In-Pit Disposal of Taconite Tailings

#6524

Laboratory Column Simulations

Final Sampling Summary June 30, 2001

Minnesota Department of Natural Resources

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Situation

As part of the In-Pit Taconite Tailings Disposal Project, taconite tailings and process waters for the experiments were collected from National Steel, Ispat Inland, and LTV Steel. Column experiments were initiated to study tailings-water interactions. Six columns (2 in. id x 15 ft), two for tailings-process water from each mine, were installed in the mezzanine at the DNR facility in Hibbing, MN. Approximately one pore volume of process water was passed through the columns over a fifty seven week period of time. Samples were taken periodically, for a total of nine samples per column.

Upon completion of the tailings-process water interaction experiments, interaction between tailings and rain water and tailings and ground water were studied. Process water was replaced by "rain" (i.e. deionized) water in one column of tailings from each mine (Oct. 10, 1997). Samples were taken periodically for 560 days (May, 1999). Ground water collected from a well in Keewatin, MN was used for the duplicate column (Sept. 26, 1997). Samples from the ground water columns were taken periodically for thirty weeks (April, 1998).

Justification

Due to a renovation project, the columns will be dismantled in March 2001. The rain water and ground water columns will have sat dormant for approximately 22 and 34 months, respectively. Thus, tailings-water interactions that may have been kinetically controlled should have had adequate time to equilibrate. One to three samples (depending on time constraints) will be taken to determine whether or not further reaction has occurred.

Expectations

Ground water interactions

Based on the concentration trends observed for relatively conservative parameters, Berndt et al. (1999) concluded that little to no reaction occurred between the tailings and ground water. Similar trends were observed for fluoride, arsenic, molybdenum, and boron. Manganese, however, may have been controlled by a carbonate mineral phase, and therefore, the P_{CO2} of the ground water. The low level of reactivity was believed to be due to the lack of dissolved oxygen in the system.

Assuming that there are no kinetically limited reactions controlling Mn, F, As, Mo, and B in the tailings-ground water environment. The concentrations of these elements in subsequent samples should be similar to those already observed. Any differences in concentrations would suggest that controlling reactions are slow.

Rain water interactions

Approximately six pore volumes of "rain" water was passed through the columns. Elevated Mg, Ca, and HCO_3 concentrations as well as high conductivity values indicated that carbonate minerals were the most reactive in taconite tailings. Manganese, again, was likely controlled by dissolution of a carbonate mineral phase. Fluoride levels were believed to be controlled by an adsorbed phase. However, the possibility of a mineral (i.e. CaF_2) phase control could not be entirely ruled out. Molybdenum and possibly boron were desorbed by rinsing with the dilute water. Little mobilization of arsenic was observed.

It was concluded at the end of this experiment that the columns had reached equilibrium (Berndt et al., 1999). Since the previous sample (560 days, sampled after approximately one year of dormancy) also indicated equilibrium conditions, no change in water chemistry is anticipated.

Sampling Procedure

Sampling of the columns started on 7/11/96. Mike Berndt attached tubing that was resistant to gas flow to the bottom of the columns. The end of the tubing was fitted with a Leur-loc fitting. Samples were collected by connecting a 30ml syringe with a Leur-loc end to the fitting on the tubing. Samples were collected for both the "slow" and the "fast" columns with this method.

The "slow" columns were sampled with the syringes until 7/31/97. At this time the column water was replaced with ground water from the Keewatin well. This process was approximately 6 weeks. Sampling was started on 9/27/97 using the same syringe method until 12/18/97. At this time the sampling method changed by allowing the effluent to flow freely into a sample bottle with a hole cut into the cap that was large enough for the tubing to fit thru the hole with a snug fit. Samples for the ground (slow) columns were collected into the open bottle until 8/19/98, at which time the experiment ended. Additional samples were collected on 2/6/01 and 2/20/01 using the syringe method as described above.

The "fast" columns were sampled with syringes until 10/10/97. At this time water was removed from above the column bed and replaced with rainwater (DDI water from the lab). The water was spiked with sodium bromide to determine when the water in the bed had been replaced with "rainwater". Sampling started on 11/6/97 using the same open bottle method as the ground water columns until 8/20/98. An additional isotope sample was collected on 2/10/99 using the open bottle method. On 2/6/01 and 2/20/01, samples were collected using the same syringe method as above.

Results Ground water interactions - Fluoride

In-Pit Ground Water Columns

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Dashed line represents original pore water concentrations. Fluoride primary and secondary drinking water quality standards are 2 ppm and 4ppm, respectively



In-Pit Ground Water Colum





In-Pit Ground Water Columns

Dashed lines represent inital pore water concentrations The drinking water quality standard was set at 1300 ppb



In-Pit Ground Water Columns

Dashed lines represent inital pore water concentrations. The drinking water quality standard is currently 50 ppb.



In-Pit Ground Water Columns

Dashed lines represent inital pore water concentrations. The drinking water quality standard is 30 ppb.



In-Pit Rain Water Columns

Dashed lines represent drinking water quality sta





Inland



In-Pit Rain Water Colum



In-Pit Rain Water Columns



Dashed lines represent drinking water quality sta:

In-Pit Rain Water Columns



Dashed lines represent drinking water quality star

Conclusions Ground water interactions

Concentrations of all five parameters are approaching those of the initial pore water. This supports Berndt et al (1999) conclusion that the injected ground water merely mixed with existing pore water and no significant reactions took place (pg 20). It appears as though sampling has removed a large portion of the injected ground water. Subsequent samples are likely to be dominated by pore water chemistry.

Rain water interactions

These data generally support the above conclusion. Boron concentrations appear to have increased slightly, approaching those of the initial pore water. Manganese concentrations, particularly in the National columns, may have decreased somewhat.

References

Berndt, M.E.; Lapakko, K.A.; Jakel, M.E. 1999. In-pit disposal of taconite tailings: geochemistry. Final report. MN Dept. Nat. Resour., Division of Lands and Minerals, Saint Paul, MN. 77 p. plus appendices.

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Appendix 1

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Laboratory Notes

IN-Pit taconite Columns EXPERIMENT: DATE REAC COMMENTS (p lima 511 A 11 5 PC Ũ annu he WCA 4 (B) Eh th. 10 sta 76 endin A.A 1 and 0 line Q an 10 m.A. (3) Eh met against Л ins Inci Sol. 7.00 M Un 11 Val l sa 263 83.5 82 nll 7

Columns (tailing Basins EXPERIMENT: COMMENTS tes on columns slow. The DATE REAC 11/96 Column's flow rate may be blower Inland Fast Jolumn, started 3:50 pm. Welected & 2.5ml 4:50 pm 26/4 ollected in ondy, ITV sen. to have a fine probe (i)815190 UPIAn rone 11. eren so Alectivole Reference 2.6 260.1 80 86.7 8/8/96 \mathcal{O} Ceas value Takren 115

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LAB NOTES

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LAB NOTES EXPERIMENT: Columns

LAB NOTES EXPERIMENT: Columns COMMENTS REAC DATE Const (T Nd Ch. Emple Collecter Voti O Eu from immo Tare ut Sample k Inl-F-10 34.72 57,12 22 270-F-10 77,96 34,91 43.05 10/4/96 Ô , an Remova lay San Ke um canse to not der. 2 were 620 's are 1 Ì Laho, 10 take 10 1 L o L o Entra Wal IN 63 LS. The lum

EXPERIMENT: DATE REAC COMMENTS 3 ollimns 96 Ń U on & anion so Ċa ples an m 3 10 ma Le. 52 a v un 2 1 GUN 0 nr 1543 Ta Ell A Dum ZS line a 11 7r -- 1 5 was M 0 m 3 0 timit Mn Ì لجمته 1 Sam ÍЛ. ni C. Z ho wa log ww 22 1 ne

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LAB NOTES

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LAB NOTES

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		of Draining			
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		taken alter thumber was purged of an			
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		Manner as preveous samples			
Intiz las	(î)	Startilian St t. I di tt lan			
913/91		With which and and and prome			
		JU UL II CALS			

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DATE REAC COMMENTS Kenoved water from top of fast columns by using the "guagler" 10/10/97 $\widehat{}$ sler" sump tuben a an AT1. amono well. au dumme al n at Bottles were the enc mme toflow were allowed ums 11/6/97 11/4/91 as of Ŵ Inland 131.6 mls/day LTV 146.7 mls/day National 94.8 mls/day average flow: Inland collection Totals: Inland 2408.5mls LTU 2797.9 mls National 1728.9 pls

EXPERIMENT: In-Pit Columns

LAB NOTES

DATE	REAC	COMMENTS
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, ,		2.5 leter of rain water was
		"run" the samples where takes
		on 15/5/91 The astumns were
		allowed to "un" whit 3,5 liter
		were this a sample was taken
		after 3.5 liter then allowed
		to un unlig a total of 4.0 laters
		was The has sampled again
int 1		All soften A
12/19/97	-0	pH reading were taken
		from allh alenery samples
12/18/02	Ô	Sample lam barra lutate Columns
1-110/41		were taken into a 60 ml sample
······································		Bottly will a hole cut in the
		love to allow typor tubing
		to fit through, Somples were
		collected by turning on value
		and allowing free flow into
		sample Battle. Cuttin sample
	· · · · · · · · · · · · · · · · · · ·	where acidified by placing 100
		of HNO3 into bottle and samp
		allowed to collect the
		appropriate amont of Alm
		for acid amount used.

EXPERIMENT:

LAB NOTES

EXPERIMENT: DATE REAC COMMENTS time Duplicate al Ø 16/98 Na \mathcal{D} wate λ Sealier Mars Met Blaker San Sam 56.81 4 84 h 5 3/33/98 continour S Ø tu Le IN. \sim in wat Mr. mis ' 1 00 tu lo n 6 (ling Ð Nain water 3 e ited 30/98 em ð P le Âı · Car 1 was L RK a l -3. 9 h. 1h ler rus é d 1 CI a

DATE	REAC	COMMENTS
4/23/98		flow reading is not accurate due
		to leaky connection at the
		volve
2/1/99		Kain Water Columno
/ /		O Bleed Volgeme was collected
		from lack Kan Water Column
		OU 133 pl sotope sample
		was taken from Each RW colu
		arme water leather to flood
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		a Ala I. P. A. S. S. C. L.
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		anton sample addiaper
2/5/01		Trimite Columns are due to be
1.1		dismonthed sometimal in the spring
		of 2001. Both Ground water and
		I ain waters are to be sampled
		twice. I weeks arout I Somes are
		to be collected in 2-60 ml Bottley
900 BC - A		I me for milals, me for amins) and
		sent to let 1952 for analysis,
		Samples to be collected in bonly
		sylinges to reduce the effects of
		alygen on the metals sample.

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XPERIM	ENT:				-
DATE	REAC		COMMENTS		
3/05/01		Column	Tailingsht,	Water ht. (ol	ouls
· · ·		Inl-GW	803/4"	15%"	
		Inl-RW	8612"	(108") 36%+2+	69;
		STV-GW	96 3/4"	13"	
		STV-RW	8915	87/4/331/2+2+	5134
		Nat-GW	89"	10%	
		Nal-RW	8212"	(101)39/3+2+52	1,11
·		Noticed water a	I the base	of Inland	
		not present in	n 1/31/01	when the	
		for sampling			
		started samplin	3 at 0800 h	us on 2/5/01	
				· · · · ·	