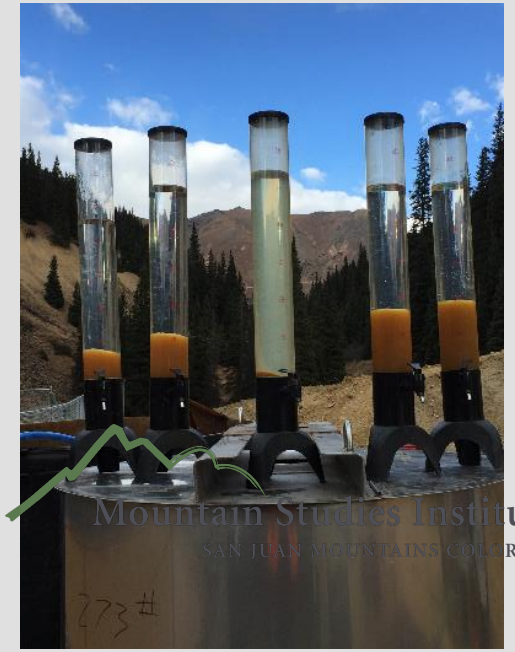
AMD, Lime Solids, & Kittimac Tailings: AN and MBT Field Trial Results (October 2017 – Spring 2018)

AN: **Yost Brothers, LLC**
Anacortes, WA

Blue Q Labs, LLC
Lebanon, OR

MBT: **HMR Solutions, Inc.**
Brooklyn, NY



SILVERTON INNOVATION EXPO

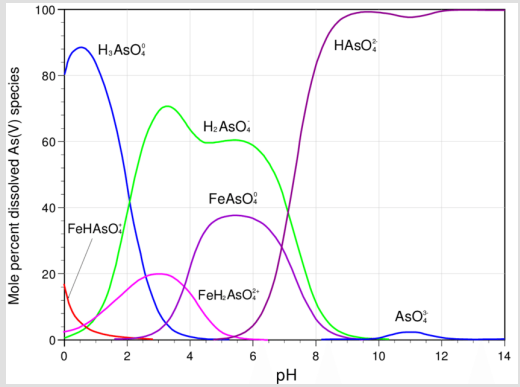
August 28-30, 2018

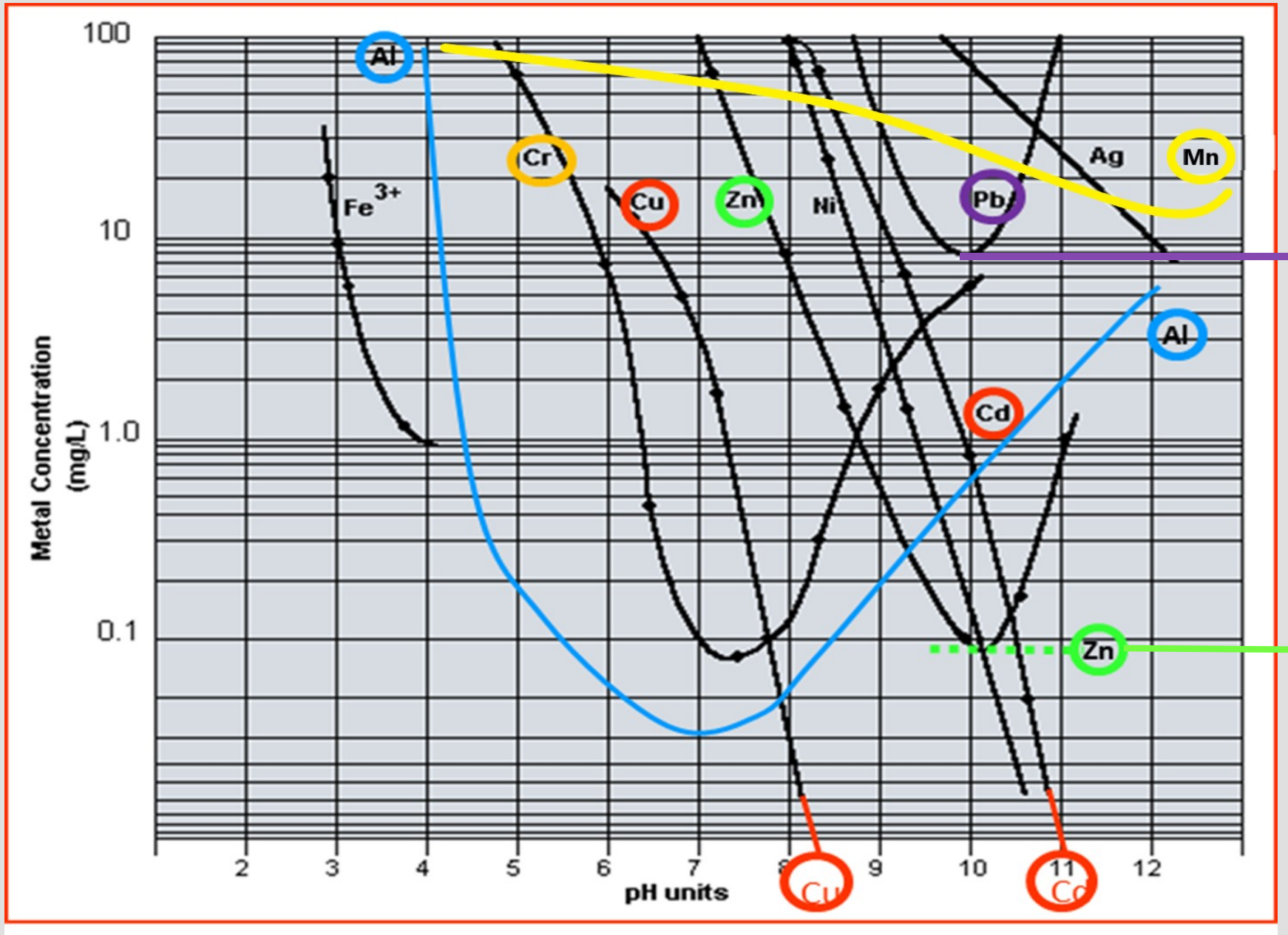
Mountain Studies Institute
SAN JUAN MOUNTAINS COLORADO

Metallic Hydroxide Precipitation Curves

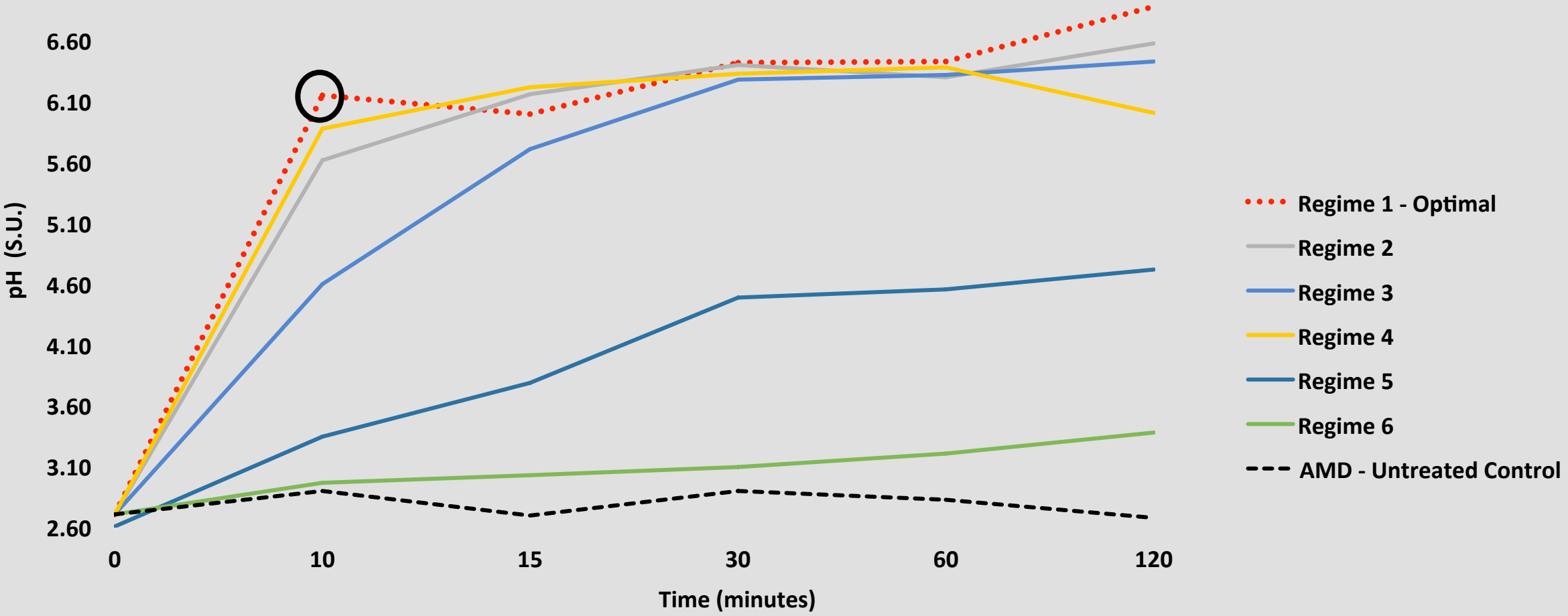
($R\text{-}OH^{-}$)

Multiple pH Points
Needed for
Maximized Heavy Metal
Removal from AMD Fluids





AN (Advanced Neutralization) Process: Stage 1
In-Water Hydroxide Manufacture: pH v. Time



Yost Brothers, LLC -- Blue Q Labs, LLC

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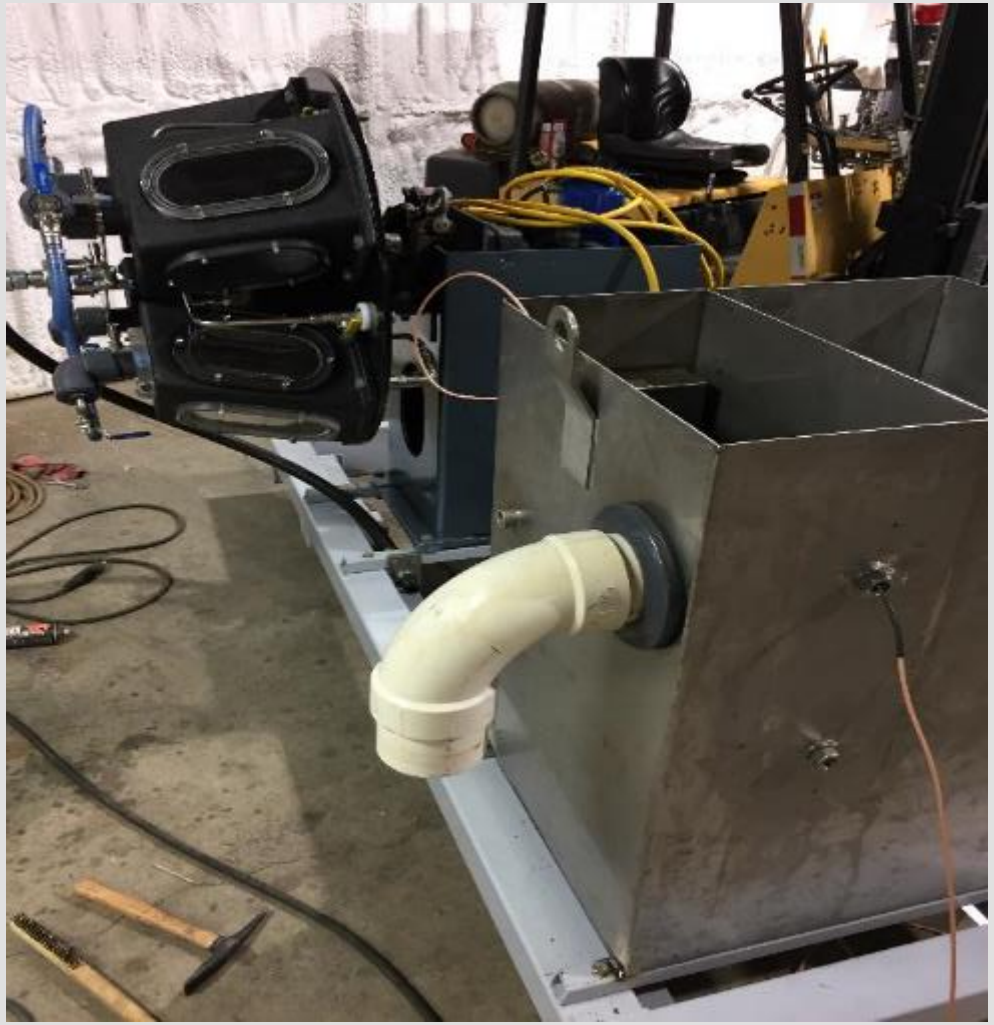
Advanced Neutralization – Equipment Scaling

1-5 gpm



5-20 gpm

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Bunker Mine/Kellogg Tunnel, Kellogg ID

Active Mine – AMD

Cement Creek Drainage Basin, Gladstone CO

Mogul Mine

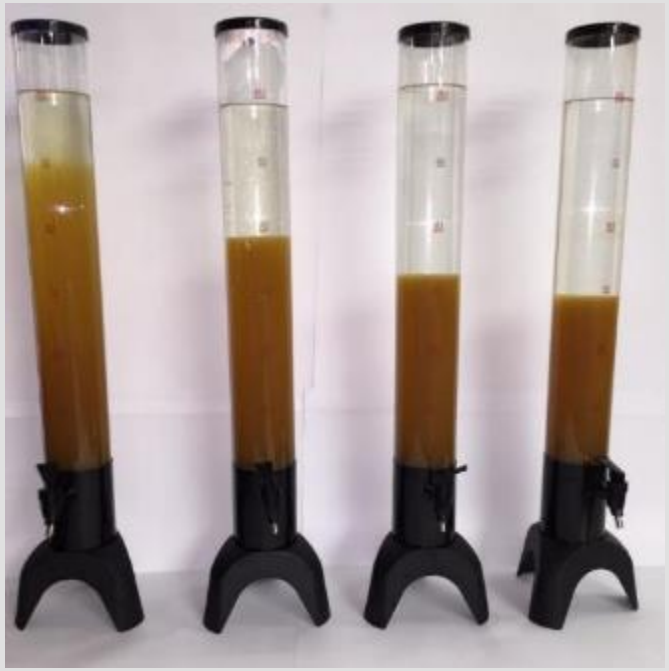
AN Solids Maturation

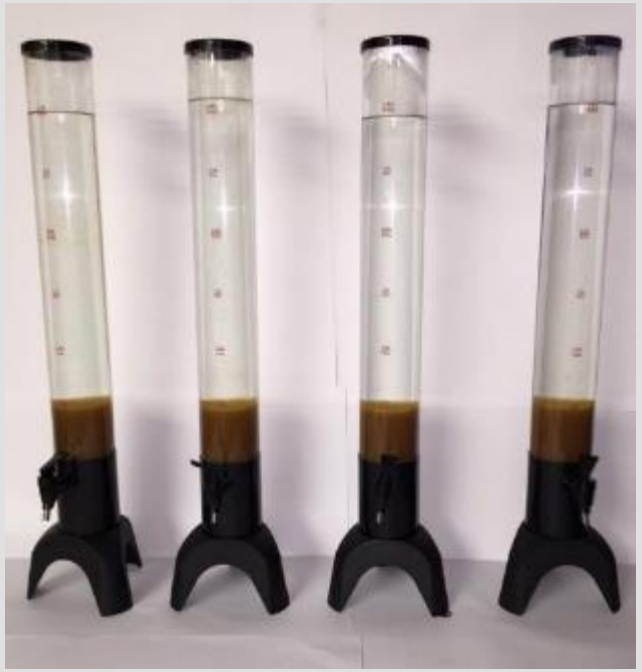
GKM – AN Clarified Effluent

AN Solids Settling Times

Left to Right:

2 minutes
5 minutes
7 minutes
10 minutes





30 minutes

9.86 gallons of Mogul Mine AMD → 86.7 g of AN solids (air dried to damp paste)

AN vs. Lime Treatment – Mogul Mine AMD

August 17, 2015 Sample Collection
Dissolved Metals

Parameter	Units	Untreated	Lime Treated pH 7.86 S.U.	Lime Treated pH 10.34 S.U.	AN Treated
Aluminum	**mg/L**	**3.5**	0.05	**0.17**	**0.06**
Arsenic	mg/L	<0.0025	0.0004 J	0.0003 J	**0.0002 J**
Cadmium	**mg/L**	**0.054**	**0.031**	<0.00025	**0.000125 J**
Chromium	mg/L	N/A	<0.001	<0.001	**N/A**
Copper	**mg/L**	**0.0187**	0.002	0.0007 J	**0.0013 J**
Iron	mg/L	25.5	<0.050	<0.050	**0.03 J**
Lead	mg/L	0.251	0.00016 J	<0.0005	**0.00016 J**
Manganese	**mg/L**	**28.1**	**22.10**	**6.80**	**0.30**
Nickel	**mg/L**	**0.016**	**0.017**	0.007	**0.009**
Silver	mg/L	0.00006 J	<0.0002	<0.0002	**<0.00001**
Zinc	**mg/L**	**32.1**	**8.740**	0.022	**0.019**
pH	**S.U.**	**3.46**	7.86	**10.34**	**6.48/7.52**

NOTES:

1) Lime treated samples w/calcium hydroxide to pH indicated.
2) pH measured in field/treatabilty laboratory
3) No filtration in treatment. Samples settled 2 hrs.
4) Untreated sample data by Green Analytical Laboratory, Durango, CO
5) Treated sample data by Edge Analytical, Inc., Burlington, WA

Lime Treated

AN Treated

Gold King Mine, Gladstone CO

April 13, 2016 – USEPA Settling Pond/Lime/Polymer and Solids Dewatering System

Gold King Mine

Gladstone, CO
Legacy Site – Mine Drainage
Issues: pH, Heavy Metals
Technologies: AN
Unresolved: Sulfate, Sulfide, Sulfur

AN Treatability Results

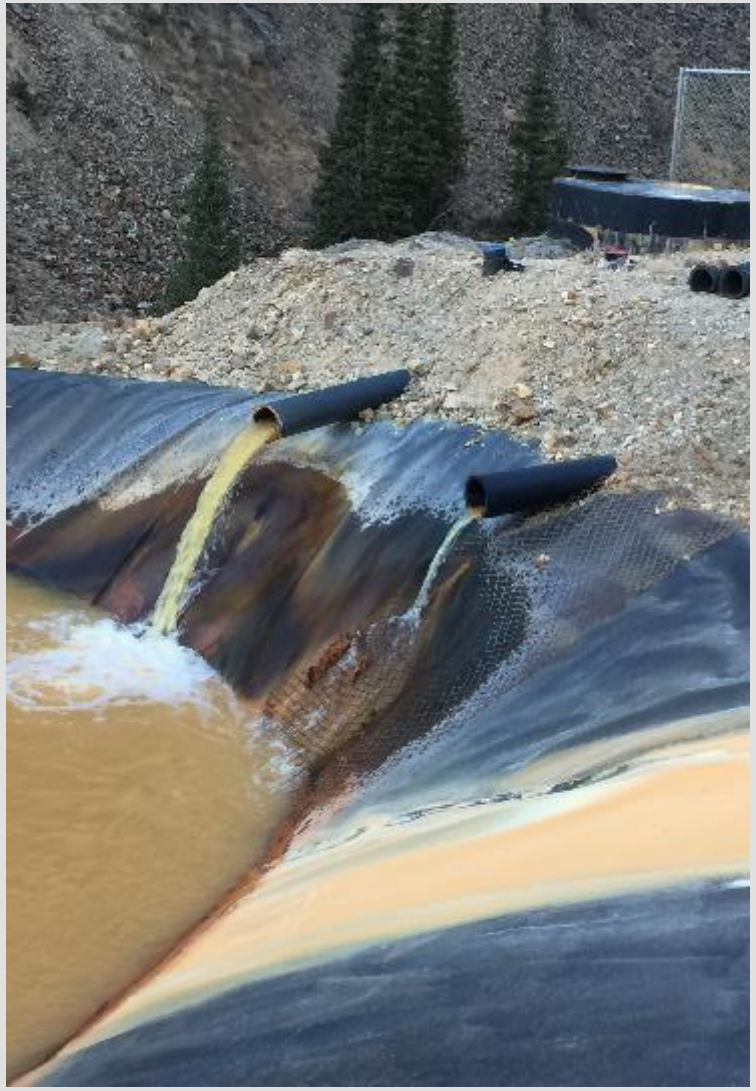
Gold King Mine AMD

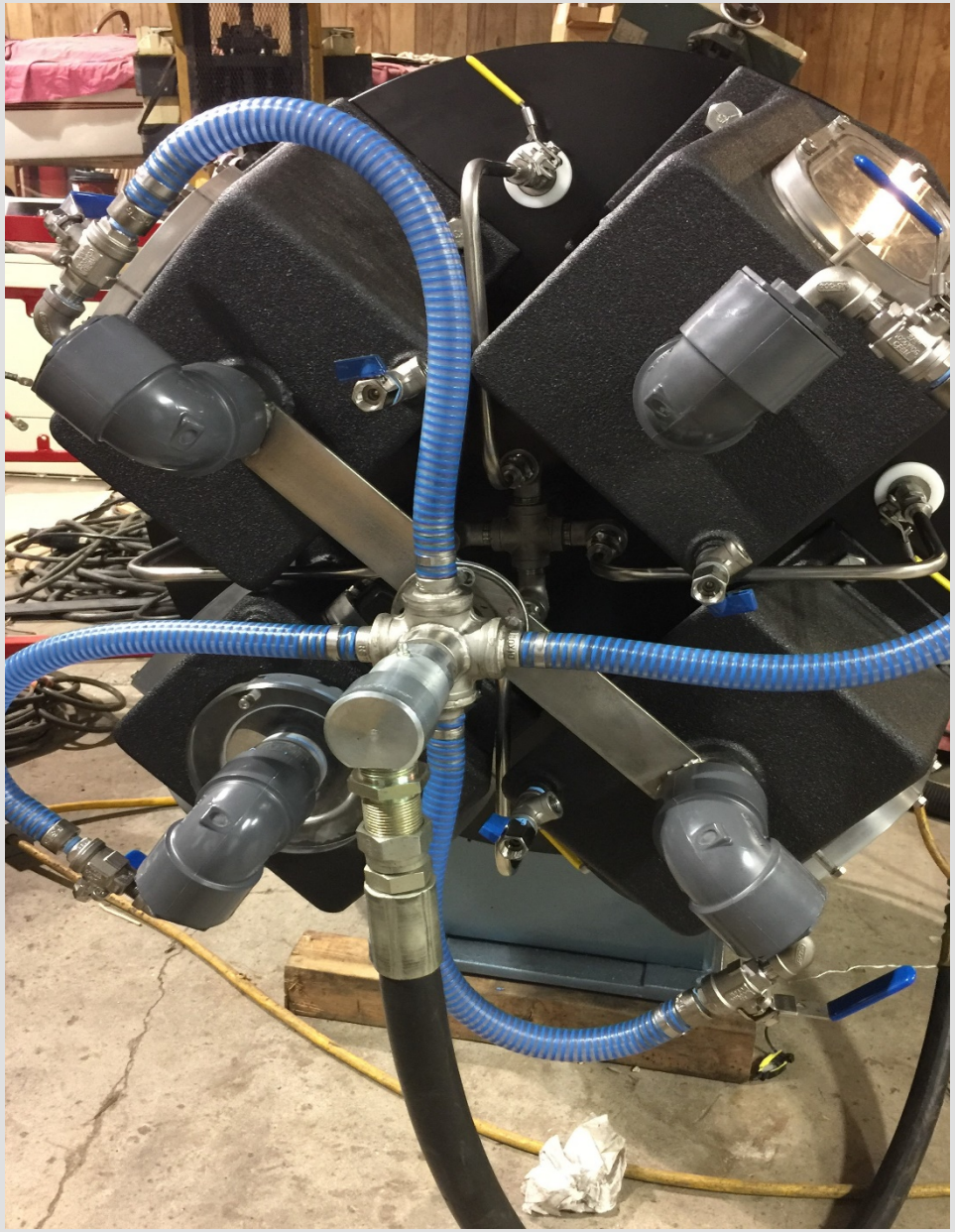
April 12-15, 2016

		AMD	AN Treated			
Parameter	**Units**	**Untreated**	**R-1**	**R-1A**	**R-2**	**R-3**
Aluminum, total	mg/L	13.9	1.43	1.39	DGap	DGap
Aluminum, dissolved	mg/L	8.94	<0.500	<0.500	DGap	DGap
Arsenic, total	mg/L	53*	NT	NT	0.0004 J	0.00035 J
Arsenic, dissolved	mg/L	62*	NT	NT	0.0005	0.00036 J
Calcium, total	mg/L	367	342	340	143.8	102.2
Calcium, dissolved	mg/L	371	335	302	151.2	90.8
Cadmium, total	mg/L	0.0379	0.0285	0.0017	0.0012	<0.00025
Cadmium, dissolved	mg/L	0.0384	0.0302	0.0014	0.0009	<0.00025
Copper, total	mg/L	2.96	0.114	<0.0100	0.008	0.002
Copper, dissolved	mg/L	2.69	0.109	<0.0100	0.0016 J	0.0013 J
Iron, total	mg/L	58.5	5.58	<0.500	23.54	2.05
Iron, dissolved	mg/L	43.8	4.28	<0.500	0.03 J	0.007 J
Lead, total	mg/L	0.0193	<0.0050	<0.0050	0.00017 J	0.0017
Lead Dissolved	mg/L	0.0086	<0.0050	<0.0050	<0.0005	<0.0005
Magnesium, total	mg/L	17.7	16.4	13.4	7.4	2.8
Magnesium, dissolved	mg/L	17.4	16.3	12.1	7.7	2.5
Manganese, total	mg/L	21.5	18.2	5.53	7.762	0.303
Manganese, dissolved	mg/L	20.0	18.6	5.44	4.631	0.012
Sulfate	mg/L	1685*	983	811	NT	NT
Sulfide, total	mg/L	NT	NT	NT	<0.05	NT
Sulfur, total	mg/L	NT	NT	NT	157	153
Sulfur, dissolved	mg/L	NT	NT	NT	167	166
Zinc, total	mg/L	21.5	5.54	<0.100	0.038	0.019
Zinc, dissolved	mg/L	10.1	5.69	<0.100	0.0074	0.001 J
pH	S.U.	5.2	5.75	7.66	6.62	7.24
pH	S.U.	3.28*				

* Historic average

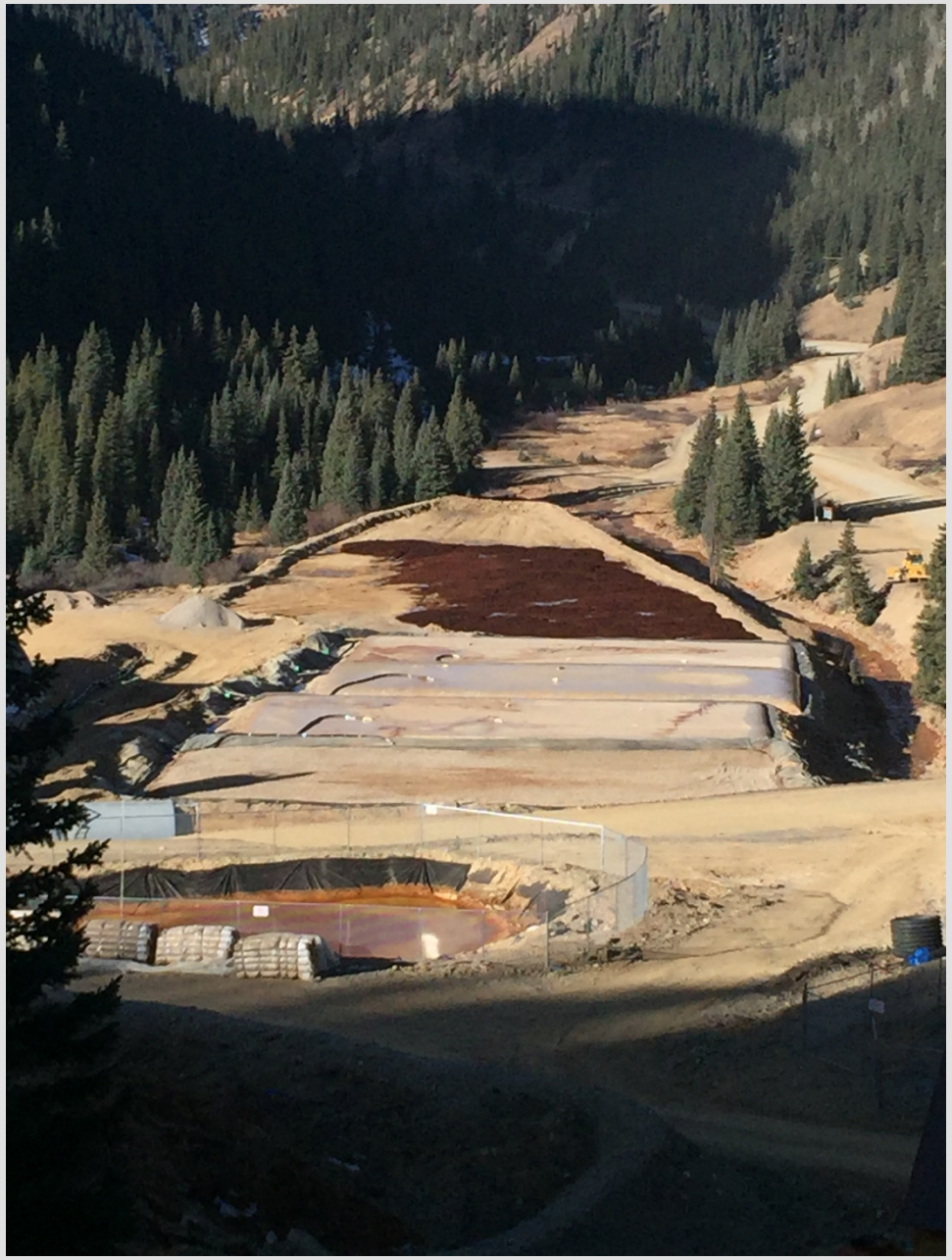
Gold King Mine Field Trial (October 2017)






IDEALARC
R3R-400
DC ARC WELDER
LINCOLN
ARC WELDER


10052017
-1000
AT
10062017
-1330
GKM
10062017
-1415

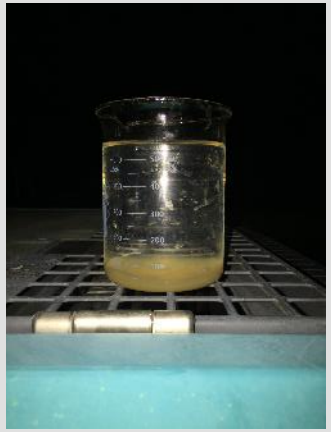



PENSKE


TARGETRENTAL www.targetrental


PENSKE


AIRMAN
TARGETRENTAL 970.247.0161



No Filtration

Gold King Mine AMD, Gladstone, Colorado

Yost Brothers, LLC Field Trials - October 24-30, 2017

Advanced Neutralization Treatment Technology

Water Treatment Analytical Data Summary - Metals as Totals

Sample ID	BLM/EPA Provided Data	BLM/EPA Provided Data	GKM 08152017	GKM 1030-1000	GKM 102617-1523	GKM 102617-1512	GKM 102617-1455	GKM 102617-1546	GKM 102617-1555	**GKM 1027-2015	GKM 1030-1730
Sample No.	NA	NA	NA	NA	1	2	3	4	5	6	7
Date	10/19/15 - 9/21/16	10/19/15 - 9/21/16	8/15/2017	10/30/2017	10/26/2018	10/26/2018	10/26/2018	10/26/2018	10/26/2018	10/26/2018	10/30/2017
Water Type	Raw Influent	EPA Lime Effluent	Raw Influent	Raw Influent	AN Treated	AN Treated	AN Treated	AN Treated	AN Treated	AN Treated	QA/QC Blind Field Blank
Flow Rate (gpm)			NA	NA	5	5	6	10	12	12**	NA
Parameters* (mg/L)											
Aluminum	18.7	4.3	45.5	4.65	26.1	6.4	12.8	1.59	1.30	<0.046	<0.046
Arsenic	0.033	0.005	<0.0050	<0.0050	<0.0250	<0.0250	<0.0250	<0.0250	<0.0250	<0.0250	<0.0050
Calcium	362.5	362.5	377	441	364	356	347	337	350	344	<0.152
Iron	84.8	13.1	174	114	61.7	41.8	28.5	58	63	13.1	<0.102
Cadmium	0.049	0.014	0.113	0.025	0.074	0.071	0.073	0.069	0.067	<0.0025	<0.0025
Cobalt	0.07	0.02	0.121	0.148	0.0882	0.0766	0.0788	0.075	0.071	0.0395	<0.0025
Copper	4.07	0.78	10.5	0.0441	5.84	2.00	2.97	0.349	<0.0025	<0.0025	<0.0025
Lead	0.028	0.006	0.055	0.0157	0.024	<0.018	<0.018	<0.018	<0.018	<0.018	<0.0025
Manganese	19.1	16.3	30.6	48.2	30.1	30.6	29.3	28.6	29.2	<0.0100	<0.0100
Nickel	0.043	0.018	NR	0.0884	0.088	0.193	0.18	0.191	0.16	<0.0050	<0.0050
Zinc	17.2	3.62	22.7	18.4	22.22	18.8	20.2	15.1	14.4	0.064	<0.0500
pH (S.U.)	NR	NR	2.81	3.62/2.95	4.32	3.33	4.51	4.29	4.95	6.12	6.71


GKM Lime Solids

MBT

Comparison of R-Hydroxide Solubility Products (Ksp)

vs.

Ksp Values for R-MBT Anions

Metal	Quicklime Ksp R-Hydroxide	MBT Ksp R-MBT	Comment
Aluminum	3×10^{-34}	9.8×10^{-21}	amphoteric
Arsenic	soluble	N/A	oxidation state
Cadmium	5.3×10^{-15}	2.53×10^{-33}	
Cobalt	1.1×10^{-15}	2.05×10^{-35}	
Copper	1.6×10^{-19}	8×10^{-37}	
Iron (II)	4.9×10^{-17}	3.6×10^{-41}	oxidation state
Iron (III)	2.79×10^{-39}	1×10^{-88}	
Lead	1.43×10^{-20}	7.9×10^{-43}	amphoteric
Manganese	2.1×10^{-13}	1×10^{-22}	oxidation state
Mercury	3.1×10^{-26}	2×10^{-53}	oxidation state
Nickel	5.5×10^{-16}	4.74×10^{-32}	
Zinc	4.1×10^{-17}	1.0×10^{-32}	amphoteric

NOTES:

1) *Amphoteric properties and valence state of metal ions are critical to solubility*
2) *Ksp values are nominal, but typically accepted in the literature*
3) *Quicklime can be substituted with any hydroxide contributing source or pozzolanic alkaline reagent*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Dedication at every turn

MBT Treatment Comparisons
Gold King Mine (GKM) Lime Solids

Bonita Peak Mining District (BPMD) NPL Site
Field Trials - October 24-30, 2017

BASELINE - Untreated Matrix	pH	Al	Fe	Cd	Co	Cu	Pb	Mn	Ni	Zn
Cement Creek Water (mg/L - Metals as Totals)	3.94	4.32	29.1	0.0122	NT	0.084	0.0233	20.9	NT	6.3
American Tunnel AMD (mg/L - Metals as Totals)	3.02	4.61	101	<0.0050	0.148	0.0201	0.0196	44.9	0.0862	18.5
Untreated GKM Lime Solids (mg/Kg - Metals as Totals)	8.29	60,100	246,000	175	146	13,100	64	22,600	103	39,200

American Tunnel AMD Leachate Fluid EPA Method 1320 (modified)

- American Tunnel AMD (pH 3.02) Water Metals Data

  vs.

- Untreated Lime Solids Leachable Metals Data

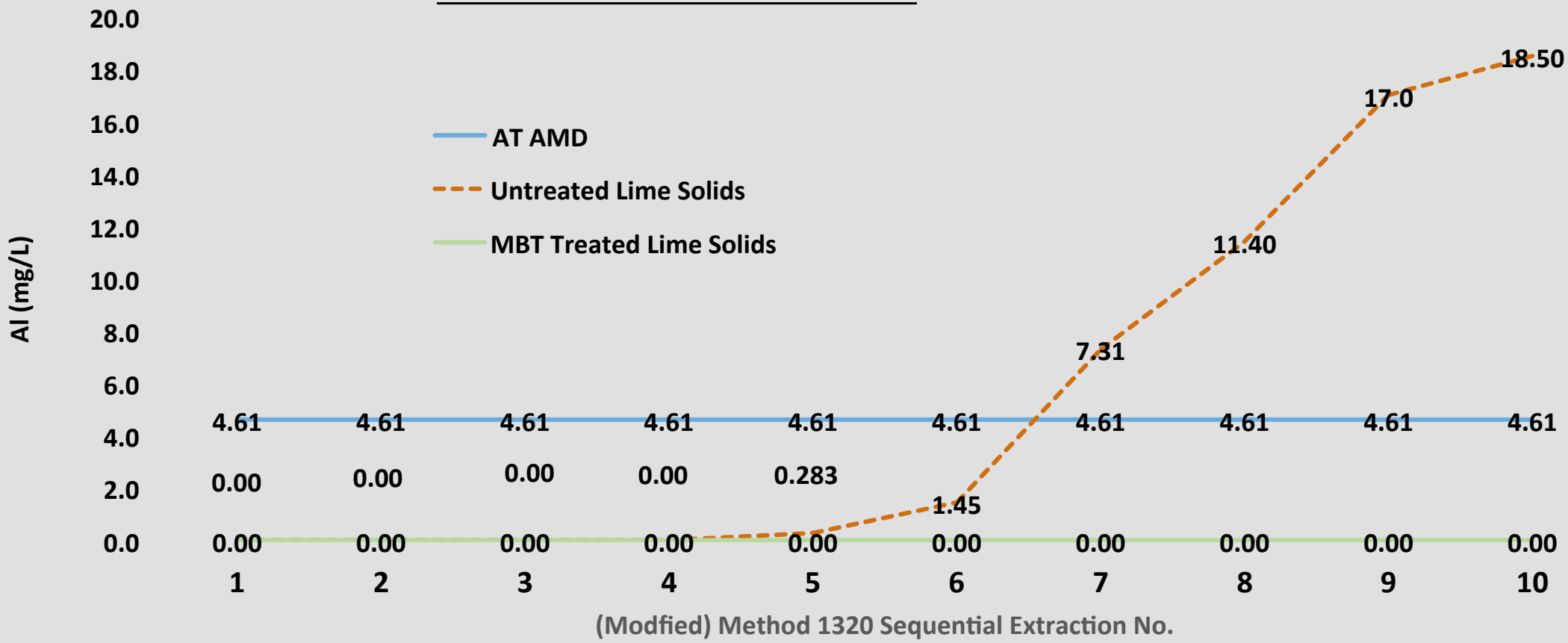
  and

- MBT Treated Lime Solids Leachable Metals Data

GOLD KING MINE - FIELD TRIAL DATA (October 2017)

Al Leachability via USEPA Method 1320 (Modified Multiple Exctraction Procedure)

American Tunnel Extraction Fluid: MBT vs. Untreated GKM Lime Solids



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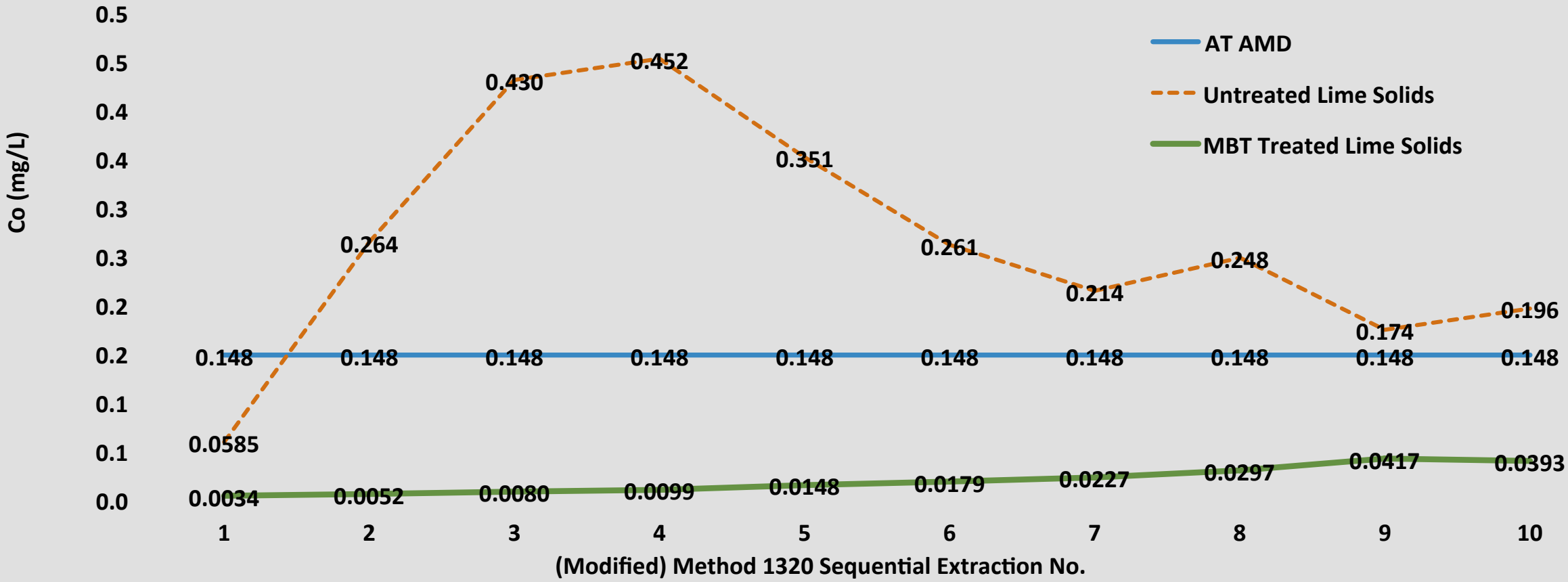
GOLD KING MINE - FIELD TRIAL DATA (October 2018)

Co Leachability via USEPA Method 1320 (Modified Multiple Extraction Procedure)

American Tunnel Extraction Fluid: MBT vs. Untreated GKM Lime Solids



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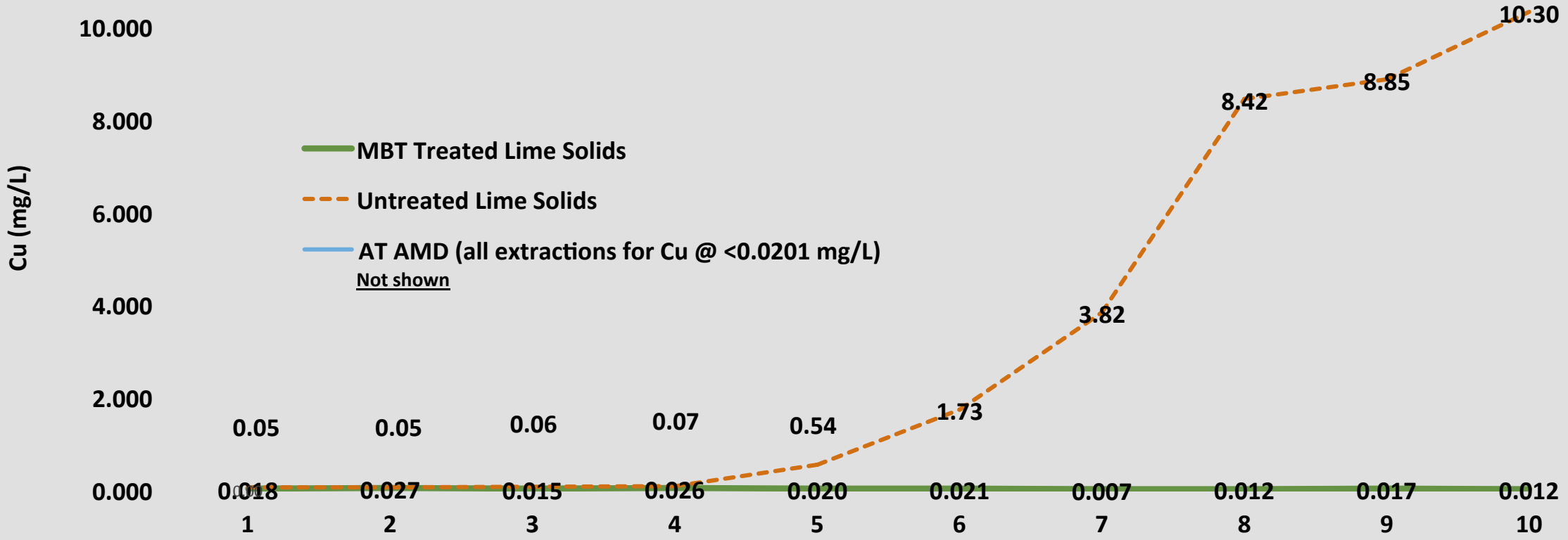
GOLD KING MINE - FIELD TRIAL DATA (October 2018)

Cu Leachability via USEPA Method 1320 (Modified Multiple Extraction Procedure)

American Tunnel Extraction Fluid: MBT vs. Untreated GKM Lime Solids



(Modified) Method 1320 Sequential Extraction No.

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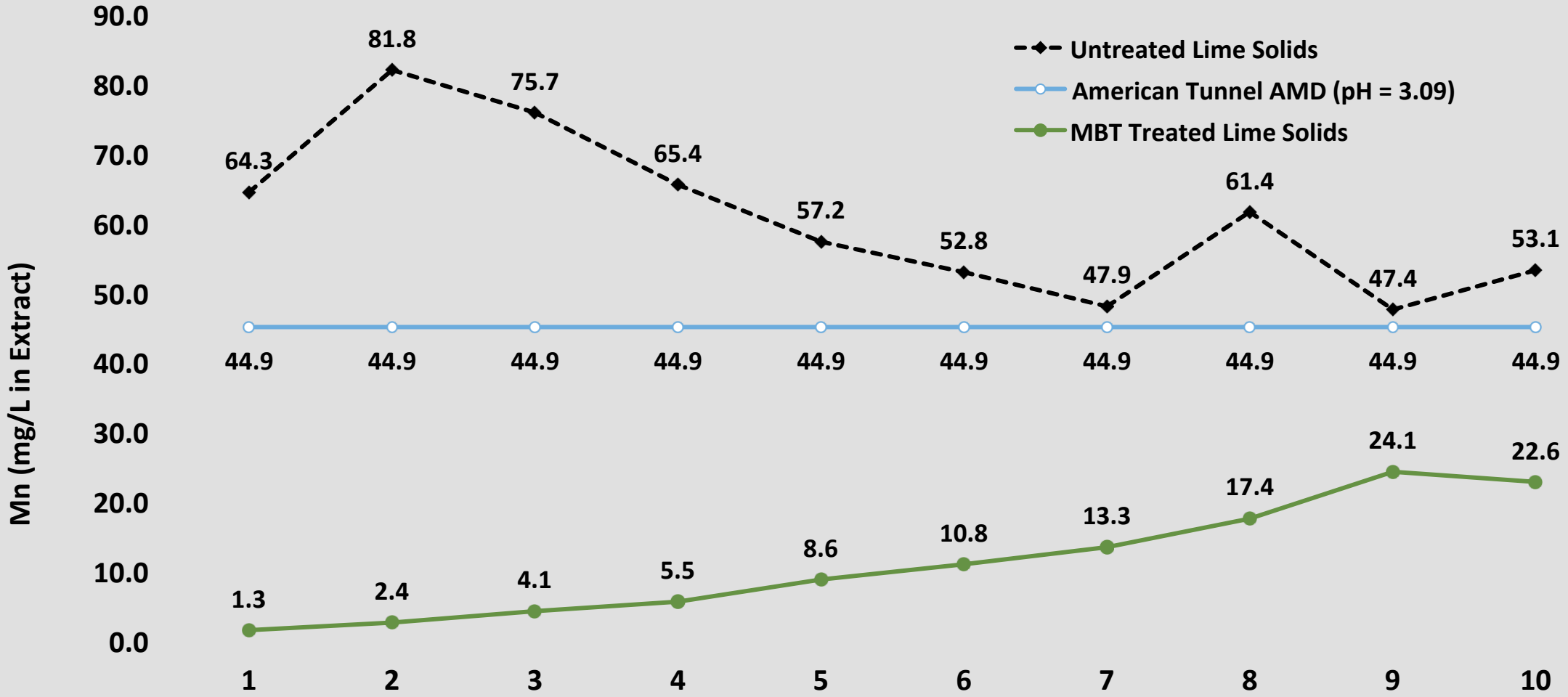
GOLD KING MINE - FIELD TRIAL DATA (October 2017)

Mn Leachability via USEPA Method 1320 (Modified Multiple Extraction Procedure)

American Tunnel Extraction Fluid: MBT vs. Untreated GKM Lime Solids



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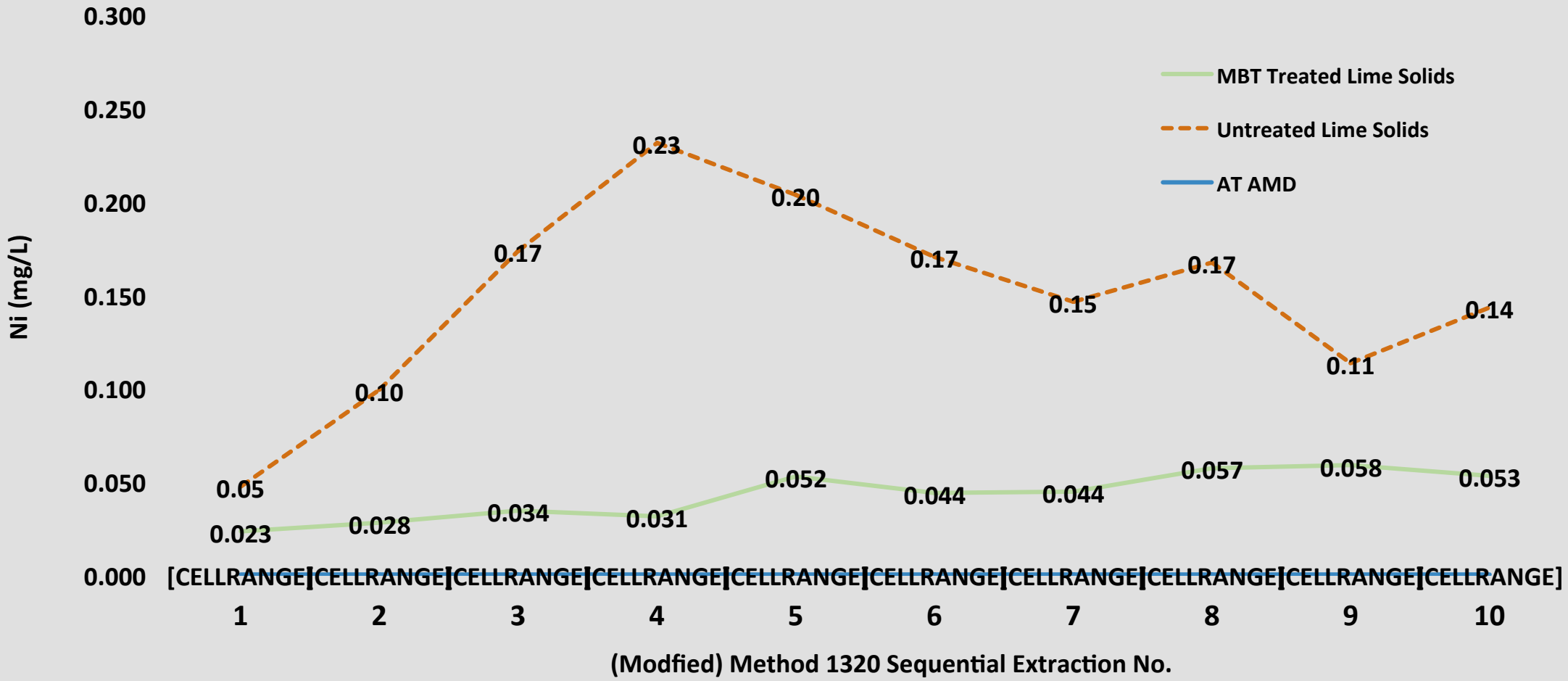
GOLD KING MINE - FIELD TRIAL DATA (October 2017)

NI **Leachability** via USEPA Method 1320 (Modified Multiple Extraction Procedure)

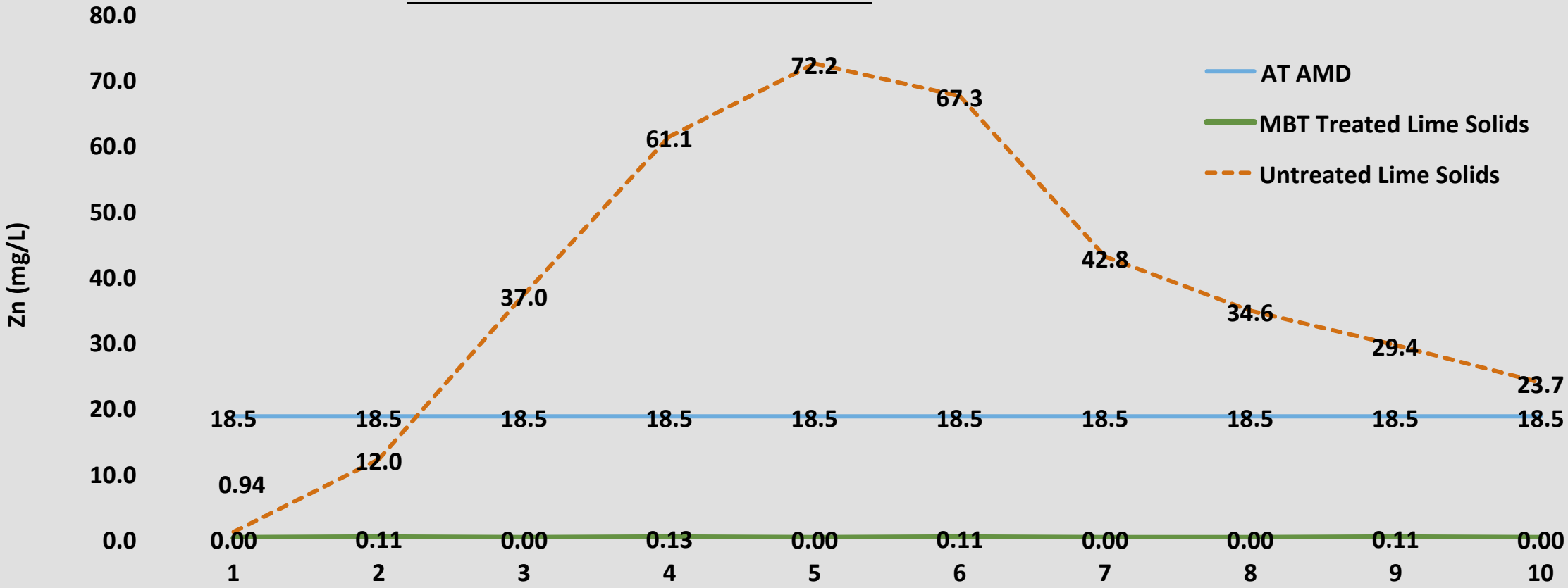
American Tunnel Extraction Fluid: MBT vs. Untreated GKM Lime Solids



GOLD KING MINE - FIELD TRIAL DATA (October 2018)

Zn Leachability via USEPA Method 1320 (Modified Multiple Extraction Procedure)

American Tunnel Extraction Fluid: MBT vs. Untreated GKM Lime Solids



Yost Brothers, LLC -- **HMR Solutions, Inc., Brooklyn, NY** -- Blue Q Labs, LLC

Cement Creek AMD Influenced Leachate Fluid EPA Method 1320 (modified)

- Cement Creek (pH 3.94) Water Metals Data

  vs.

- Untreated Lime Solids Leachable Metals Data

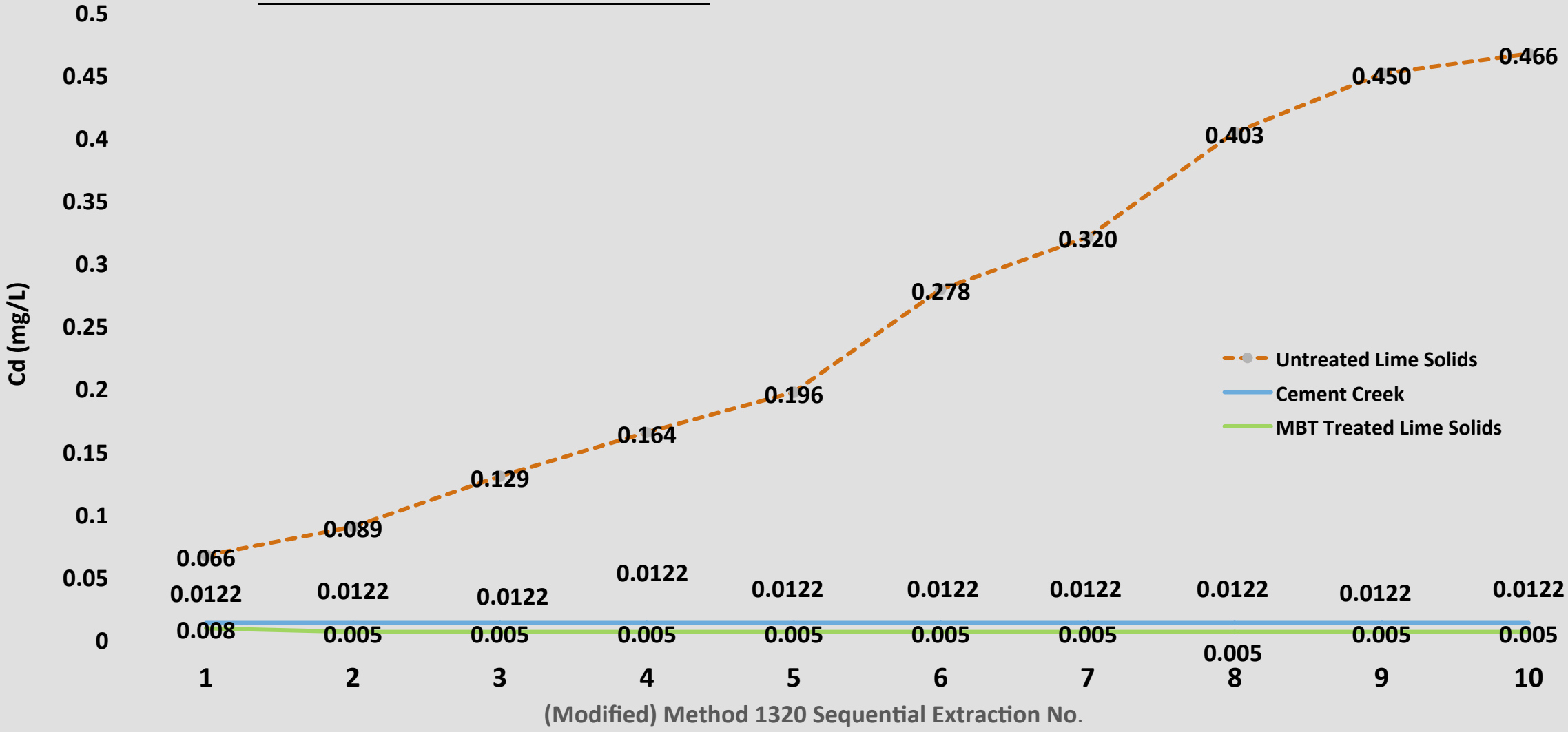
  and

- MBT Treated Lime Solids Leachable Metals Data

GOLD KING MINE - FIELD TRIAL DATA (OCTOBER 2018)

Cd Leachability via USEPA Method 1320 (Modified - Multiple Extraction Procedure)

Cement Creek Extraction Fluid: MBT Treated vs. Untreated GKM Lime Solids



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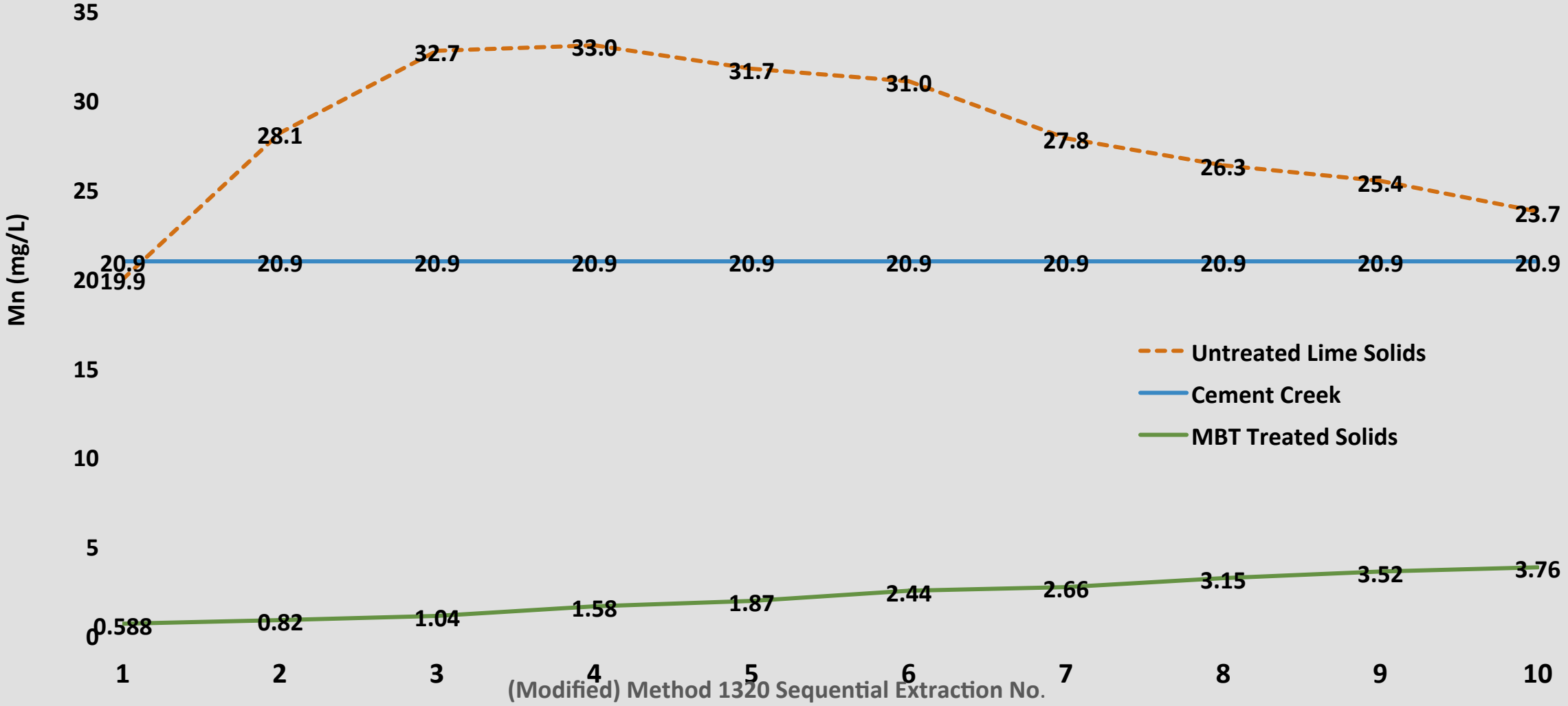
GOLD KING MINE - FIELD TRIAL DATA (October 2017)

Mn Leachability via USEPA Method 1320 (Modified- Multiple Extraction Procedure)

Cement Creek Extraction Fluid: MBT Treated vs. Untreated GKM Lime Solids



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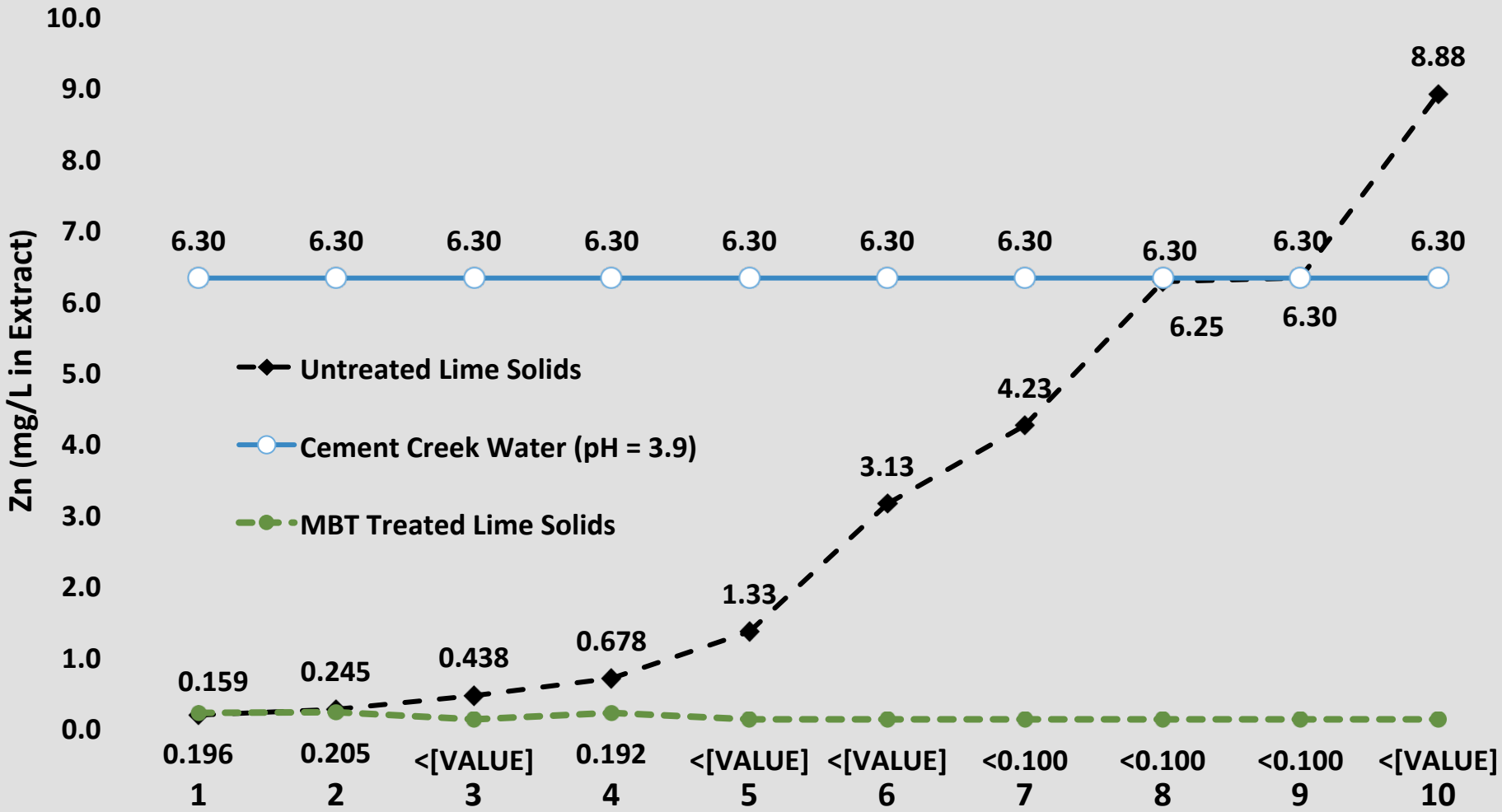
GOLD KING MINE - FIELD TRIAL DATA (OCTOBER 2017)

Zn Leachability via USEPA Method 1320 (Modified - Multiple Extraction Procedure)

Cement Creek Extraction Fluid: MBT vs. Untreated GKM Lime Solids



HMR Solutions, Inc - Brooklyn, NY

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Field Trials – Extended Studies

Samples:

- Gold King Mine Lime Solids
- Kittimac Tailings
- Lime Solids : Kittimac Tailings @ 1:1; 1:2; and 1:5 Mass Ratio Blends

Treatments:

- Untreated
- Quicklime Treated (pH ~11.5)
- MBT Treated (Dosing from October 2018 Field Trials (NO OPTIMIZATION)

GKM Lime Solids

Kittimac Tailings

MBT Treated Blends

DATA SUMMARY TABLE
UNTREATED MATERIALS
HMR 2017 October Field Trial - Extended Study (Spring 2018)
BPMD NPL Site - Gladstone CO

Untreated vs. Quicklime Treated vs. MBT Treated:
GKM Lime Solids; Kittimac Tailings; and GKM Lime Solids:Kittimac Tailing Material Blends

Waste/Blend of Waste	Method	Units	*pH (S.U.)	Al	As	Cd	Cu	Fe	Pb	Mn	Ni	Zn	Comments
UNTREATED MATERIALS													
UNTREATED - GKM Lime Solids	Totals	mg/Kg	8.29	**60,100**	**70.5**	**175**	**13,100**	**246,000**	64.1	**22,600**	**103**	**39,200**	
UNTREATED - Kittimac Tailings	Totals	mg/Kg	8.11	2162	5.37	<0.89	253	4686	**3540**	43.6	<0.89	161	
UNTREATED - LS:KT (1:1)	Totals	mg/Kg	N/A	31,131	38	88	6,677	125,343	1,802	11,322	52	19,681	Calc. as avg @ 1:1 mass ratio blend. (ND = 0 mg/Kg in calc.)
UNTREATED MATERIALS													
UNTREATED - GKM Lime Solids (LS)	TCLP	mg/L	8.29	9.11	<0.103**	0.579	21.3	<0.102	0.022	107	0.0291	152	
UNTREATED - Kittimac Tailings (KT)	TCLP	mg/L	8.11	0.51	<0.100	<0.025	0.77	3.47	**62.6**	0.14	<0.01	0.83	**Exceeds TC Limit**
UNTREATED- LS:KT (1:1)	TCLP	mg/L	7.91	7.98	<0.0005	0.25	12.8	1.6	**17.1**	47.7	0.15	53.6	**Exceeds TC Limit**
UNTREATED- LS:KT (1:2)	TCLP	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	
UNTREATED- LS:KT (1:5)	TCLP	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	
UNTREATED - Kittimac Tailings (KT)	SPLP	mg/L	8.29	0.336	NT	0.0009	0.0442	0.746	0.001	2.08	NT	0.153	
UNTREATED - Kittimac Tailings	SPLP	mg/L	8.11	0.03	<0.100	<0.010	0.77	<0.05	9.31	0.031	<0.010	0.32	
UNTREATED- LS:KT (1:1)	SPLP	mg/L	7.91	0.28	<0.0005	<0.005	0.01	<0.05	<0.010	2.99	<0.010	0.02	

DATA SUMMARY TABLE
TREATED MATERIALS
HMR 2017 October Field Trial - Extended Study (Spring 2018)
BPMD NPL Site - Gladstone CO

Untreated vs. Quicklime Treated vs. MBT Treated:
GKM Lime Solids; Kittimac Tailings; and GKM Lime Solids:Kittimac Tailing Material Blends

Waste/Blend of Waste	Method	Units	*pH (S.U.)	Al	As	Cd	Cu	Fe	Pb	Mn	Ni	Zn	Comments
GKM Lime Solids (LS)	QL	mg/L	10.95	2.51	<0.0005	0.43	10.3	0.29	0.07	87.9	0.23	72.5	
GKM Lime Solids (LS)	MBT	mg/L	9.11	<0.046	<0.103	<0.250	<0.113	<0.102	<0.018	0.356	<0.250	0.027	
Kittimac Tailings (KT)	QL	mg/L	12.08	14.9	<0.100	<0.025	2.1	22.5	**67.7**	0.24	<0.010	0.8	**Exceeds TC Limit**
Kittimac Tailings (KT)	MBT	mg/L	8.64	0.09	<0.100	<0.005	0.04	0.28	0.034	0.035	<0.010	0.03	
LS: KT (1:1)	QL	mg/L	11.84	2.11	<0.100	**0.19**	5.01	1.08	**2.69**	12.2	0.08	**37.6**	**Exceeds LDR Limit**
LS: KT (1:1)	MBT	mg/L	10.26	<0.010	<0.100	<0.025	0.02	0.11	<0.050	0.60	<0.02	0.02	
LS: KT (1:2)	QL	mg/L	11.57	11.0	<0.100	0.14	8.17	5.00	**15.1**	11.1	0.08	33.8	**Exceeds TC Limit**
LS: KT (1:2)	MBT	mg/L	10.07	0.22	<0.100	0.06	1.29	0.33	0.11	24.2	0.11	7.65	
LS: KT (1:5)	QL	mg/L	11.73	5.31	<0.100	0.06	4.33	0.28	**26.5**	2.66	0.04	16.3	**Exceeds TC Limit**
LS: KT (1:5)	MBT	mg/L	10.05	0.85	<0.100	<0.025	2.69	0.25	0.34	12.9	0.06	13.7	
GKM Lime Solids (LS)	QL	mg/L	10.95	12.1	<0.0005	<0.005	<0.02	<0.05	0.02	0.001	<0.010	0.02	
GKM Lime Solids (LS)	MBT	mg/L	9.11	0.219	NT	<0.0005	0.0162	0.206	0.001	0.058	NT	0.049	
Kittimac Tailings (KT)	QL	mg/L	12.08	0.74	<0.100	<0.025	0.09	<0.050	9.53	<0.001	<0.010	0.02	
Kittimac Tailings (KT)	MBT	mg/L	8.64	0.02	<0.0005	<0.005	<0.02	<0.05	0.02	0.003	<0.010	<0.02	
LS: KT (1:1)	QL	mg/L	11.84	11.9	<0.100	<0.025	0.04	<0.050	0.16	0.001	<0.010	0.06	
LS: KT (1:1)	MBT	mg/L	10.26	2.01	<0.100	<0.025	0.04	<0.050	0.03	0.002	<0.010	0.02	
LS: KT (1:2)	QL	mg/L	11.57	13.2	<0.100	<0.025	0.05	<0.050	0.03	0.001	<0.010	0.03	
LS: KT (1:2)	MBT	mg/L	10.07	0.84	<0.004	<0.025	0.04	0.05	0.010	0.017	0.01	0.07	
LS: KT (1:5)	QL	mg/L	11.73	6.88	<0.100	<0.025	0.05	0.13	0.19	0.007	<0.010	0.04	
LS: KT (1:5)	MBT	mg/L	10.05	0.11	<0.100	<0.025	0.03	<0.050	0.020	0.001	<0.010	<0.020	

USEPA Regulations and CDPHE Water Quality Control Commission Numeric Standards

Regulation	Units	Method	pH (S.U.)	Al	As	Cd	Cu	Fe	Pb	Mn	Ni	Zn	Comments
USEPA - LDR's	mg/L	1311		--	5.0	0.11	--	--	0.75	--	11	4.3	Applicable if waste "exhibits Toxicity Characteristic (TC)" PRIOR to placement
USEPA - RCRA Limits	mg/L	1311	<2 & >12.5	--	5.0	1.0	--	--	5.0	--	--	--	RCRA - Corrosivity and Toxicity Characteristics
USEPA - PRIMARY DWS	mg/L	Total			0.010	0.005	1.3		0.015				SDWA - National Primary DWS
USEPA - SECONDARY DWS	mg/L	Total	6.5 - 8.5	0.05 - 0.20			1	0.3		0.05		5	SDWA - National Secondary DWS
USEPA - Combined DWS	mg/L	Total	6.5 - 8.5	0.05 - 0.20	0.010	0.005	1	0.3	0.015	0.05		5	SDWA - Combined Primary + Secondary Stds
CO Regulation No. 11	mg/L	totals			0.010	0.005	1.3		0.015		--		5 CCR 1002-11 (AS OF 5/7/2018)
CO Regulation No. 11	mg/L	totals	6.5 - 8.5	0.05 - 0.20			1.0	0.3		0.05		5	5 CCR 1002-11 (AS OF 5/7/2018)
CO Regulation No. 11	mg/L	totals	6.5 - 8.5	0.05 - 0.20	0.010	0.005	1.0	0.3	0.015	0.05		5	
CO Reg 31 - Basic Surf Stds Aquatic Life - Acute	**ug/L**	Total		**2,307**	**340**	**2.13**	**10.2**	**N/A**	**47**	**2713**	**367**	**123**	adjusted for hardness at 75 mg/L data per formula's provided by CDPHE on 6/20/2018. As, Fe not hardness affected
CO Reg 31 - Basic Surf Stds Aquatic Life - Chronic	**ug/L**	Total		**329**	**150**	**0.342**	**7.004**	**1000**	**1.837**	**1499**	**40.8**	**93**	adjusted for hardness at 75 mg/L data per formula's provided by CDPHE on 6/20/2018. As, Fe not hardness affected
CO Reg 31 - Basic Surf Stds	**ug/L**	Total	6.5 - 9.0		**100**	**10**	**200**		**100**	**200**	**200**	**2000**	5 CCR 1002-31 (AS OF 1/31/2018)
CO Reg 31 - Basic Surf Stds	**ug/L**	Total		-	**0.02-10**	**5**	**1000**	**300 (dis)**	**50**	**50 (dis)**	**100**	**5000**	5 CCR 1002-31 (AS OF 1/31/2018)
CO Reg 41 - Basic GW Stds	mg/L	Total			0.01	0.005			0.05		0.1		
CO Reg 41 - Basic GW Stds	mg/L	Total	6.5 - 8.5				1	0.3				5	
CO Reg 41 - Basic GW Stds	mg/L	Total	6.5 - 8.5	5	0.1	0.01	0.2	5	0.1	0.2	0.2	2	

Rigor Level Allocation of Federal and State Numeric Water Quality Standard Thresholds: Most, Moderate, Least

Regulation	Units	Method	pH (S.U.)	Al	As	Cd	Cu	Fe	Pb	Mn	Ni	Zn	Comments
Most Stringent Ltds	**mg/L**	**totals**	**6.5 - 8.5**	**0.05**	**0.00002**	**0.0003**	**0.007**	**0.3**	**0.002**	**0.05**	**0.04**	**0.09**	**Most stringent numeric limits by parameter**
Moderately Stringent Ltds	**mg/L**	**totals**	**6.5 - 9.0**	**0.329 - 2.307**	**0.150**	**0.002**	**1.000**	**1.000**	**0.047**	**1.499**	**0.200**	**0.123**	**Moderately stringent numeric limits by parameter**
Least Stringent Ltds	**mg/L**	**totals**	**3.7 - 9.0**	**5**	**0.340**	**0.01**	**1.3**	**5**	**0.1**	**2.713**	**0.37**	**5**	**Least stringent numeric water limits by parameter**
USEPA - LDR's	mg/L	1311		--	5	0.11	--	--	0.75	--	11	4.3	**Treatment Standard if RCRA waste exhibits characteristic toxicity**
RCRA Limits	mg/L	1311	<2 & >12.5	--	5.0	1.0	--	--	5.0	--	--	--	**RCRA - Toxicity Characteristics, if material is deemed a Solid Waste**

USEPA and CDPHE Water Quality Commission: Numeric Standards
vs.
Quicklime and MBT Treated GKM Lime Solids, Kittimac Tailings and GKM Lime Solids:Kittimac Tailing Material Blends

LEAST Stringent/Restrictive Water Quality Numeric Low Level Standards vs. Heavy Metals in Treated Material TCLP Extracts

Waste/Blend of Waste	Units	Method	*pH (S.U.)	Al	As	Cd	Cu	Fe	Pb	Mn	Ni	Zn	Comments	
UNTREATED - GKM Lime Solids	mg/Kg	totals	8.29	60,100	70.5	175	13,100	246,000	64.1	22,600	103	39,200	Data from 10/2017 field trials	
UNTREATED - Kittimac Tailings	mg/Kg	totals	8.11	2162	5.37	<0.89	253	4686	3540	43.6	<0.89	161		
Least Stringent Ltds >>>	**mg/L**	**TCLP**	**3.7 - 9.0**	**5**	**0.1**	**0.01**	**1.3**	**5**	**0.1**	**0.2**	**0.2**	**5**	**Least stringent numeric limits by parameter**	
UNTREATED - GKM Lime Solids	mg/L	**TCLP**	8.29	9.11	<0.103**	0.579	21.3	<0.102	0.022	107	0.029	152	Al, Cd, Cu, Mn, Zn over.	
UNTREATED - Kittimac Tailings	mg/L	**TCLP**	8.11	0.51	<0.100	<0.025	0.77	3.47	**62.6**	0.14	<0.01	0.83	Pb over	**RCRA Hazardous waste**
UNTREATED- LS:KT (1:1)	mg/L	**TCLP**	7.91	7.98	<0.0005	0.25	12.8	1.6	**17.1**	47.7	0.15	53.6		
UNTREATED- LS:KT (1:2)			NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	not tested (NT)	cost control
UNTREATED- LS:KT (1:5)			NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	not tested (NT)	cost control
Quicklime (CaO) Treated														
Kittimac Tailings	mg/L	**TCLP**	12.08	14.9	<0.100	<0.025	2.1	22.5	**67.7**	0.24	<0.010	0.80	Al, Cu, Fe, Pb, over. Mn close	**RCRA Hazardous waste**
GKM Lime Solids	mg/L	**TCLP**	10.95	2.51	<0.0005	0.43	10.3	0.29	0.07	87.9	0.23	72.5		Non-haz
GKM LS:Kittimac Tailings (1:1)	mg/L	**TCLP**	11.84	2.11	<0.100	0.19	5.01	1.08	**2.69**	12.2	0.08	37.6	Cd, Cu, Fe, Pb, Mn, Zn over	Non-haz
GKM LS:Kittimac Tailings (1:2)	mg/L	**TCLP**	11.57	11.0	<0.100	0.14	8.17	5.00	**15.1**	11.1	0.08	33.8	Al, Cd, Cu, Fe, Pb, Mn, Zn over. Fe close	**RCRA Hazardous waste**
GKM LS:Kittimac Tailings (1:5)	mg/L	**TCLP**	11.73	5.31	<0.100	0.06	4.33	0.28	**26.5**	2.66	0.04	16.3	Al, Cd, Cu, Pb, Mn, Zn over	**RCRA Hazardous waste**
MBT Treated														
Kittimac Tailings	mg/L	**TCLP**	8.64	0.09	0.027	<0.005	0.04	0.28	0.034	0.035	<0.010	0.03	All Pass	
GKM Lime Solids	mg/L	**TCLP**	8.9	<0.046	<0.103	<0.250	<0.113	<0.102	<0.018	0.356	<0.250	0.027	Mn close/over - optimizable to WQS	10/2017 field trial data
GKM LS:Kittimac Tailings (1:1)	mg/L	**TCLP**	10.26	<0.010	<0.100	<0.025	0.02	0.11	<0.050	0.6	<0.02	0.02	Mn over - optimizable	
GKM LS:Kittimac Tailings (1:2)	mg/L	**TCLP**	10.07	0.22	<0.100	0.06	1.29	0.33	0.11	24.2	0.11	7.65	Cd, Mn, Zn over. Pb close	optimizable
GKM LS:Kittimac Tailings (1:5)	mg/L	**TCLP**	10.05	0.85	<0.100	<0.025	2.69	0.25	0.34	12.9	0.06	13.7	Cu, Pb, Mn, Zn over	optimizable

USEPA and CDPHE Water Quality Commission: Numeric Standards
vs.
Quicklime and MBT Treated GKM Lime Solids, Kittimac Tailings and GKM Lime Solids:Kittimac Tailing Material Blends

MODERATELY Stringent/Restrictive Water Quality Numeric Low Level Standards vs. Heavy Metals in Treated Material TCLP Extracts

Waste/Blend of Waste	Units	Method	*pH (S.U.)	Al	As	Cd	Cu	Fe	Pb	Mn	Ni	Zn	Comments	
UNTREATED - GKM Lime Solids	mg/Kg	totals	8.29	60,100	70.5	175	13,100	246,000	64.1	22,600	103	39,200	Data from 10/2017 field trials	
UNTREATED - Kittimac Tailings	mg/Kg	totals	8.11	2162	5.37	<0.89	253	4686	3540	43.6	<0.89	161		
Moderately Stringent Ltds >>>	**mg/L**	**TCLP**	**6.5 - 9.0**	**0.2**	**0.01**	**0.01**	**1.0**	**0.3 (dis)**	**0.05**	**0.05 (dis)**	**0.2**	**5**	**Moderately stringent numeric limits by parameter**	
UNTREATED - GKM Lime Solids	mg/L	**TCLP**	8.29	9.11	<0.103**	0.579	21.3	<0.102	0.022	107	0.029	152	Al, Cd, Cu, Mn, Zn over.	
UNTREATED - Kittimac Tailings	mg/L	**TCLP**	8.11	0.51	<0.100	<0.025	0.77	3.47	**62.6**	0.14	<0.01	0.83	Al, Fe, Pb, Mn over.	**RCRA Hazardous waste**
UNTREATED- LS:KT (1:1)	mg/L	**TCLP**	7.91	7.98	<0.0005	0.25	12.8	1.6	**17.1**	47.7	0.15	53.6		**RCRA Hazardous waste**
UNTREATED- LS:KT (1:2)			NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	not tested (NT)	cost control
UNTREATED- LS:KT (1:5)			NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	not tested (NT)	cost control
Quicklime (CaO) Treated														
Kittimac Tailings	mg/L	**TCLP**	12.08	14.9	<0.100	<0.025	2.1	22.5	**67.7**	0.24	<0.010	0.80	Al, Cu, Fe, Pb, Mn over	**RCRA Hazardous waste**
GKM Lime Solids	mg/L	**TCLP**	10.95	2.51	<0.0005	0.43	10.3	0.29	0.07	87.9	0.23	72.5		Non-haz
GKM LS:Kittimac Tailings (1:1)	mg/L	**TCLP**	11.84	2.11	<0.100	0.19	5.01	1.08	**2.69**	12.2	0.08	37.6	Al, Cd, Cu, Fe, Pb, Mn, Zn over	Non-haz
GKM LS:Kittimac Tailings (1:2)	mg/L	**TCLP**	11.57	11.0	<0.100	0.14	8.17	5.00	**15.1**	11.1	0.08	33.8	Al, Cd, Cu, Fe, Pb, Mn, Zn over	**RCRA Hazardous waste**
GKM LS:Kittimac Tailings (1:5)	mg/L	**TCLP**	11.73	5.31	<0.100	0.06	4.33	0.28	**26.5**	2.66	0.04	16.3	Al, Cd, Cu, Pb, Mn, Zn over	**RCRA Hazardous waste**
MBT Treated														
Kittimac Tailings	mg/L	**TCLP**	8.64	0.09	0.027	<0.005	0.04	0.28	0.034	0.035	<0.010	0.03	As over - optimizable to WQS	
GKM Lime Solids	mg/L	**TCLP**	8.9	<0.046	<0.103	<0.250	<0.113	<0.102	<0.018	0.356	<0.250	0.027	Mn close/over - optimizable to WQS	10/2017 field trial data
GKM LS:Kittimac Tailings (1:1)	mg/L	**TCLP**	10.26	<0.010	<0.100	<0.025	0.02	0.11	<0.050	0.6	<0.02	0.02	Mn over - optimizable	
GKM LS:Kittimac Tailings (1:2)	mg/L	**TCLP**	10.07	0.22	<0.100	0.06	1.29	0.33	0.11	24.2	0.11	7.65	Cd, Cu, Pb, Mn, Zn over - Al/Fe close	optimizable
GKM LS:Kittimac Tailings (1:5)	mg/L	**TCLP**	10.05	0.85	<0.100	<0.025	2.69	0.25	0.34	12.9	0.06	13.7	Al, Cu, Pb, Mn, Zn over	optimizable

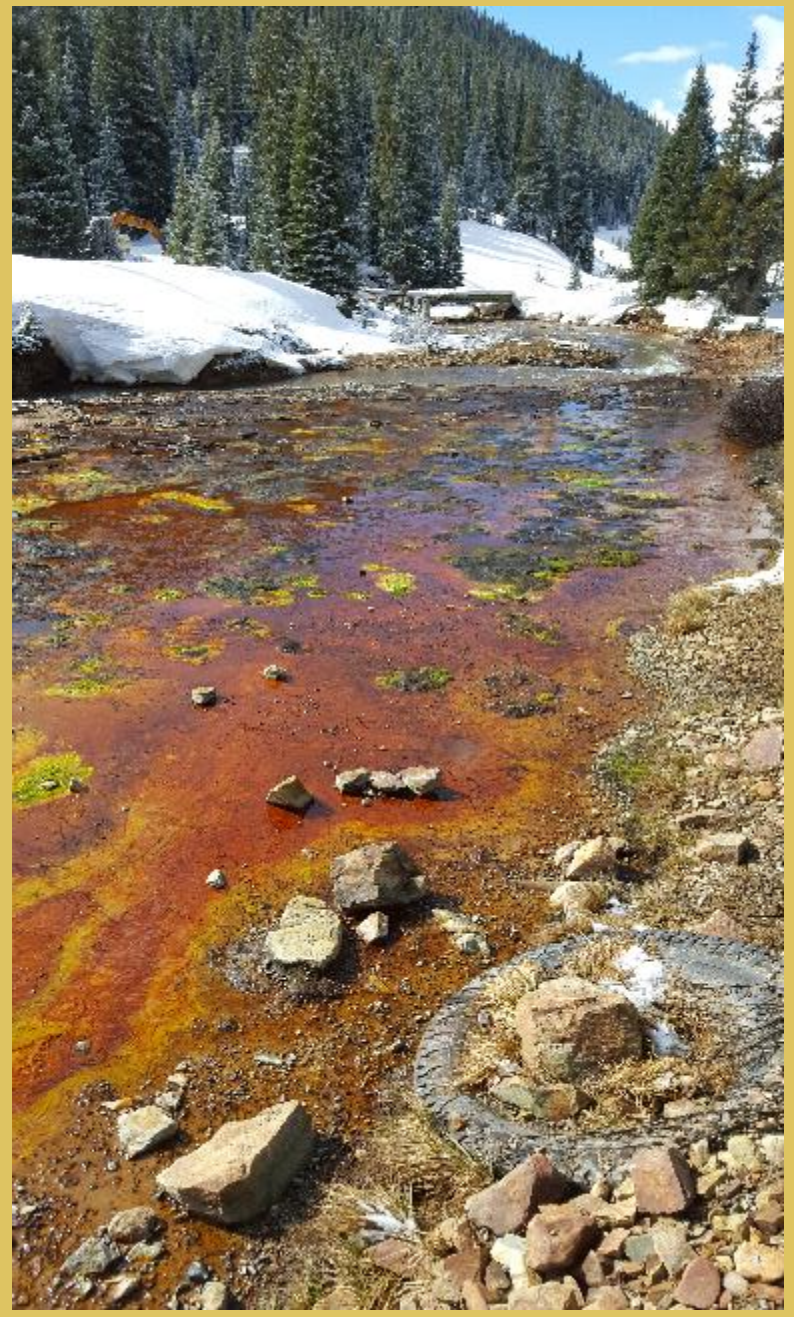
USEPA and CDPHE Water Quality Commission: Numeric Standards
vs.
Quicklime and MBT Treated GKM Lime Solids, Kittimac Tailings and GKM Lime Solids:Kittimac Tailing Material Blends

Most Stringent/Restrictive Water Quality Numeric Low Level Standards vs. Heavy Metals in Treated Material TCLP Extracts (See Table 1)

Waste/Blend of Waste	Units	Method	*pH (S.U.)	Al	As	Cd	Cu	Fe	Pb	Mn	Ni	Zn	Comments	
UNTREATED - GKM Lime Solids	mg/Kg	totals	8.29	60,100	70.5	175	13,100	246,000	64.1	22,600	103	39,200	Data from 10/2017 field trials	
UNTREATED - Kittimac Tailings	mg/Kg	totals	8.11	2162	5.37	<0.89	253	4686	3540	43.6	<0.89	161		
Most Stringent Ltds >>>	**mg/L**	**TCLP**	**6.5 - 8.5**	**0.05**	**0.00002**	**0.005**	**0.2**	**0.3**	**0.015**	**0.05**	**0.1**	**2**	**Most stringent numeric limits by parameter**	
UNTREATED - GKM Lime Solids	mg/L	**TCLP**	8.29	9.11	<0.103**	0.579	21.3	<0.102	0.022	107	0.029	152	Al, Cd, Cu, Mn, Zn over. Pb close	10/2017 field trial data
UNTREATED - Kittimac Tailings	mg/L	**TCLP**	8.11	0.51	<0.100	<0.025	0.77	3.47	**62.6**	0.14	<0.01	0.83	Al, Cd, Cu, Fe, Pb, Mn over.	**RCRA Hazardous waste**
UNTREATED- LS:KT (1:1)	mg/L	**TCLP**	7.91	7.98	<0.0005	0.25	12.8	1.6	**17.1**	47.7	0.15	53.6	all over but As	**RCRA Hazardous waste**
UNTREATED- LS:KT (1:2)	mg/L	**TCLP**	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	not tested (NT)	cost control
UNTREATED- LS:KT (1:5)	mg/L	**TCLP**	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	not tested (NT)	cost control
Quicklime (CaO) Treated														
Kittimac Tailings	mg/L	**TCLP**	12.08	14.9	<0.100	<0.025	2.1	22.5	**67.7**	0.24	<0.010	0.80	Al, Cu, Fe, Pb, Mn over	**RCRA Hazardous waste**
GKM Lime Solids	mg/L	**TCLP**	10.95	2.51	<0.0005	0.43	10.3	0.29	0.07	87.9	0.23	72.5	All over but As and Fe	
GKM LS:Kittimac Tailings (1:1)	mg/L	**TCLP**	11.84	2.11	<0.100	0.19	5.01	1.08	**2.69**	12.2	0.08	37.6	Al, Cd, Cu, Fe, Pb, Mn, Zn over	Non-haz
GKM LS:Kittimac Tailings (1:2)	mg/L	**TCLP**	11.57	11.0	<0.100	0.14	8.17	5.00	**15.1**	11.1	0.08	33.8	Al, Cd, Cu, Fe, Pb, Mn, Zn over	**RCRA Hazardous waste**
GKM LS:Kittimac Tailings (1:5)	mg/L	**TCLP**	11.73	5.31	<0.100	0.06	4.33	0.28	**26.5**	2.66	0.04	16.3	Al, Cd, Cu, Pb, Mn, Zn over	**RCRA Hazardous waste**
MBT Treated														
Kittimac Tailings	mg/L	**TCLP**	8.64	0.09	0.027	<0.005	0.04	0.28	0.034	0.035	<0.010	0.03	Al, As over. Pb close. All optimizable to WQS	
GKM Lime Solids	mg/L	**TCLP**	9.11	<0.046	<0.103	<0.250	<0.113	<0.102	<0.018	0.356	<0.250	0.027	Mn close/over - optimizable to WQS	10/2017 field trial data
GKM LS:Kittimac Tailings (1:1)	mg/L	**TCLP**	10.26	<0.010	<0.100	<0.025	0.02	0.11	<0.050	0.6	<0.02	0.02	Mn over - optimizable to WQS	
GKM LS:Kittimac Tailings (1:2)	mg/L	**TCLP**	10.07	0.22	<0.100	0.06	1.29	0.33	0.11	24.2	0.11	7.65	Al, Cd, Cu, Pb, Mn, Zn over - Fe/Ni close	optimizable
GKM LS:Kittimac Tailings (1:5)	mg/L	**TCLP**	10.05	0.85	<0.100	<0.025	2.69	0.25	0.34	12.9	0.06	13.7	Al, Cu, Pb, Mn, Zn over	optimizable

Field Trial Summary

- AMD Treatment Alternatives to lime are available that meet numeric standards and be inserted within mine tunnels/adits, etc.
- Leachable hazardous metal substances defined by CERCLA can be treated for long-term chemical stability for viable in-mine/in-mine pool management
- Reputable contractors coupled with technology providers are willing to take the risk of treatment failure using hard dollar, fixed/unit price bonded contracting mechanisms---need the opportunity and defined performance requirements



QUESTIONS?

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