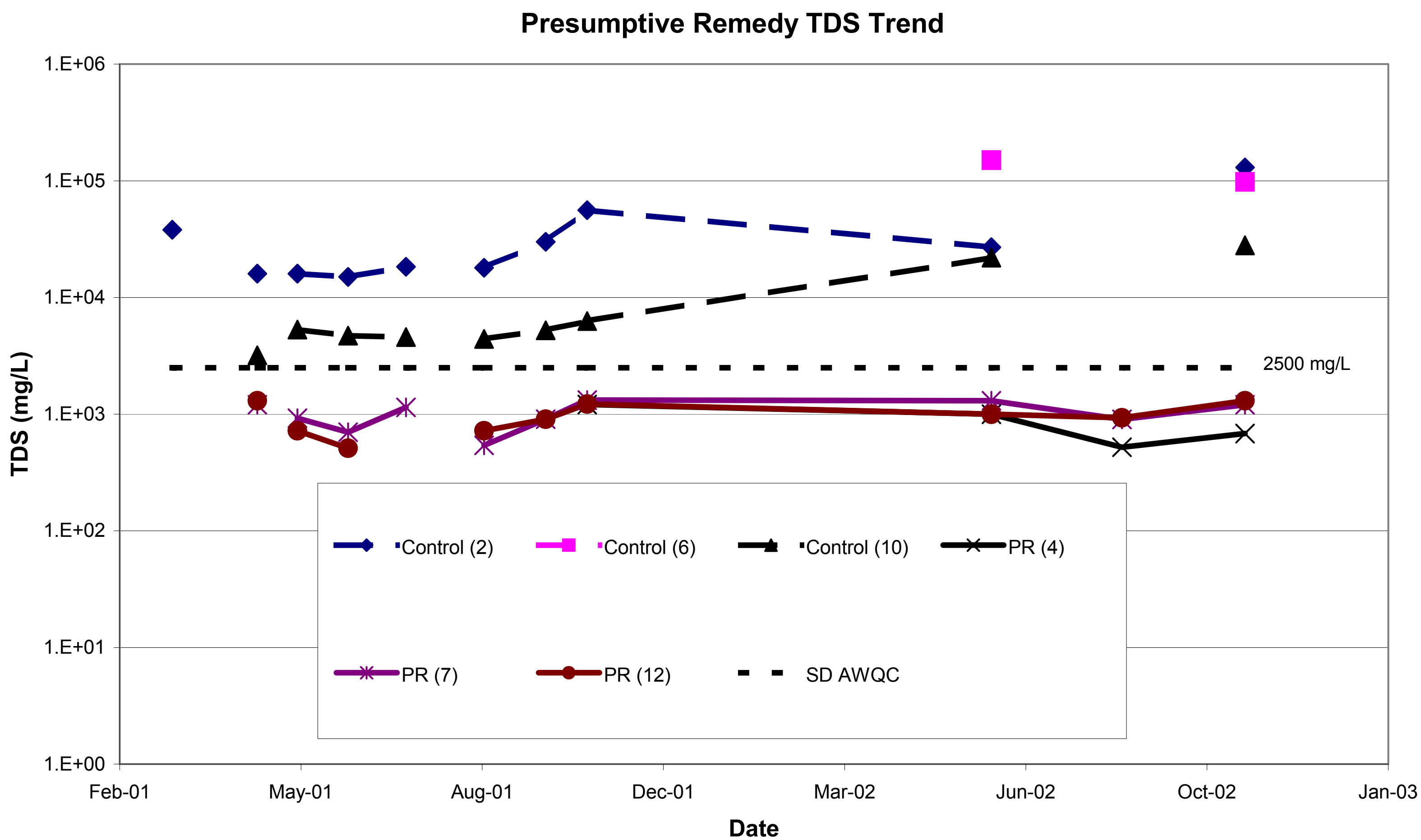

Figure 4-2. PR TDS trend.

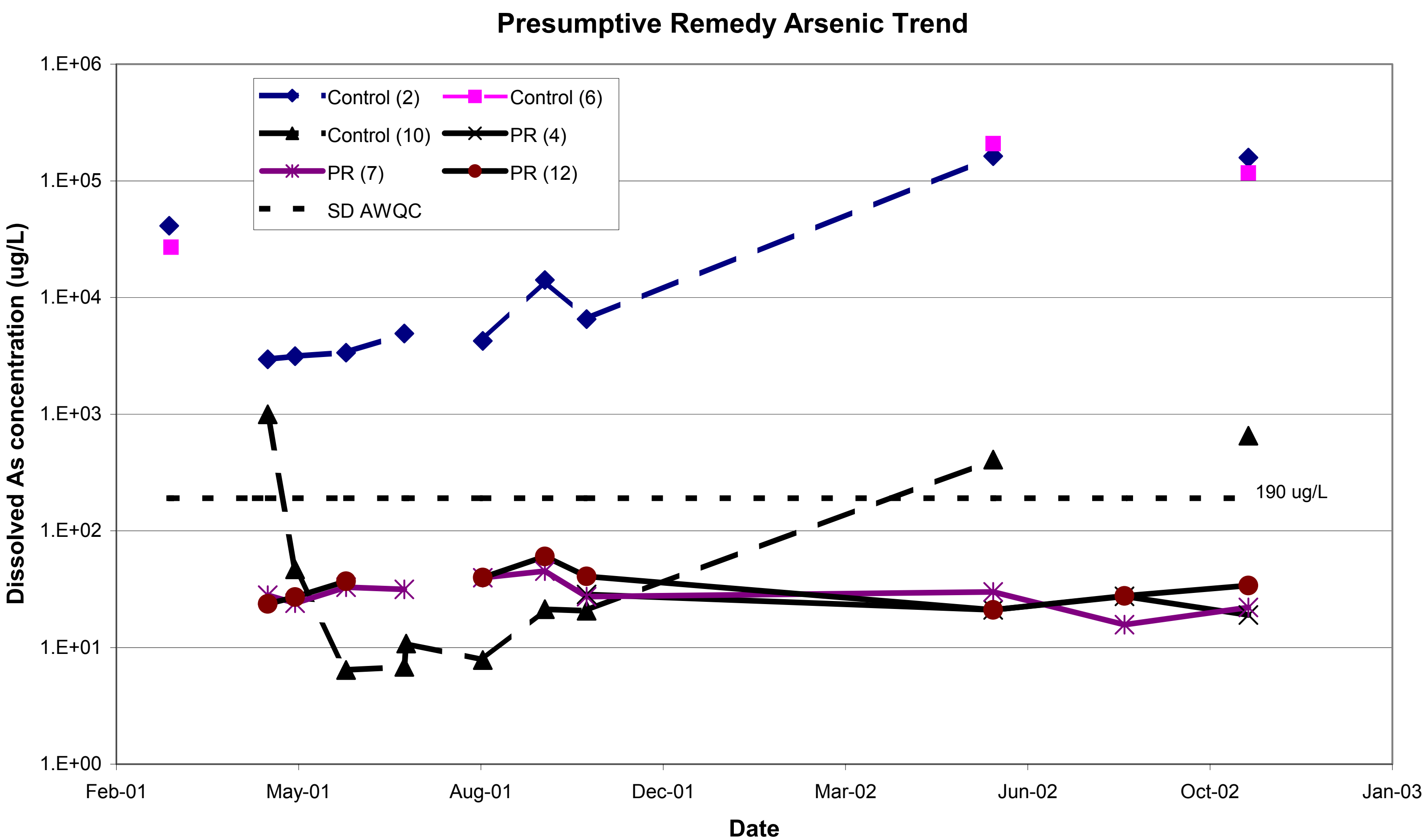

Figure 4-3. PR arsenic trend.

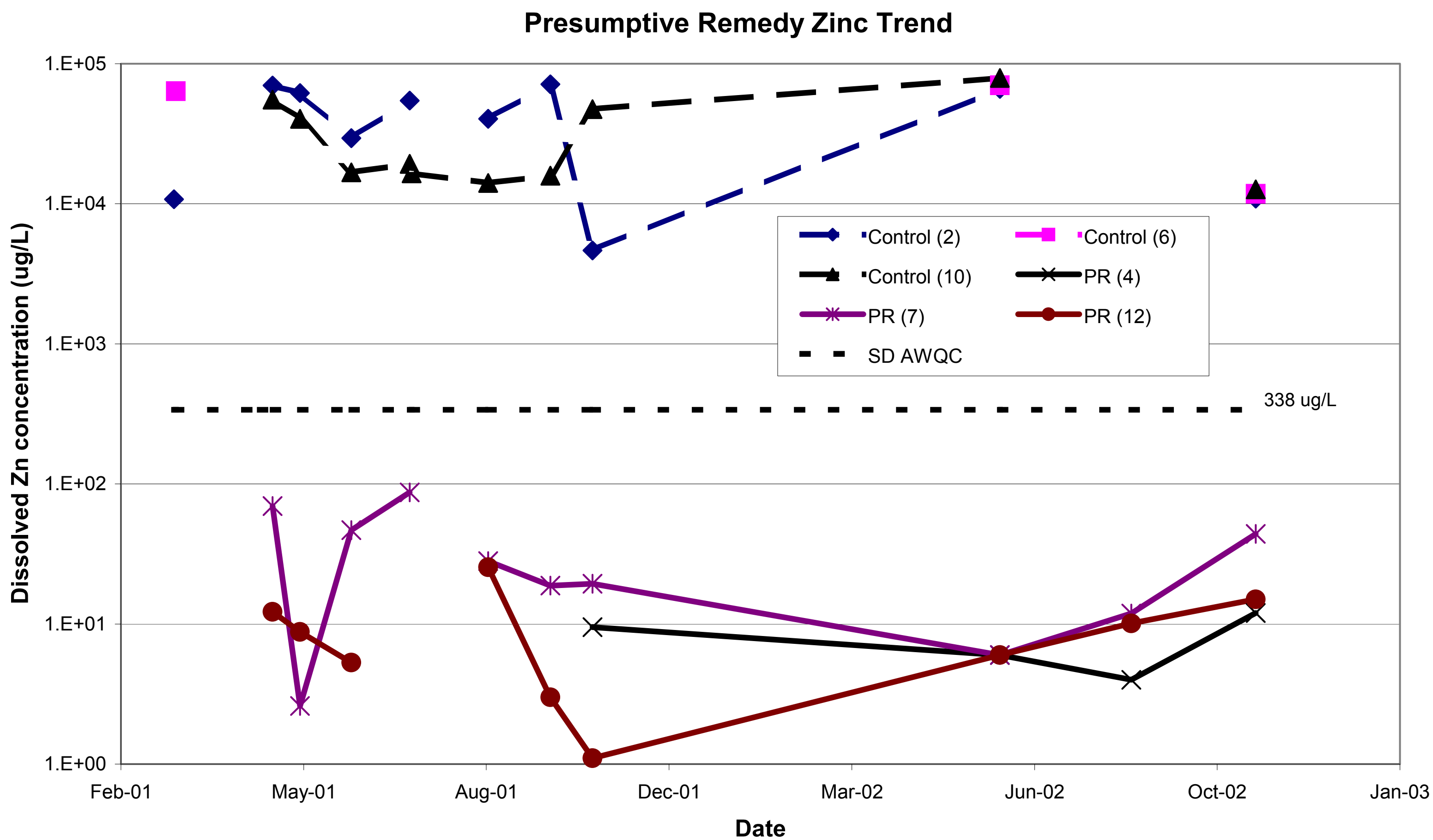

Figure 4-4. PR zinc trend.

Table 4-1. PR Dosage Rates

	Cell 4	Cell 7	Cell 12
Waste rock (yd^3)	125	125	125
CaO (lb)	7,050	6,700	7,000
CaO (lb) per ton of waste rock based on a waste rock bulk density of 1.5 tons/yd^3	37.6	35.7	37.3

Table 4-2. PR Aluminum Percent Reduction

Presumptive Remedy Percent Reduction of Dissolved Al (µg/L)											
Date	**Control (2)**	**Control (6)**	**Control (10)**	**Control Average**	**PR (4)**	**PR (7)**	**PR (12)**	**PR Average**	**PR % reduction**	**Statistical Evaluation of PR % reduction**	
03/09/01	162,000	NS	NS	162,000	NS	NS	NS	NC	NC	Mean	99.96%
03/10/01	NS	891,000	NS	891,000	NS	NS	NS	NC	NC	Standard Error	0.02%
04/25/01	NS	NS	NS	NC	NS	NS	NS	NC	NC	Median	99.99%
05/02/01	750,000	NS	698,000	724,000	NS	53	69	61	99.99%	Standard Deviation	0.06%
05/17/01	753,000	NS	189,000	471,000	NS	53	53	53	99.99%	Sample Variance	0.00%
06/14/01	386,000	NS	37,800	211,900	NS	31	14	22	99.99%	Range	0.20%
07/16/01	480,000	NS	18,600	249,300	NS	212	NS	212	99.91%	Minimum	99.80%
07/17/01	NS	NS	36,300	36,300	NS	NS	NS	NC	NC	Maximum	99.99%
08/28/01	396,000	NS	1,090	198,545	NS	756	46	401	99.80%		
10/01/01	1,070,000	NS	57,100	563,550	NS	116	11	64	99.99%		
10/24/01	322,000	NS	138,000	230,000	71	55	55	60	99.97%		
06/04/02	3,120,000	3,170,000	2,100,000	2,796,667	139	586	540	422	99.98%		
08/15/02	NS	NS	NS	NC	263	356	252	290	NC		
10/22/02	2,950,000	1,870,000	338,000	1,719,333	115	161	42	106	99.99%		

NS – Sampled not submitted to laboratory due to lack of effluent
NC – Percent not calculated due to lack of data

Table 4-3. PR Iron Percent Reduction

Presumptive Remedy Percent Reduction of Dissolved Fe (µg/L)											
Date	Control (2)	Control (6)	Control (10)	Control Average	PR (4)	PR (7)	PR (12)	PR Average	PR % reduction	Statistical Evaluation of PR % reduction	
03/09/01	644,000	NS	NS	644,000	NS	NS	NS	NC	NC	Mean	100.00%
03/10/01	NS	554,000	NS	554,000	NS	NS	NS	NC	NC	Standard Error	0.00%
04/25/01	NS	NS	NS	NC	NS	NS	NS	NC	NC	Median	100.00%
05/02/01	1,150,000	NS	488,000	819,000	NS	17	27	22	100.00%	Standard Deviation	0.00%
05/17/01	1,280,000	NS	8,860	644,430	NS	17	20	18	100.00%	Sample Variance	0.00%
06/14/01	1,250,000	NS	2,550	626,275	NS	26	19	23	100.00%	Range	0.01%
07/16/01	2,130,000	NS	6,600	1,068,300	NS	131	NS	131	99.99%	Minimum	99.99%
07/17/01	NS	NS	4,320	4,320	NS	NS	NS	NC	NC	Maximum	100.00%
08/28/01	1,070,000	NS	219	535,110	NS	102	35	68	99.99%		
10/01/01	5,680,000	NS	5,040	2,842,520	NS	8	8	8	100.00%		
10/24/01	9,910,000	NS	12,800	4,961,400	23	23	23	23	100.00%		
06/04/02	28,300,000	35,300,000	14,700	21,204,900	145	901	145	397	100.00%		
08/15/02	NS	NS	NS	NC	86	19	19	41	NC		
10/22/02	29,400,000	21,400,000	53,300	16,951,100	113	49	22	61	100.00%		

NS – Sampled not submitted to laboratory due to lack of effluent
NC – Not calculated due to lack of data

Table 4-4. PR Sulfate Percent Reduction

Presumptive Remedy Percent Reduction of SO_4 (mg/L)											
Date	Control (2)	Control (6)	Control (10)	Control Average	PR (4)	PR (7)	PR (12)	PR Average	PR % reduction	Statistical Evaluation of % reduction	
03/09/01	27,100	NS	NS	27,100	NS	NS	321	321	98.82%	Mean	95.32%
03/10/01	NS	NS	NS	NC	NS	NS	NS	NC	NC	Standard Error	2.37%
04/25/01	12	NS	2,200	1,106	NS	286	NS	286	74.14%	Median	97.41%
05/02/01	NS	NS	NS	NC	NS	NS	NS	NC	NC	Standard Deviation	7.49%
05/17/01	11,700	NS	4,530	8,115	NS	271	238	255	96.86%	Sample Variance	0.56%
06/14/01	12,300	NS	3,490	7,895	NS	173	234	204	97.42%	Range	25.37%
07/16/01	16,590	NS	3,618	10,104	NS	221	NS	221	97.81%	Minimum	74.14%
07/17/01	NS	NS	NS	NC	NS	NS	NS	NC	NC	Maximum	99.52%
08/28/01	14,000	NS	3,200	8,600	NS	210	390	300	96.51%		
10/01/01	22,600	NS	3,850	13,225	NS	208	530	369	97.21%		
10/24/01	38,000	NS	4,500	21,250	540	360	710	537	97.47%		
06/04/02	91,000	110,000	17,000	72,667	210	350	490	350	99.52%		
08/15/02	NS	NS	NS	NC	190	330	560	360	NC		
10/22/02	77,000	66,000	19,000	54,000	280	430	3,500	1,403	97.40%		

NS – Sampled not submitted to lab due to lack of effluent
NC – Not calculated due to lack of data

5. MT^2 Envirobond Technology Performance

MT^2 treated each lift of waste rock by spraying a solution onto the waste rock that covered the surface area of each lift. The solution was mixed in a tank by recirculation. Table 5-1 shows the dosage rates for the MT^2 Envirobond treatment.

Tables 5-2 to 5-4 illustrate the percent reduction by the Envirobond treatment for dissolved aluminum, dissolved iron, and sulfate. The Envirobond treatment did achieve a 90% reduction or greater for aluminum and iron for the duration of the demonstration. The percent reduction mean was 99.98% and 99.99% for aluminum and iron respectively.

The Envirobond treatment did not achieve at least a 90% reduction for sulfate. The Envirobond sulfate values ranged from -2,313.89% to 88.37%, and the Envirobond treatment did not show a positive sulfate reduction until October 24, 2002. The negative percent reduction indicates an actual increase of sulfate when compared to the control cells, which may be due to an acceleration of sulfide oxidation from the hydrogen peroxide. The overall sulfate reduction mean was -275.04%.

Figure 5-1 shows the pH trend from the Envirobond treatment. The Envirobond treatment did increase the pH to within the discharge limits of the 6.5 and 8.8.

Figure 5-2 shows the TDS trend actually increased when compared to the control cells for the 2001 field season, and during the 2002 field season; the TDS declined but still did not make the discharge limit of 2,500 mg/L. The increase of the TDS values from the Envirobond treatment is due to the fact that the treatment increased concentrations of sulfate, potassium, and arsenic during the demonstration. This may be an initial affect that will change over time; however, it was not evident during this demonstration.

Figure 5-3 shows a similar trend for arsenic. The Envirobond treatment effluent had higher concentrations of arsenic during the 2001 field season when compared to the control cells and then decreased during the 2002 field season. The arsenic trend for the Envirobond treatment did not achieve the discharge limit of 190 µg/L during the demonstration. The arsenic increase from the Envirobond treatment may be caused from the liberation of arsenic that was originally tied with the iron in the waste rock.

Figure 5-4 illustrates the zinc trend for the Envirobond treatment, which was successful in meeting the 338 µg/L discharge limit with the exception of the October 1 and March 10, 2001, sampling events.

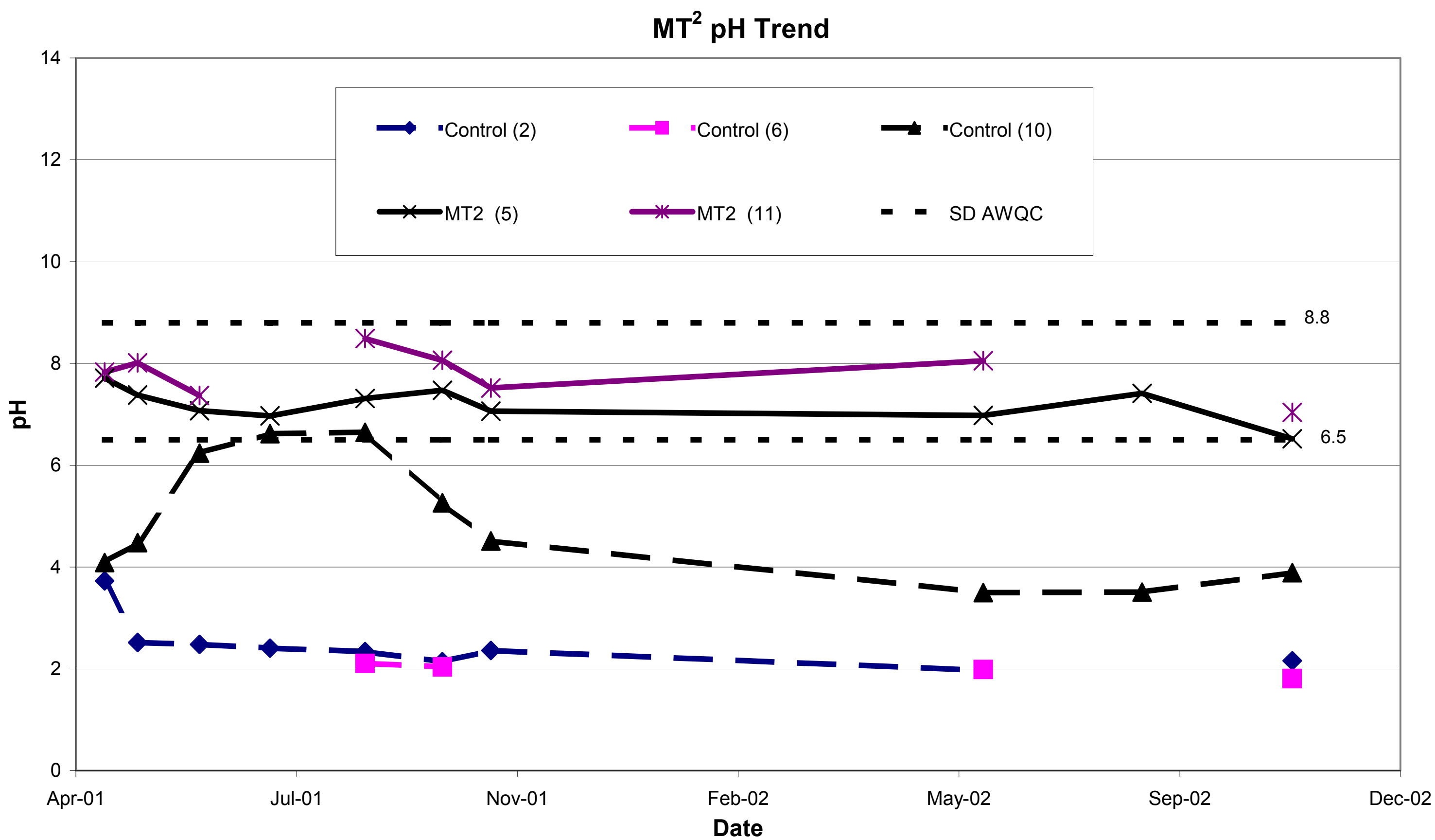

Figure 5-1. MT² pH trend.

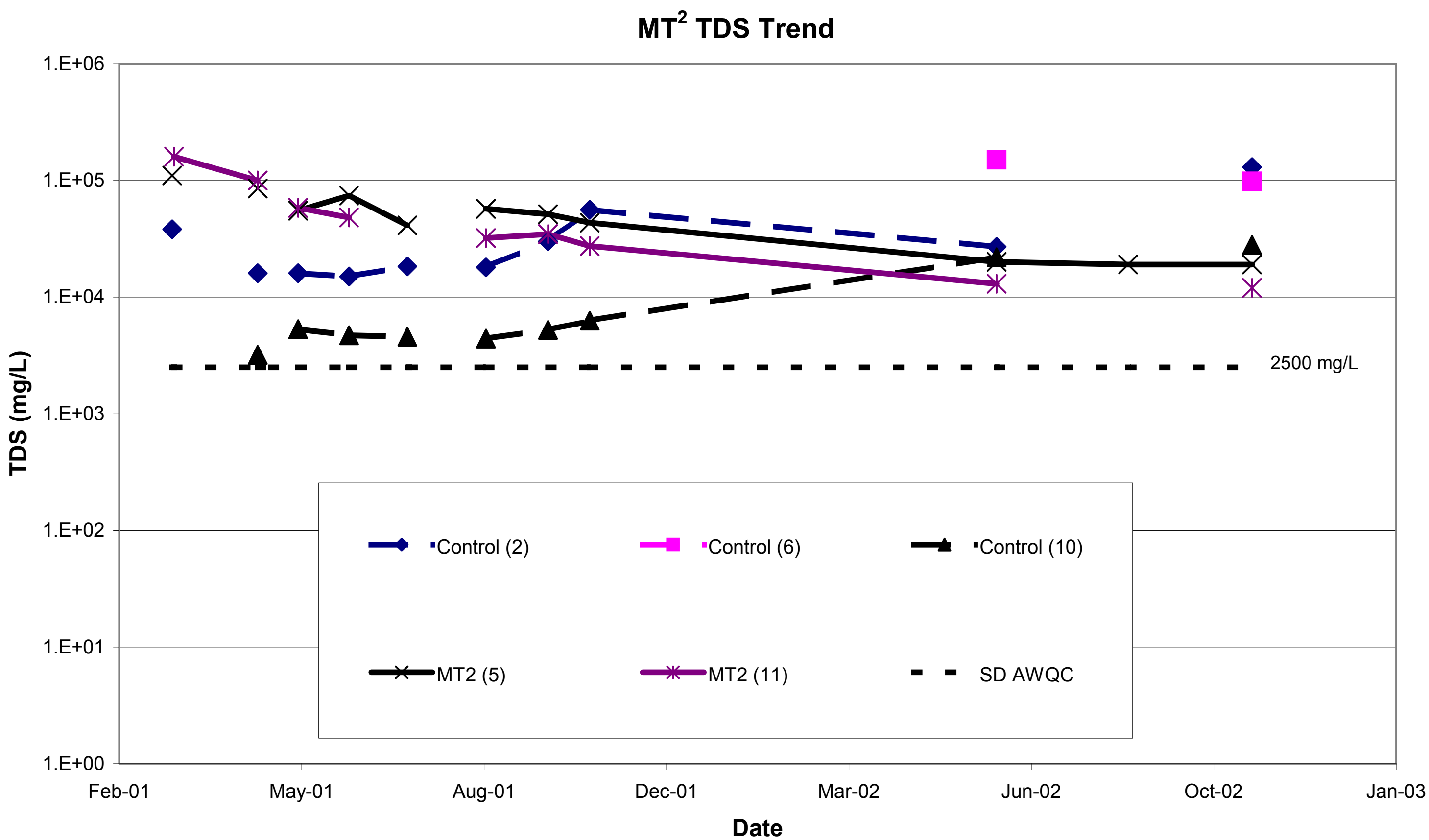

Figure 5-2. MT^2 TDS trend.

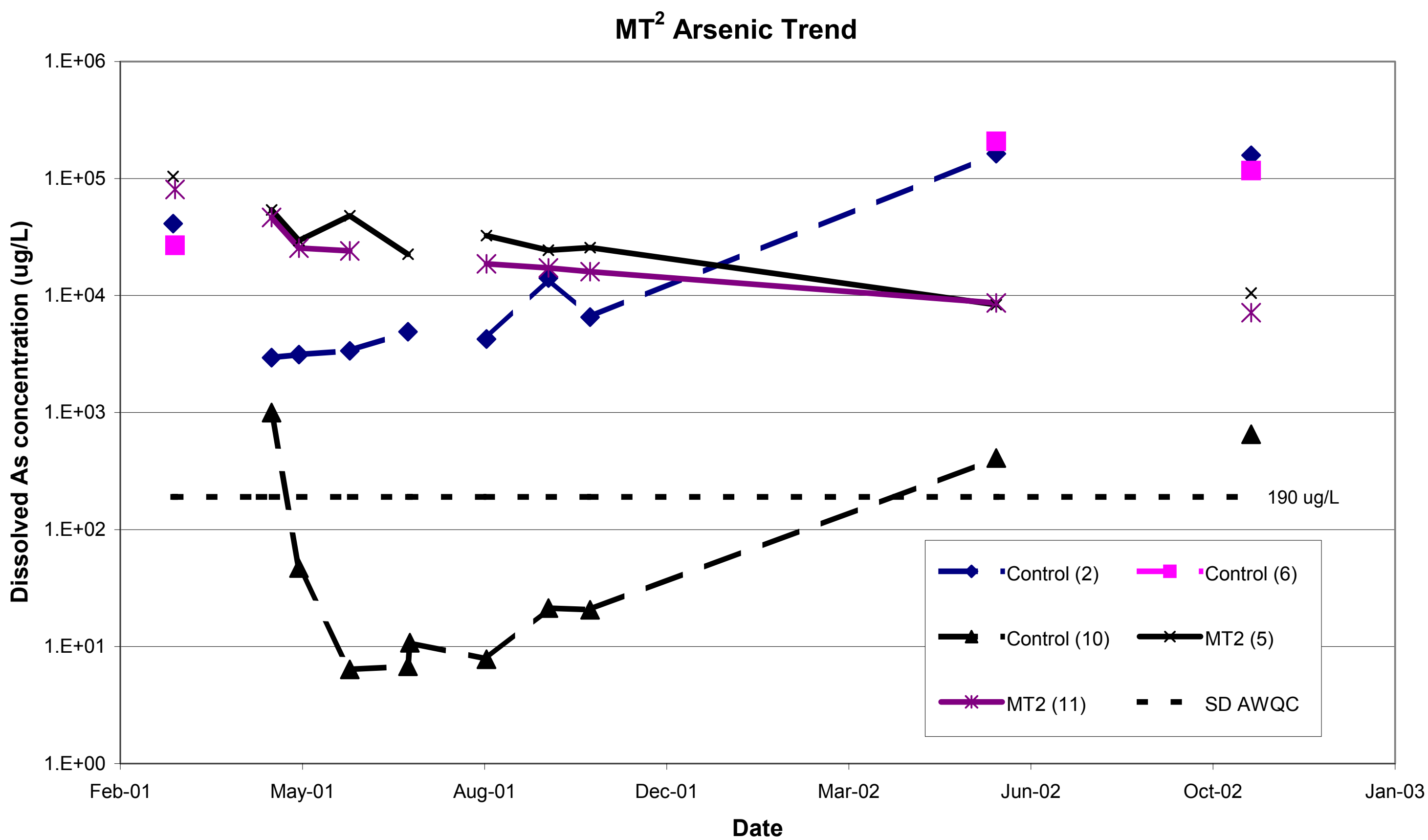

Figure 5-3. MT² arsenic trend.

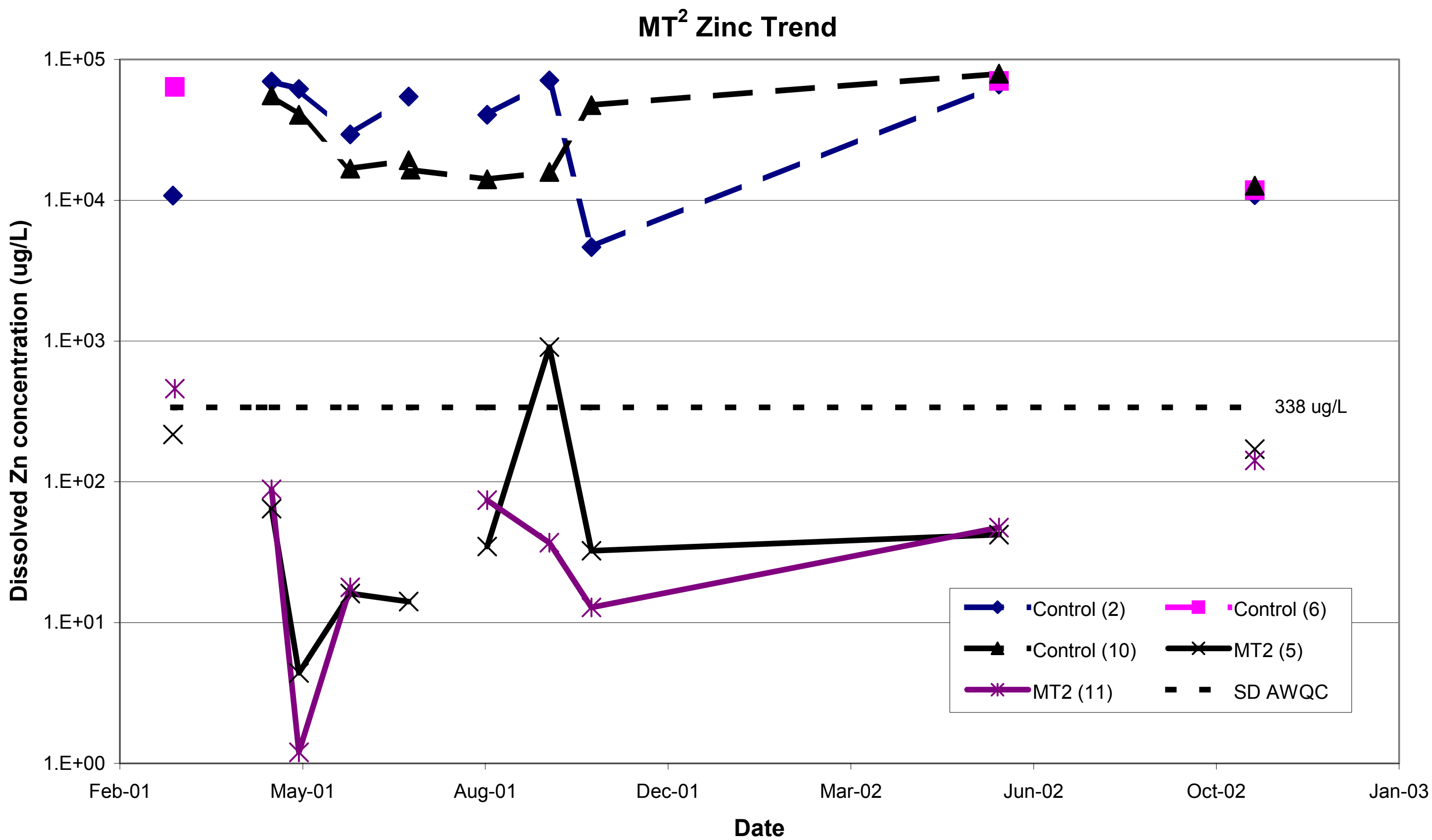

Figure 5-4. MT² zinc trend.

Table 5-1. MT^2 Envirobond Treatment Dosage Rates

Treatment Material	Cell 5	Cell 11	Dosage Rate per Ton of Waste Rock Based on a 1.5 tons/yd^3 Bulk Density
Waste rock	125 yd^3	125 yd^3	
Envirobond material	11,000 lb	11,000 lb	58.7 lb/ton
Hydrogen peroxide (50%)	88 gal	88 gal	0.47 gal/ton
Water	3,731	3,525	19.3 gal/ton (avg)

Table 5.2. MT^2 Aluminum Percent Reduction

MT^2 Percent Reduction of Dissolved Al (µg/L)										
Date	Control (2)	Control (6)	Control (10)	Control Average	MT^2 (5)	MT^2 (11)	MT^2 Average	MT^2 % Reduction	Statistical Evaluation of % reduction	
03/09/01	162,000	NS	NS	162,000	124	NS	124	99.92%	Mean	99.98%
03/10/01	NS	891,000	NS	891,000	NS	766	766	99.91%	Standard Error	0.01%
04/25/01	NS	NS	NS	NC	NS	NS	NC	NC	Median	99.99%
05/02/01	750,000	NS	698,000	724,000	100	187	143	99.98%	Standard Deviation	0.03%
05/17/01	753,000	NS	189,000	471,000	53	103	78	99.98%	Sample Variance	0.00%
06/14/01	386,000	NS	37,800	211,900	5	5	5	100.00%	Range	0.08%
07/16/01	480,000	NS	18,600	249,300	7	NS	7	100.00%	Minimum	99.91%
07/17/01	NS	NS	36,300	36,300	NS	NS	NS	NS	Maximum	100.00%
08/28/01	396,000	NS	1,090	198,545	7	7	7	100.00%		
10/01/01	1,070,000	NS	57,100	563,550	11	11	11	100.00%		
10/24/01	322,000	NS	138,000	230,000	55	55	55	99.98%		
06/04/02	3,120,000	3,170,000	2,100,000	2,796,667	139	388	264	99.99%		
08/15/02	NS	NS	NS	NC	NS	NS	NC	NC		
10/22/02	2,950,000	1,870,000	338,000	1,719,333	28	31	30	100.00%		

NS – Sampled not submitted to lab due to lack of effluent
NC – Not calculated due to lack of data

Table 5-3. MT^2 Iron Percent Reduction

MT^2 Percent Reduction of Dissolved Iron (µg/L)										
Date	**Control (2)**	**Control (6)**	**Control (10)**	**Control Average**	**MT^2 (5)**	**MT^2 (11)**	**MT^2 Average**	**MT^2 % Reduction**	**Statistical Evaluation of % reduction**	
03/09/01	644,000	NS	NS	644,000	103	NS	103	99.98%	Mean	99.99%
03/10/01	NS	554,000	NS	554,000	NS	299	299	99.95%	Standard Error	0.00%
04/25/01	NS	NS	NS	NC	NS	NS	NC	NC	Median	100.00%
05/02/01	1,150,000	NS	488,000	819,000	92	118	105	99.99%	Standard Deviation	0.02%
05/17/01	1,280,000	NS	8,860	644,430	54	39	47	99.99%	Sample Variance	0.00%
06/14/01	1,250,000	NS	2,550	626,275	19	19	19	100.00%	Range	0.05%
07/16/01	2,130,000	NS	6,600	1,068,300	22	NS	22	100.00%	Minimum	99.95%
07/17/01	NS	NS	4,320	4,320	NS	NS	NC	NC	Maximum	100.00%
08/28/01	1,070,000	NS	219	535,110	19	62	41	99.99%		
10/01/01	5,680,000	NS	5,040	2,842,520	8	8	8	100.00%		
10/24/01	9,910,000	NS	12,800	4,961,400	23	23	23	100.00%		
06/04/02	28,300,000	35,300,000	14,700	21,204,900	145	145	145	100.00%		
08/15/02	NS	NS	NS	NC	NS	NS	NC	NC		
10/22/02	29,400,000	21,400,000	53,300	16,951,100	18	18	18	100.00%		

NS – Sampled not submitted to lab due to lack of effluent
NC – Not calculated due to lack of data

Table 5-4. MT^2 Sulfate Percent Reduction

MT^2 Percent Reduction of Sulfate (mg/L)										
Date	**Control (2)**	**Control (6)**	**Control (10)**	**Control Average**	**MT^2 (5)**	**MT^2 (11)**	**MT^2 Average**	**MT^2 % Reduction**	**Statistical Evaluation of % reduction**	
03/09/01	27,100	NS	NS	27,100	34,200	NS	34,200	-26.20%	Mean	-275.04%
03/10/01	NS	NS	NS	NC	NS	26,400	26,400	NC	Standard Error	228.75%
04/25/01	12	NS	2,200	1,106	27,300	26,100	26,700	-2313.89%	Median	-63.39%
05/02/01	NS	NS	NS	NC	NS	NS	NC	NC	Standard Deviation	723.36%
05/17/01	11,700	NS	4,530	8,115	NS	19,100	20,550	-153.23%	Sample Variance	5232.56%
06/14/01	12,300	NS	3,490	7,895	35,200	17,000	26,100	-230.59%	Range	2402.26%
07/16/01	16,590	NS	3,618	10,104	18,921	NS	18,921	-87.26%	Minimum	-2313.89%
07/17/01	NS	NS	NS	NC	NS	NS	NC	NC	Maximum	88.37%
08/28/01	14,000	NS	3,200	8,600	22,000	12,000	17,000	-97.67%		
10/01/01	22,600	NS	3,850	13,225	22,300	14,600	18,450	-39.51%		
10/24/01	38,000	NS	4,500	21,250	20,000	12,000	16,000	24.71%		
06/04/02	91,000	110,000	17,000	72,667	11,000	5,900	8,450	88.37%		
08/15/02	NS	NS	NS	NC	180	NS	180	NC		
10/22/02	77,000	66,000	19,000	54,000	11,000	5,300	8,150	84.91%		

NS – Sampled not submitted to lab due to lack of effluent
NC – Not calculated due to lack of data

6. UNR Technology Performance

The UNR Permanganate Passivation technology was applied to the waste rock in two phases. The first phase involved mixing magnesium oxide and CaO with the waste rock with a front-end loader. During the second phase, a mixture of water, caustic soda, and potassium permanganate was sprayed on the waste rock after each lift was loaded into the cells.

Table 6-1 shows the dosage rates used by UNR.

Tables 6-1 and 6-2 show the aluminum and iron trends for UNR's Permanganate Passivation treatment technology. Both the aluminum and iron trends achieved at least a 90% reduction when compared to the control cells. The aluminum and iron reduction means were 99.97% and 99.99% respectively.

Table 6-3 shows that the sulfate trend for the Permanganate Passivation technology did not achieve 90% reduction with the exception of the October 24, 2001, and October 22, 2002, sampling events. The mean sulfate reduction was 73.43% when compared to the control cells.

Figures 6-1 to 6-4 illustrate the UNR Permanganate Passivation trends for pH, TDS, dissolved aluminum, and dissolved iron. The UNR Permanganate Passivation pH trend ranges from 3.81 to 10.05 and shows a general increase of pH when compared to the control cells with 9 of 14 sample values within the discharge limits of 6.5 and 8.8.

Figure 6-2 shows a general decrease in the TDS concentration when compared to the control cells and trends very close to the discharge limit of 2,500 mg/L.

The arsenic trend (Figure 6-3) shows that with the exception of the August 15, 2002, sampling event, the Permanganate Passivation technology did reduce the arsenic concentrations to below the discharge limit of 190 µg/L.

The Permanganate Passivation technology was successful in reducing the zinc concentration (Figure 6-4) to below the discharge limit of 338 µg/L for the duration of the demonstration.

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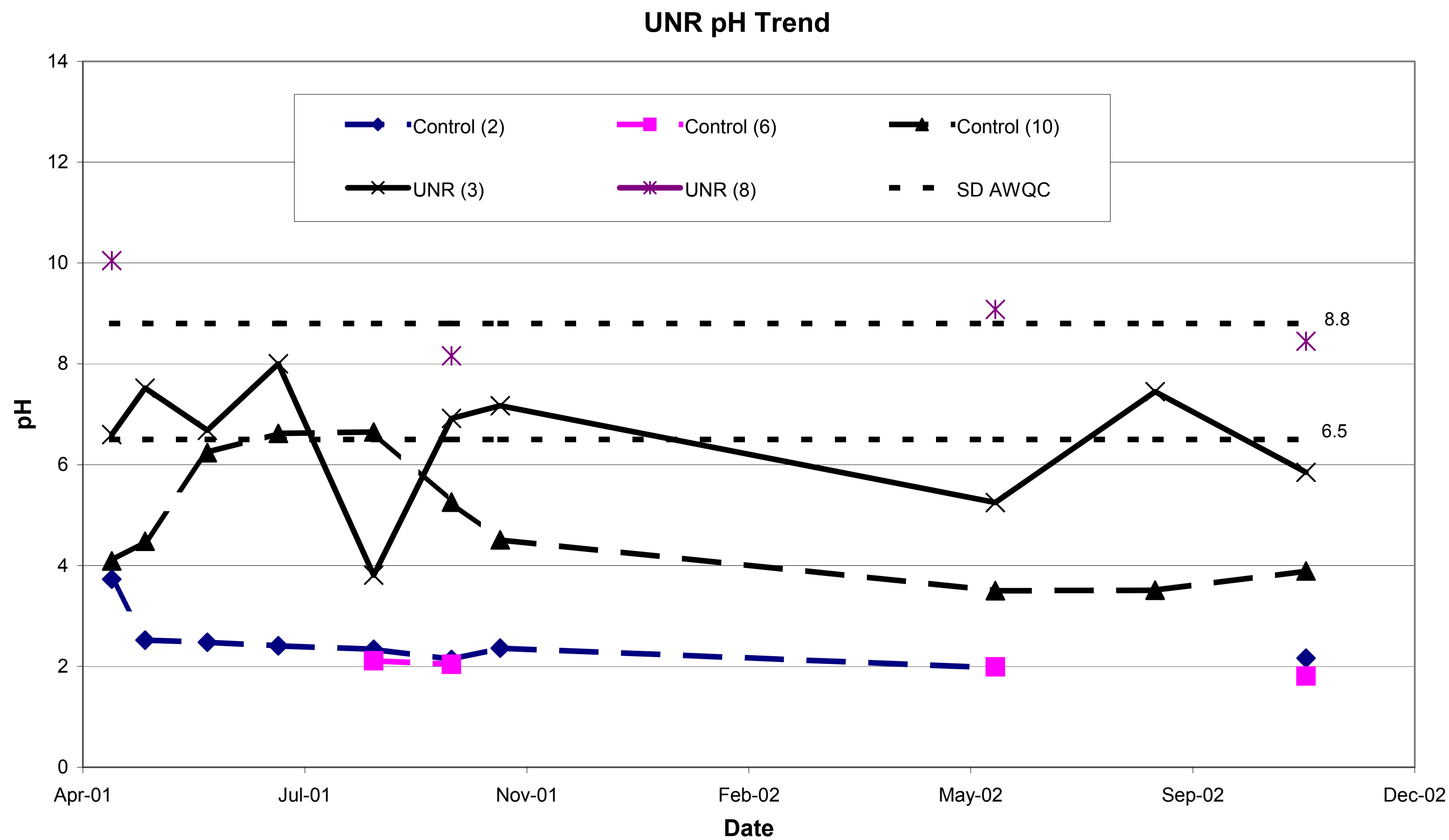

Figure 6-1. UNR pH trend.

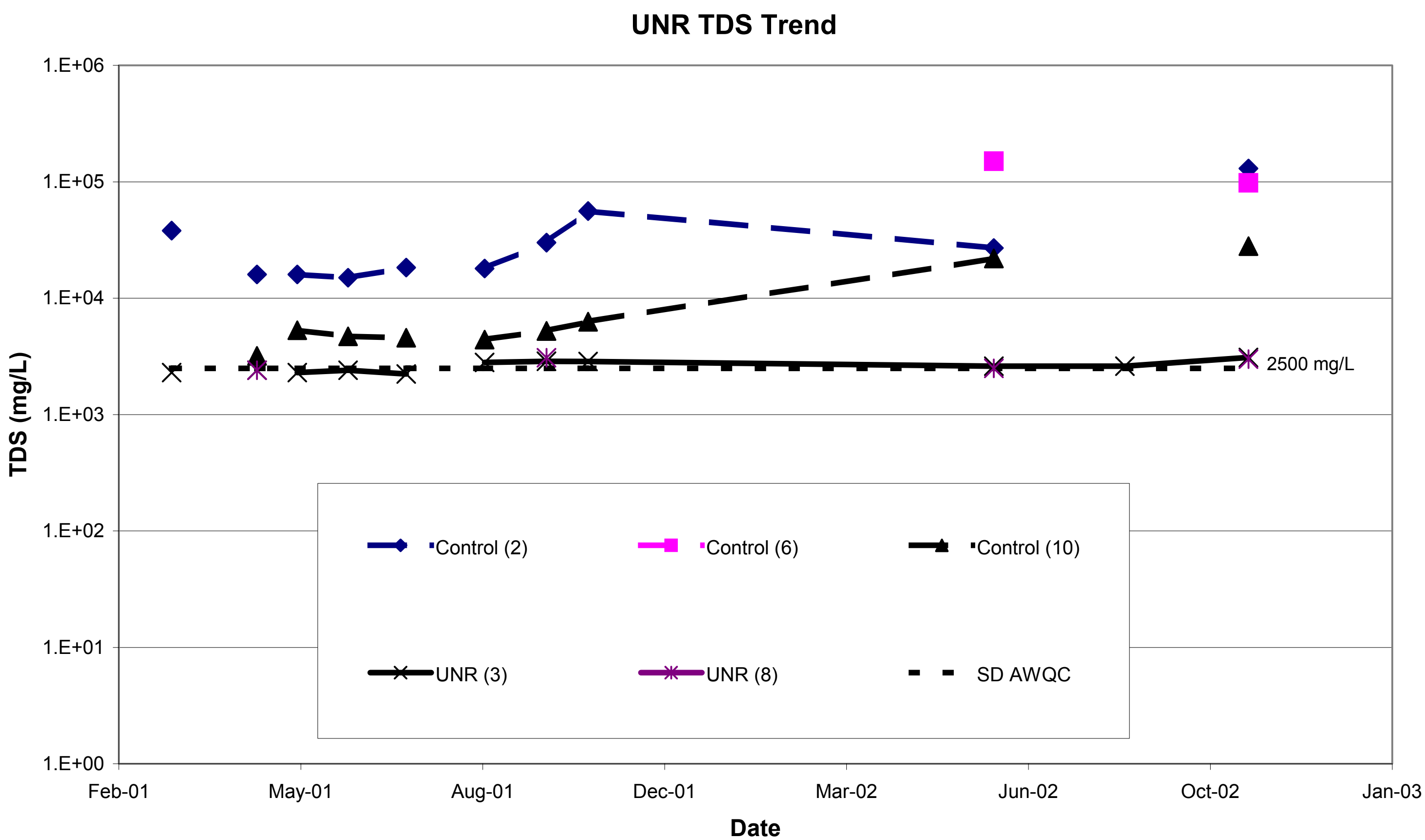

Figure 6-2. UNR TDS trend

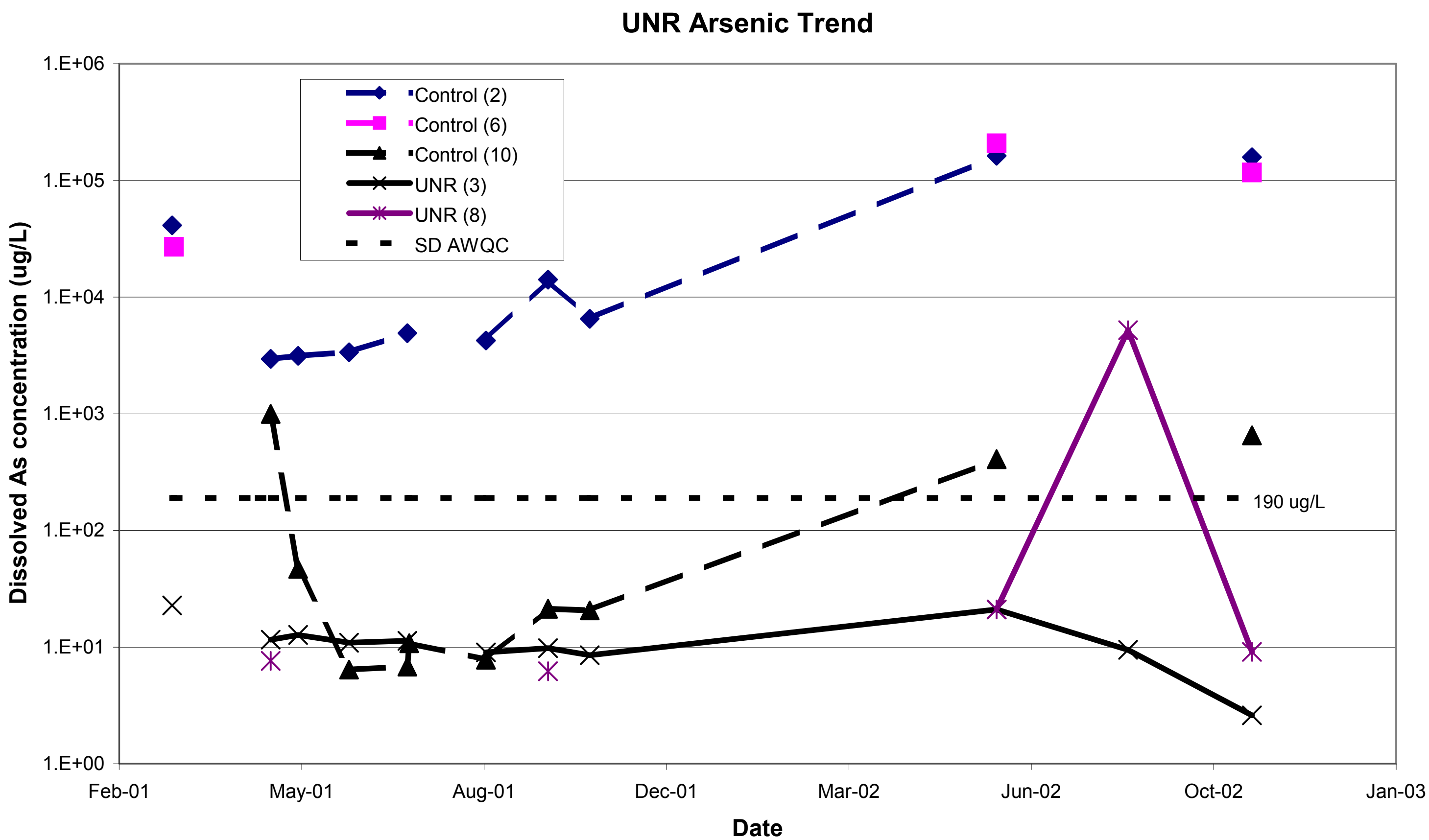

Figure 6-3. UNR arsenic trend.

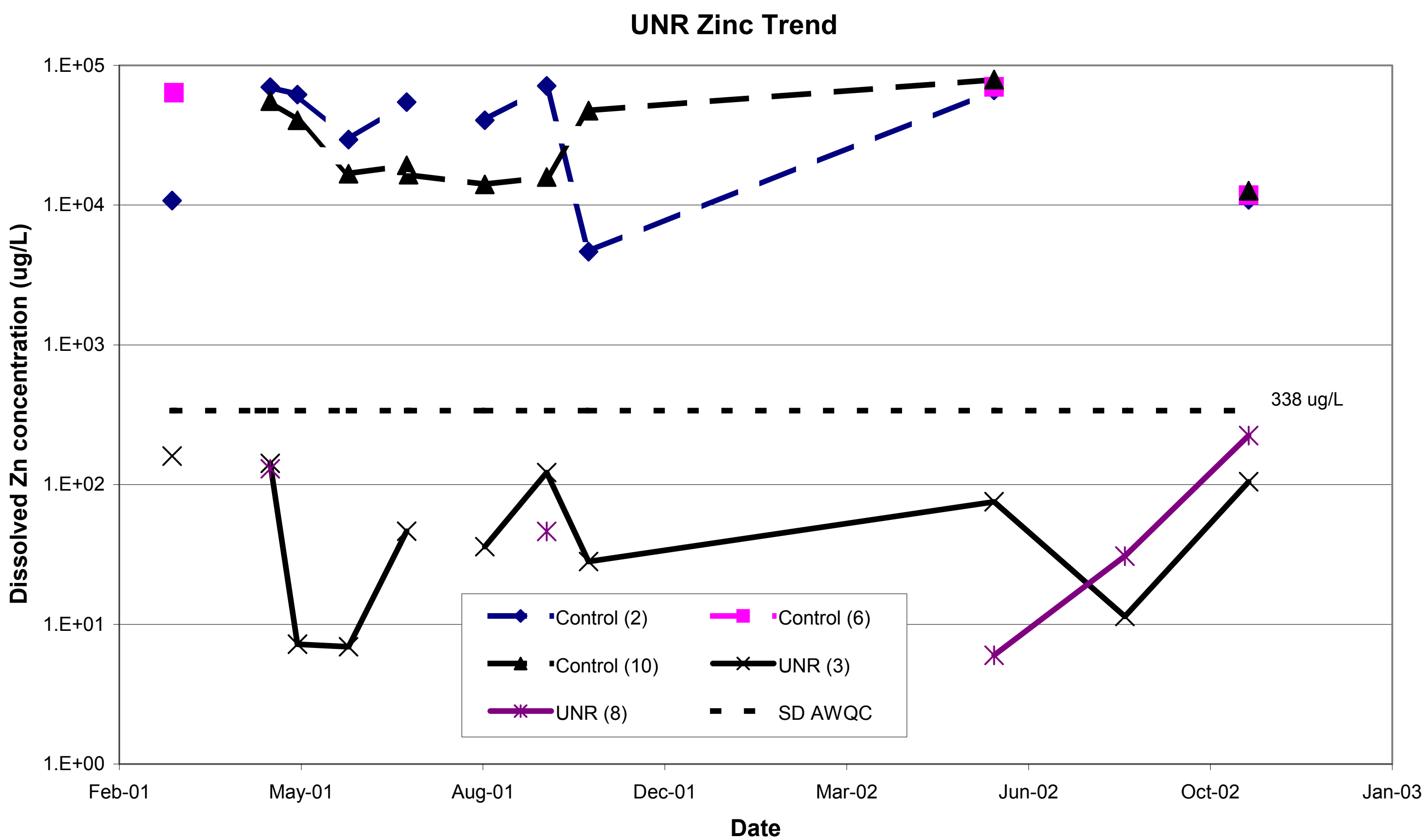

Figure 6-4. UNR zinc trend.

Table 6-1. UNR Passivation Technology Dosage Rates

Treatment Material	Cell 3	Cell 8	Per Ton Basis Based on a 1.5 tons/yd^3 Bulk Density
Waste rock	125 yd^3	125 yd^3	
Water	450 gal	450 gal	2.4 gal/ton
Potassium Permanganate	144 lb	144 lb	0.77 lb/ton
Caustic Soda	54 lb	54 lb	0.29 lb/ton
Magnesium Oxide	764 lb	764 lb	4.1 lb/ton
CaO	1,908 lb	1,908 lb	10.2 lb/ton

Table 6-2. UNR Aluminum Percent Reduction

UNR Percent Reduction of Dissolved Aluminum (µg/L)										
Date	**Control (2)**	**Control (6)**	**Control (10)**	**Control Average**	**UNR (3)**	**UNR (8)**	**UNR Average**	**UNR % Reduction**	**Statistical Evaluation of % reduction**	
03/09/01	162,000	NS	NS	162,000	144	NS	144	99.91%	Mean	99.97%
03/10/01	NS	891,000	NS	891,000	NS	NS	NC	NC	Standard Error	0.01%
04/25/01	NS	NS	NS	NC	NS	NS	NC	NC	Median	99.98%
05/02/01	750,000	NS	698,000	724,000	53	53	53	99.99%	Standard Deviation	0.03%
05/17/01	753,000	NS	189,000	471,000	53	NS	53	99.99%	Sample Variance	0.00%
06/14/01	386,000	NS	37,800	211,900	43	NS	43	99.98%	Range	0.09%
07/16/01	480,000	NS	18,600	249,300	179	NS	179	99.93%	Minimum	99.91%
07/17/01	NS	NS	36,300	36,300	NS	NS	NC	NC	Maximum	100.00%
08/28/01	396,000	NS	1,090	198,545	54	NS	54	99.97%		
10/01/01	1,070,000	NS	57,100	563,550	11	11	11	100.00%		
10/24/01	322,000	NS	138,000	230,000	55	NS	55	99.98%		
06/04/02	3,120,000	3,170,000	2,100,000	2,796,667	139	512	326	99.99%		
08/15/02	NS	NS	NS	NC	268	170	219	NC		
10/22/02	2,950,000	1,870,000	338,000	1,719,333	48	28	38	100.00%		

NS – Sampled not submitted to laboratory due to lack of effluent
NC – Not calculated due to lack of data

Table 6-3. UNR Iron Percent Reduction

UNR Percent Reduction of Dissolved Iron (µg/L)										
Date	Control (2)	Control (6)	Control (10)	Control Average	UNR (3)	UNR (8)	UNR Average	UNR % Reduction	Statistical Evaluation of % reduction	
03/09/01	644,000	NS	NS	644,000	559	NS	559	99.91%	Mean	99.99%
03/10/01	NS	554,000	NS	554,000	NS	NS	NC	NC	Standard Error	0.01%
04/25/01	NS	NS	NS	NC	NS	NS	NC	NC	Median	100.00%
05/02/01	1,150,000	NS	488,000	819,000	17	17	17	100.00%	Standard Deviation	0.03%
05/17/01	1,280,000	NS	8,860	644,430	17	NS	17	100.00%	Sample Variance	0.00%
06/14/01	1,250,000	NS	2,550	626,275	19	NS	19	100.00%	Range	0.09%
07/16/01	2,130,000	NS	6,600	1,068,300	189	NS	189	99.98%	Minimum	99.91%
07/17/01	NS	NS	4,320	4,320	NS	NS	NC	NC	Maximum	100.00%
08/28/01	1,070,000	NS	219	535,110	20	NS	20	100.00%		
10/01/01	5,680,000	NS	5,040	2,842,520	28	8	18	100.00%		
10/24/01	9,910,000	NS	12,800	4,961,400	23	NS	23	100.00%		
06/04/02	28,300,000	35,300,000	14,700	21,204,900	940	538	739	100.00%		
08/15/02	NS	NS	NS	NC	19	66	43	NC		
10/22/02	29,400,000	21,400,000	53,300	16,951,100	18	18	18	100.00%		

NS – Sampled not submitted to laboratory due to lack of effluent
NC – Not calculated due to lack of data

Table 6-4. UNR Sulfate Percent Reduction

UNR Percent Reduction of Dissolved Sulfate (µg/L)										
Date	Control (2)	Control (6)	Control (10)	Control Average	UNR (3)	UNR (8)	UNR Average	UNR % Reduction	Statistical Evaluation of % reduction	
03/09/01	27,100	NS	NS	27,100	1,710	NS	1,710	93.69%	Mean	73.43%
03/10/01	NS	NS	NS	NC	NS	NS	NC	NC	Standard Error	12.20%
04/25/01	12	NS	2,200	1,106	1,330	1,650	1,490	-34.71%	Median	83.42%
05/02/01	NS	NS	NS	NC	NS	NS	NC	NC	Standard Deviation	38.58%
05/17/01	11,700	NS	4,530	8,115	1,660	NS	1,660	79.54%	Sample Variance	14.88%
06/14/01	12,300	NS	3,490	7,895	1,790	NS	1,790	77.33%	Range	130.91%
07/16/01	16,590	NS	3,618	10,104	1,826	NS	1,826	81.93%	Minimum	-34.71%
07/17/01	NS	NS	NS	NC	NS	NS	NC	NC	Maximum	96.20%
08/28/01	14,000	NS	3,200	8,600	2,000	NS	2,000	76.74%		
10/01/01	22,600	NS	3,850	13,225	1,920	2,070	1,995	84.91%		
10/24/01	38,000	NS	4,500	21,250	2,100	NS	2,100	90.12%		
06/04/02	91,000	110,000	17,000	72,667	15,000	1,700	8,350	88.51%		
08/15/02	NS	NS	NS	NC	1,900	NS	1,900	NC		
10/22/02	77,000	66,000	19,000	54,000	2,100	2,000	2,050	96.20%		

NS – Sampled not submitted to laboratory due to lack of effluent
NC – Not calculated due to lack of data

7. KEECO SME Technology Performance

KEECO applied its SME treatment as a liquid spray similar to the MT^2 treatment (i.e., mixed the treatment material with water in a tank by recirculation). Once each lift was placed, KEECO personnel would spray the treatment solution on the surface area of the waste rock. Table 7-1 shows the dosage rates for the KEECO SME treatment.

Tables 7-2 to 7-4 outline the KEECO SME treatment percent reduction of dissolved aluminum, dissolved iron, and sulfate.

The SME treatment did reduce the aluminum concentration (Table 7-2) by at least 90% during the 2001 field season; however, it failed to do so during the 2002 season. The SME aluminum reduction mean is 88.14%.

The SME iron reduction (Table 7-3) had a similar trend in that the treatment achieved at least a 90% reduction until the last sampling event on October 22, 2002. The mean iron reduction of the SME treatment is 94.82%.

Table 7-4 shows the sulfate trend for the SME treatment achieved 90% reduction only once on June 4, 2002. The SME sulfate reduction mean is 33.18%.

Figures 7-1 to 7-4 show the KEECO SME treatment trends for pH, TDS, dissolved arsenic, and dissolved zinc compared to the site discharge standards and the control cells.

The SME pH trend (Figure 7-1) ranges from 7.92 to 1.99 and starts near the lower discharge limit of 6.5 but then falls below the limit during the 2002 season.

The SME TDS concentrations (Figure 7-2) stay near the discharge limit of 2,500 mg/L during the 2001 field season but increase during the 2002 field season to above the discharge limit.

The SME arsenic trend (Figure 7-3) starts below the discharge limit of 190 μg/L but then increases to above the limit during the 2002 season.

Figure 7-4 shows the SME zinc trend is above the discharge limit of 338 μg/L, with the exception of the August 28, 2001, sampling event.

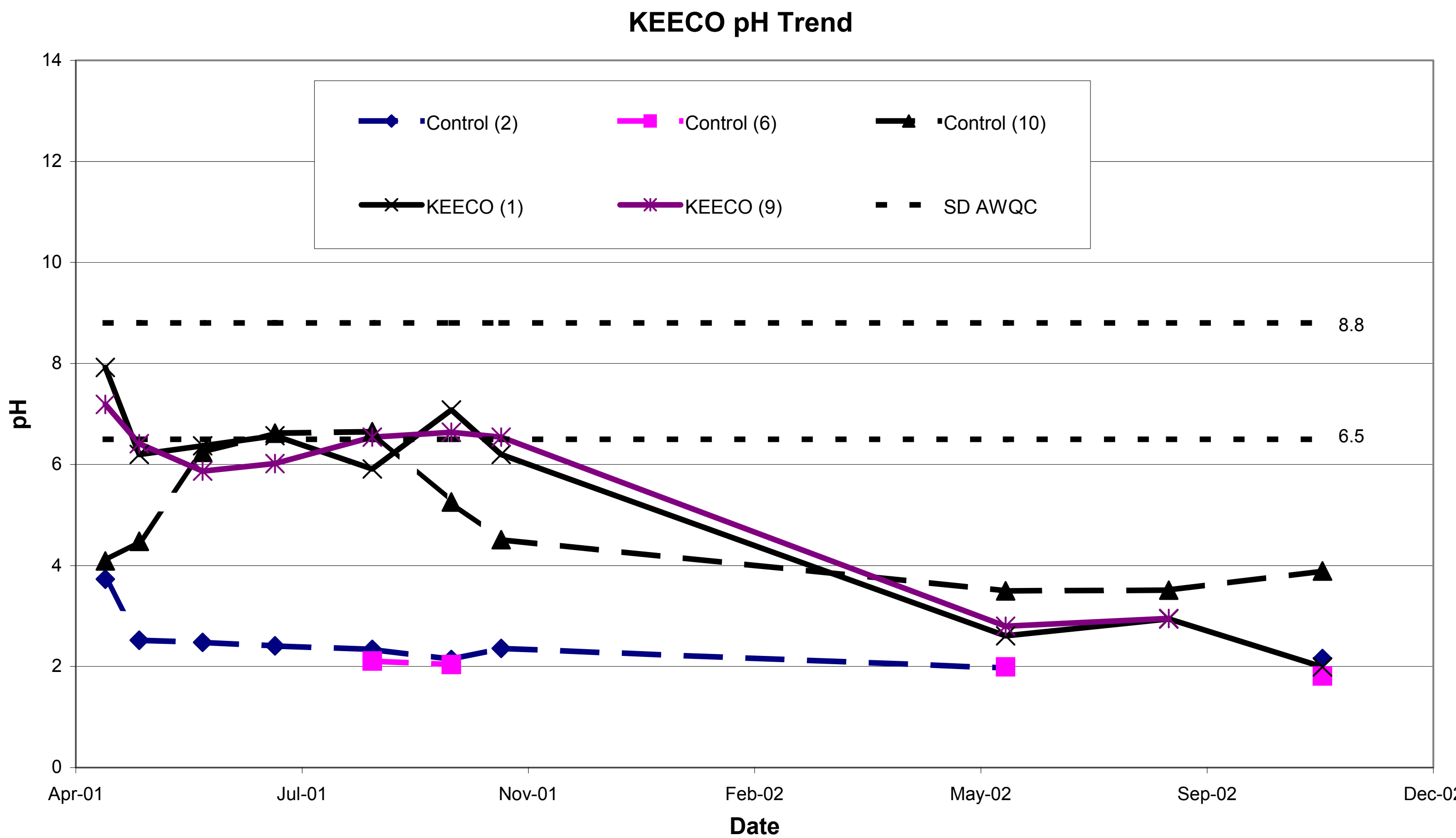

Figure 7-1. KEECO pH trend.

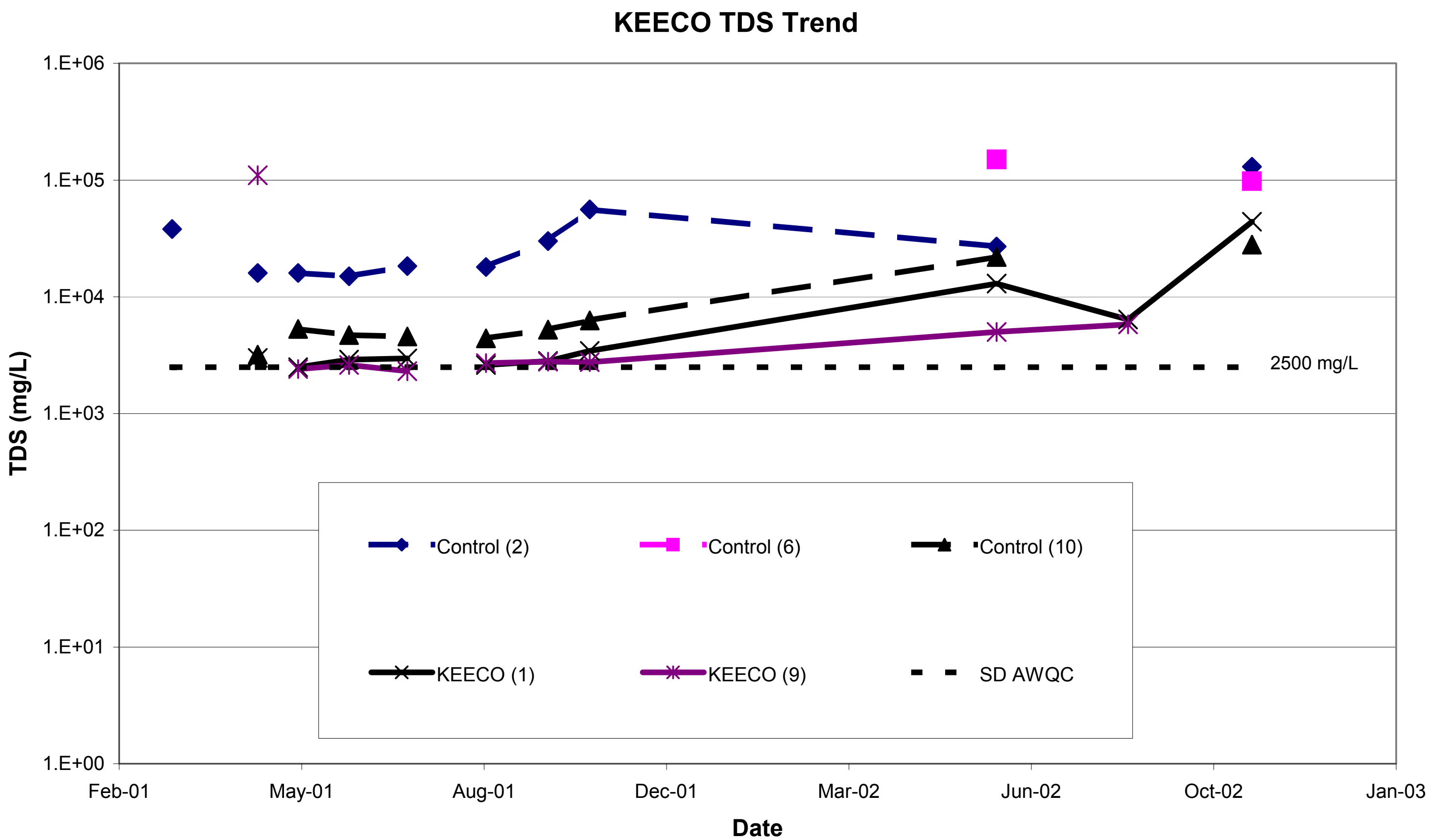

Figure 7-2. KEECO TDS trend.

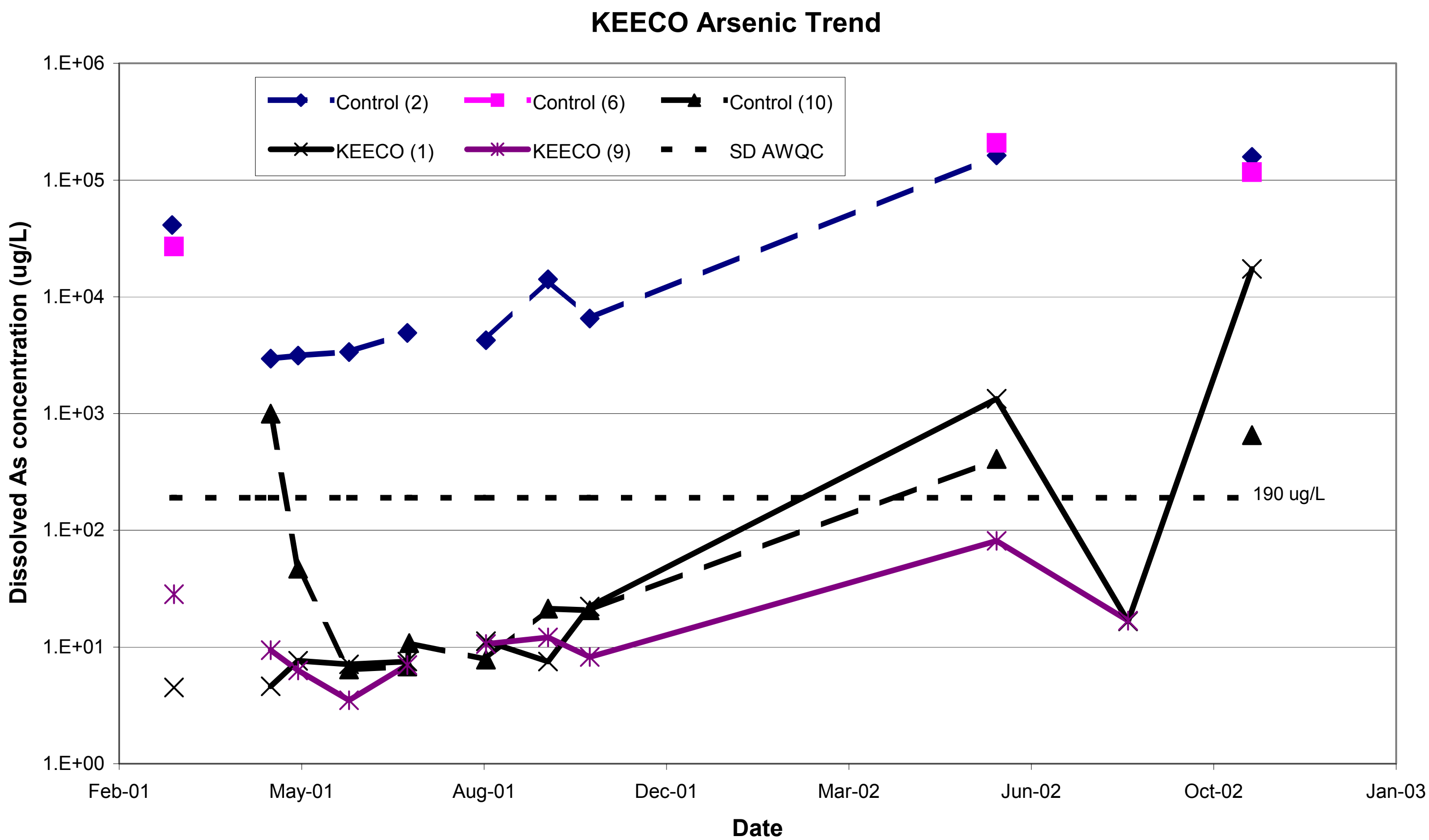

Figure 7-3. KEECO arsenic trend.

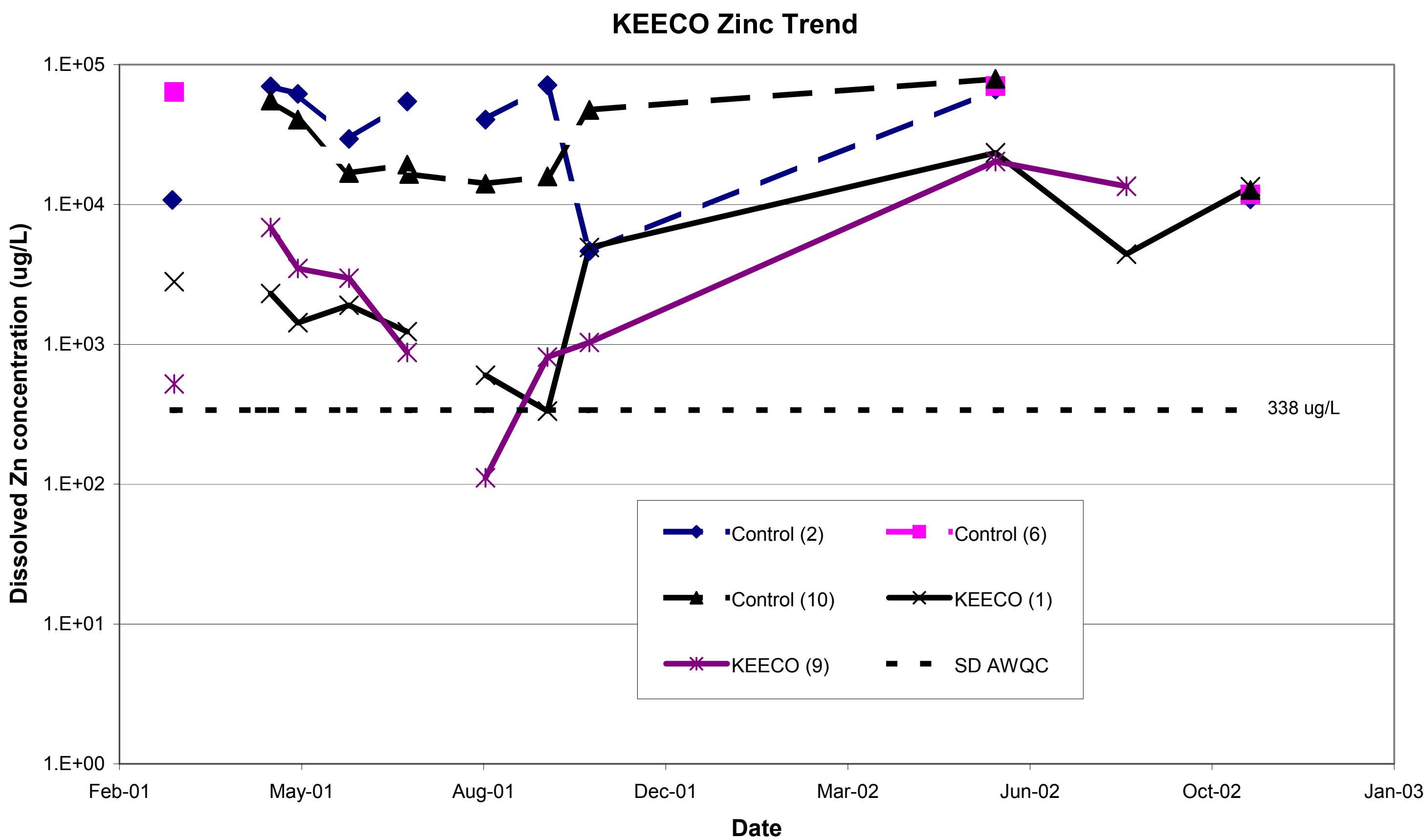

Figure 7-4. KEECO zinc trend.

Table 7-1. KEECO SME Technology Dosage Rates

Treatment Material	Cell 1	Cell 9	Per Ton Dosage Rates Based on a 1.5
Waste rock	125 yd^3	125 yd^3	
KEECO Material	2,250 lb	2,250 lb	12 lb/ton
Water	1,800 gal	1,800 gal	9.6 gal/ton

Table 7-2. KEECO Aluminum Percent Reduction

KEECO Percent Reduction of Dissolved Aluminum (µg/L)										
Date	**Control (2)**	**Control (6)**	**Control (10)**	**Control Average**	**KEECO (1)**	**KEECO (9)**	**KEECO Average**	**KEECO % Reduction**	**Statistical Evaluation of % reduction**	
03/09/01	162,000	NS	NS	162,000	NS	NS	NC	NC	Mean	88.14%
03/10/01	NS	891,000	NS	891,000	2,040	218	1,129	99.87%	Standard Error	9.25%
04/25/01	NS	NS	NS	NC	NS	NS	NC	NC	Median	98.65%
05/02/01	750,000	NS	698,000	724,000	4,350	23,400	13,875	98.08%	Standard Deviation	29.25%
05/17/01	753,000	NS	189,000	471,000	168	7,260	3,714	99.21%	Sample Variance	8.55%
06/14/01	386,000	NS	37,800	211,900	4,130	9,700	6,915	96.74%	Range	94.10%
07/16/01	480,000	NS	18,600	249,300	1,030	1,700	1,365	99.45%	Minimum	5.78%
07/17/01	NS	NS	36,300	36,300	NS	NS	NC	NC	Maximum	99.87%
08/28/01	396,000	NS	1,090	198,545	666	135	401	99.80%		
10/01/01	1,070,000	NS	57,100	563,550	62	1,380	721	99.87%		
10/24/01	322,000	NS	138,000	230,000	12,000	2,590	7,295	96.83%		
06/04/02	3,120,000	3,170,000	2,100,000	2,796,667	598,000	198,000	398,000	85.77%		
08/15/02	NS	NS	NS	NC	50,400	77,700	64,050	NC		
10/22/02	2,950,000	1,870,000	338,000	1,719,333	1,620,000	NS	1,620,000	5.78%		

NS – Sampled not submitted to laboratory due to lack of effluent
NC – Not calculated due to lack of data

Table 7-3 KEECO Iron Percent Reduction

KEECO Percent Reduction of Dissolved Iron (µg/L)										
Date	**Control (2)**	**Control (6)**	**Control (10)**	**Control Average**	**KEECO (1)**	**KEEC O (9)**	**KEECO Average**	**KEECO % Reduction**	**Statistical Evaluation of % reduction**	
03/09/01	644,000	NS	NS	644,000	NS	NS	NC	NC	Mean	94.82%
03/10/01	NS	554,000	NS	554,000	16	818	417	99.92%	Standard Error	4.57%
04/25/01	NS	NS	NS	NC	NS	NS	NC	NC	Median	99.85%
05/02/01	1,150,000	NS	488,000	819,000	2,520	9,630	6,075	99.26%	Standard Deviation	14.44%
05/17/01	1,280,000	NS	8,860	644,430	19	144	81	99.99%	Sample Variance	2.08%
06/14/01	1,250,000	NS	2,550	626,275	11,700	12,400	12,050	98.08%	Range	46.18%
07/16/01	2,130,000	NS	6,600	1,068,300	22	333	178	99.98%	Minimum	53.81%
07/17/01	NS	NS	4,320	4,320	NS	NS	NC	NC	Maximum	99.99%
08/28/01	1,070,000	NS	219	535,110	1,710	158	934	99.83%		
10/01/01	5,680,000	NS	5,040	2,842,520	15	398	206	99.99%		
10/24/01	9,910,000	NS	12,800	4,961,400	10,200	2,830	6,515	99.87%		
06/04/02	28,300,000	35,300,000	14,700	21,204,900	929,000	127,000	528,000	97.51%		
08/15/02	NS	NS	NS	NC	9,720	12,000	10,860	NC		
10/22/02	29,400,000	21,400,000	53,300	16,951,100	7,830,000	NS	7,830,000	53.81%		

NS – Sampled not submitted to laboratory due to lack of effluent
NC – Not calculated due to lack of data

Table 7-4. KEECO Sulfate Percent Reduction

KEECO Percent Reduction of Sulfate (mg/L)										
Date	**Control (2)**	**Control (6)**	**Control (10)**	**Control Average**	**KEECO (1)**	**KEECO (9)**	**KEECO Average**	**KEECO % Reduction**	**Statistical Evaluation of % reduction**	
03/09/01	27,100	NS	NS	27,100	NS	NS	NC	NC	Mean	33.18%
03/10/01	NS	NS	NS	NC	NS	NS	NC	NC	Standard Error	44.02%
04/25/01	12	NS	2,200	1,106	1,990	7,230	4,610	-316.78%	Median	77.91%
05/02/01	NS	NS	NS	NC	NS	NS	NC	NC	Standard Deviation	132.07%
05/17/01	11,700	NS	4,530	8,115	2,050	1,970	2,010	75.23%	Sample Variance	174.43%
06/14/01	12,300	NS	3,490	7,895	2,110	1,980	2,045	74.10%	Range	407.01%
07/16/01	16,590	NS	3,618	10,104	2,059	1,609	1,834	81.85%	Minimum	-316.78%
07/17/01	NS	NS	NS	NC	NS	NS	NC	NC	Maximum	90.23%
08/28/01	14,000	NS	3,200	8,600	2,000	1,800	1,900	77.91%		
10/01/01	22,600	NS	3,850	13,225	1,810	1,910	1,860	85.94%		
10/24/01	38,000	NS	4,500	21,250	2,500	2,000	2,250	89.41%		
06/04/02	91,000	110,000	17,000	72,667	9,100	5,100	7,100	90.23%		
08/15/02	NS	NS	NS	NC	4,900	4,400	4,650	NC		
10/22/02	77,000	66,000	19,000	54,000	32,000	NS	32,000	40.74%		

NS – Sampled not submitted to lab due to lack of effluent
NC – Not calculated due to lack of data

8. Technology Conceptual Design and Cost Evaluation

As part of the requirements of the subcontract with MSE, the technology providers were to provide a cost estimate and conceptual treatment design to treat a hypothetical waste rock pile at the Gilt Edge Mine. The representative application was a waste rock pile containing 500,000 yd^3 or 750,000 tons of waste rock with the same composition that was used for the technology evaluation. The technology vendors designed the conceptual treatment assuming the waste rock was being treated while being transported and loaded into a dry pit on the Gilt Edge site. The technology providers were given the performance data for the project and were allowed to use different dosage rates for the cost estimate and conceptual design if they felt it was to their advantage.

8.1 KEECO Conceptual Design

KEECO proposed to treat the waste rock by building a portable enclosed structure adjacent to the pit and treat the waste rock in batches before it was loaded into the pit. The treatment facility included the enclosed structure, concrete mixing corral, slurry delivery unit, reagent delivery silos, and a water storage tank. Based on the results from the technology evaluation, KEECO increased the dosage rate for the conceptual design from 0.6% to 3.0%.

8.2 MT^2 Conceptual Design

The MT^2 treatment procedure included spraying the waste rock after it was dumped and spread out into
1-ft-thick lifts inside the pit. The equipment used to treat the waste rock included a tractor towing a spray unit over the waste rock, tanks, gravel pads for mixing areas, and mixing equipment. MT^2 proposed to use a material called ECOBOND for the conceptual design. For the technology evaluation, MT^2 used a dosage rate of 3%; however, for the conceptual design, a different method was used to calculate the dosage rates. MT^2 felt it necessary to treat only the top 2 inches of each layer loaded into the pit and it would treat that with a 1.5% dosage rate along with a new material, ECOBOND ARD 2 at a 0.1%. According to MT^2, ECOBOND ARD 2 would prevent the leaching of arsenic from the waste rock.

8.3 UNR Conceptual Design

The UNR conceptual design included using a system of silos, hoppers, and a conveyor belt to mix the waste rock with the magnesium oxide and CaO and then load the waste rock into the pit in 5-ft lifts. Once the waste rock was in place, each lift would be treated with the second phase of the treatment using an irrigation system for 8 hours. The dosage rates for the conceptual design were not adjusted from the technology evaluation.

8.4 Presumptive Remedy Conceptual Design

The PR conceptual design includes mixing the waste rock with CaO at the same dosage rate as the technology evaluation. The waste rock would be mixed with CaO by a local subcontractor adjacent to the pit prior to loading the waste rock into the pit. The subcontractor would use CaO silos and heavy equipment to mix the waste rock and CaO. The assumption was made that since the CaO has a limited life, CaO treatment would need to be attempted in the future to prevent ARD.

8.5 Conceptual Design Costs

Costs considered by each technology vendor for the conceptual design were reagent cost, capital, labor, equipment rental, operation and maintenance, engineering, permitting, disposal, consumables, and mobilization/demobilization, etc. Since a subcontractor would be used for the PR, no capital or separate labor is included in the cost. Table 8-1 shows the cost for each technology vendor to treat the representative application of a 750,000-ton waste rock pile.

Table 8-1. Technology Vendor's Conceptual Design Cost

Cost component	KEECO	UNR	MT2	PR
Reagent Cost	$10,137,000	$1,859,820	$3,273,750	$899,438
Capital	$250,000	$24,300	$23,000	$0
Equipment Rental	$280,000	$324,840	$230,000	$0
Operation and Maintenance	$0	$0	$0	$0
Engineering	$0	$100,000	$41,600	$0
Subcontracts	$0	$0	$0	$3,750,000
Operating Labor	$918,000	$360,000	$366,000	$0
Other	$1,097,998	$572,448	$100,400	$125,000
Total Cost	$12,682,998	$3,241,408	$4,034,750	$4,774,438

9. Quality Assurance

The QC activities completed during this technology demonstration included collecting field duplicates and extra volume for matrix spike/ matrix spike duplicate (MS/MSD) analysis, calibrating field instruments, and decontaminating the equipment used. A total of 20 field duplicates and extra volume for 11 MS/MSD analyses were submitted for a total of 110 water samples. Also, five field duplicates and extra volume for three MS/MSD analyses were submitted for the waste rock samples. The field instruments were calibrated at least on a daily basis, and the calibration was checked at least at the end of each day of use. The decontamination and sampling procedures required by CDM's SAP were adhered to throughout the investigation. All QC activities for this investigation were in accordance with EPA's *Guidance for Data Quality Assessment, Practical Methods for Data Analysis* (Ref. 2) and CDM's SAP (Ref. 3).

Once the samples were analyzed, the data was evaluated, validated, and reviewed by CDM QA/QC staff prior to using it for the technology evaluation. Samples that were flagged with an "R" (rejected due to poor QC) were not used for the technology evaluation. If a sample was flagged with other qualifiers, it was used as reported. There were zero rejected samples for the pH, TDS, arsenic, aluminum, iron, zinc, and sulfate data sets.

10. Conclusions

By evaluating the parameters of pH, TDS, dissolved arsenic, aluminum, iron, zinc, and sulfate, it was possible to determine that some technologies performed better than others. Table 10-1 summarizes the effectiveness of each technology in reducing the relevant contaminants by at least 90% or achieving the SD AWQC for the Gilt Edge site.

The PR performed well; however, the high pH may indicate the waste rock was overdosed, and the CaO does have a limited life. Once the CaO is exhausted, it may need to be reapplied, depending on the circumstance.

The Envirobond treatment from MT^2 did reduce some contaminants; however, the fact that it increased concentrations of arsenic, TDS, and sulfate cannot be ignored. If the Envirobond technology is to become a viable treatment, then modifications would need to be made to prevent such increases in the future. Also, the approach by MT^2 of treating only the top 2 inches of each layer of the hypothetical waste rock for the cost estimate is questionable since each lift is made of sulfidic waste rock through the whole thickness not just the top 2 inches. If MT^2 were to treat the whole thickness of each lift, the cost would increase substantially.

UNR's Permanganate Passivation treatment performed well, and it is cost effective compared to the other treatments. The advantage of the Permanganate Passivation treatment is that, in theory, it will not degrade over time and a one-time application is all that is required.

The SME treatment by KEECO did not perform well past the first field season. Increasing the treatment dosage may solve this problem; however, it will add to the cost and make it very expensive compared to the other treatments.

Table 10-1. Technology Performance Summary

Technology	Achieve 90% Reduction?			Achieve SD Discharge Limits?				Cost to Treat 750,000 Tons of Waste Rock	Comments
	Al	Fe	Sulfate	pH	TDS	As	Zn		
PR	Yes	Yes	Yes	No	Yes	Yes	Yes	$4,774,438	Effective, but pH was elevated above 8.8 and will fail once CaO is exhausted
MT^2	Yes	Yes	No	Yes	No	No	Yes	$4,034,750	Actually increased TDS, sulfate, and arsenic concentrations
UNR	Yes	Yes	No	Yes	Yes	Yes	Yes	$3,241,408	Effective and has longer life than lime treatment
KEECO	No	Yes	No	No	No	No	No	$12,682,998	Expensive and failed during second field season

11. References

1. CDM, *Multi-Cell Treatability Study Report for Gilt Edge Mine NPL Site, Lawrence County, South Dakota*, June 2002.

2. EPA, *Guidance for Data Quality Assessment, Practical Methods for Data Analysis*, EPA QA/G-9, QA00 Update, EPA/600/R-96/084, July 2000.

3. CDM, *Sampling and Analysis Plan for Multi-Cell Acid Rock Drainage (ARD) Treatment Technological Evaluation, Gilt Edge Mine, Lawrence County, South Dakota*, April 2001.