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TAILINGS BASIN WATER QUALITY BASED ON LEVEL II WATER BUDGET USING A CONSERVATIVE MASS BALANCE CALCULATION

Regional Copper-Nickel Study
Minnesota Environmental Quality Board

Author: Kim Lapakko

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The objectives of this section are to develop a method of determining aqueous chemic concentrations of various parameters in the tailings basin and to make initial estimations of potential concentrations of copper, nickel, cobalt, zinc, and sulfate. Water quality of the tailings basin is of environmental concern when considering the possibility of seepage into ground water, spillage within milling operations and accidental discharge from the tailings basin. Water quality considerations may also affect decisions regarding treatment of and/or metals recovery from the tailings basin water. The efficiency of differential flotation processes is also dependent upon the quality of water used (Iwasaki, et al. 1975).[1]

Determination of water quality within the tailings basin involves consideration of the quality and quantity of flow into and out of the tailings basin. In addition it is necessary to include the change of water quality with time due to chemical conditions within the tailings basin. Integration of these three factors yields the final concentration for a given chemical parameter.

As an initial estimation the tailings basin water quality will be assumed to be the quality of the combined inputs for a 20 x 10^6 mtpy open pit operation. For a given parameter the final concentration may be expressed $C_f = \frac{\Sigma C_i V_i}{\Sigma V_i}$, where C_i and V_i are the volume and concentration from a given source and C_f the final concentration of the parameter. The input volumes and concentration are presented in Table 1. The sources of the values used are given below the table. Mass inputs and final concentrations are listed in Table 2.

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[1] Removal of Potential Copper & Nickel Pollutants from Mine and Mill Effluents Preliminary Study.

Note that two models are presented for the concentrations in water from the open pit. The concentrations in model A are based on data from the U.S. Steel bulk sample site, and are orders of magnitude higher than those in model B, which are based on data from the Amax basin inflow.

Both volume and concentration from a given source are important. The volume of input from the various sources was determined in the Level II Water Budget Report. The methodology involved determination of runoff coefficients for the various areas contributing flow to the tailings basin. The runoff coefficient for a given site represents the fraction of precipitation on the site which is transported to the tailings basin. Two methods were used to determine the volume of runoff. The results varied slightly due to different assumptions regarding evaporative losses. Only values from method I were used in calculations. This method assumes an inverse relationship between precipitation and evaporation. This probably overestimates wet year runoff, and thus represents a worst case estimate. The concentrations used are from situations similar to those predicted at the proposed mining site and represent potential site conditions. They are not intended to be used in the context of precise prediction.

The values presented in Table 2 indicate the relative importance of the mass input from various sources. The majority of chemical mass is contributed by the stockpiles of lean ore and waste rock and the open pit mine, particularly using model A. A range of input is presented for the open pit due to the wide range in previously observed cases. It seems likely that the actual contribution would be near the lower end of the range presented.

Chemical contribution from overburden piles, the plant site and the undisturbed watershed is small and is generally negligible in comparison to the lean ore, waste rock and open pit. However, the magnitude of contribution from these areas may increase due to impacts from mining processes such as dust generation, with subsequent deposition onto the undisturbed areas, overburden piles, and plant site.

The total volume of runoff collected may depend on water requirements for the milling process. The make up water requirements are due to various losses and are presented in Table VIII of the Level II Water Budget Report. The volume of runoff does not necessarily equal the water volume required for the milling process. For the purpose of calculation it was assumed that if runoff exceeded requirements, unimpacted water from the undisturbed watershed and plant site would be diverted. If milling requirements exceeded runoff it was assumed that additional water of a negligibl chemical content was appropriated. These assumptions imply that the chemical mass input to the tailings basin is constant.

The constant mass is that from the sources contributing contaminated water such as the stockpiles and the open pit. Collection of these waters is given priority. Additional collection due to the net effect of precipitation and evaporation on the tailings basin has also been considered. The sum of these two volumes represents the minimum input to the tailings basin.

The volume of make up water required for the milling process depends on the permeability of the base of the tailings basin. As the permeability of the base increases the loss of water due to seepage increases, therefore the makeup water requirement increases.

The concentrations for five situations are presented in Table 3. The concentrations represent the constant mass inputs presented in Table 2 divided by a variable volume of input, thus as the volume collected increases the concentration decreases. The first case represents the volume due to collection of all runoff from the mining and milling site. The second case represents the volume due to minimum runoff collection of impacted waters and net precipitation on the basin. The final three cases are based on collection of a volume equal to that required by milling processes.

It is of importance to note that for an impermeable or semi-permeable base in a wet year the minimum collection volume exceeds the volume required for milling. Under these conditions it is necessary to provide storage or treatment for the excess to avoid discharging impacted water to the environment. In the other cases the mining requirements exceed the minimum collection volumes.

There are additional variables which will cause variations in the predicted concentrations. The effect of smelting processes has not been considered. The volumetric runoff inputs have been determined using the mine characteristics at the end of mining operations. These characteristics tend to increase the mass loading to the tailings basin. Potential changes in concentration due to chemical considerations are ignored. The chemical nature of the system may be greatly affected by milling processes. Data from pilot-plant Copper-Nickel studies indicated that the pH of tailings discharge may be in the range of 8-9. This would facilitate metals removal by hydroxide precipitation. Low pH in the tailings basin would tend to increase metals concentrations. Reagents used in the flotation process also tend to precipitate metals. Adsorption of metals onto taili would also tend to reduce metals concentrations. Although the concentrations predi are strictly a first order approximation they do indicate a potential for environmental impact. Monitoring of tailings basin water quality is advisable.

[illegible]

ource	Area HA	Method I				Method II				Concentration mgl^{-1}				
		AVE[a]		WET[b]		AVE[a]		WET[b]						
		K_{ro}	V^c_{ro} $1*10^{-6}$	K_{ro}	V^c_{ro} $1*10^{-6}$	K_{ro}	V^c_{ro} $1*10^{-6}$	K_{ro}	V^d_{ro} $1*10^{-6}$	Cu	Ni	Co	Zn	SO_4
lant Site	160	0.75	880	0.85	1400	0.75	880	0.82	1300	~0[j]	~0[j]	~0[j]	~0[j]	~0[j]
pen (A)	230	0.46	760	0.68	1500	0.46	760	0.61	1400	21[e]	25[e]	0.62[f]	0.22[f]	438[e]
it (B)	230	0.46	760	0.68	1500	0.46	760	0.61	1400	0.004[k]	0.060[k]	0.003[k]	0.058[k]	11[k]
verburden iles	70	0.37	180	0.62	430	0.37	180	0.54	370	0.011[i]	0.012[i]	~0[j]	~0[j]	~0
aste Rock iles	400	0.30	880	0.58	2300	0.30	880	0.49	1900	0.053[g]	2.42[g]	0.021[g]	0.040[g]	1260[g]
ean Ore iles	400	0.30	880	0.58	2300	0.30	880	0.49	1900	1.71[h]	39.8[h]	2.4[h]	2.4[h]	3620[h]
ndisturbed atershed	1200	0.43	3800	0.66	7800	0.43	3800	0.58	6900	~0[j]	~0[j]	~0[j]	~0[j]	~0[j]
ndergroud ine	0	--	--	--	--	--	--	--	--					
et PPT. (PPT.-Evap.)			4800		10,000									
ΣV:1 x 10^{-6}			7400		16,000									

[a] Ave Year: 28.57" PPT

[b] Wet Year: 39" PPT

[c] V_{ro} From Table VII Level II Water Budget Report, $1.233*10^6$ l (AC-FT) $^{-1}$ if two numbers listed, first number used

[d] $V_{ro} = K_{ro} * A*P* 2.54*10^5$ liters, A in hectares, P in inches

[e] USSPIT 2-5-77

[f] USSPIT 10-15-76

[g] Model I

[h] Model II

[i] AMAX Ref. # 750068, p. 18, 19 Ave. last 2 samp

[j] Assumed to be negligible

[k] From Physical, Chemical & Biological Data summary, 1977, AMAX. Basin inflow

Table 2:
Annual Volumetric & Mass Input to Tailings Basin; 20×10^6 mtpy Operation

Source	Vi $l(yr)^{-1}*10^{-6}$	Average Year Mass Leached: $mg*10^{-8}$ $(yr)^{-1}$					Vi^b $l(yr)^{-1}*10^{-6}$	Wet Year Mass Leached: $mg*10^{-8}$ $(yr)^{-1}$				
		Cu	Ni	Co	Zn	SO_4		Cu	Ni	Co	Zn	SO_4
Plant Site	880	0	0	0	0	0	1400	0	0	0	0	0
Open (A)	760	160	190	4.7	1.7	3300	1500	320	380	9.3	3.3	6600
Pit (B)	760	0.030	0.46	0.023	0.44	84	1500	0.060	0.90	0.045	0.87	160
Overburden	180	0.020	0.022	0	0	0	430	0.047	0.052	0	0	0
Waste Rock	880	0.47	21	0.18	0.35	11,000	2300	1.2	56	0.48	0.92	29,000
Lean Ore	880	15	350	21	21	32,000	2300	39	915	55	55	83,000
Undisturbed Watershed	3800	0	0	0	0	0	7800	0	0	0	0	0
Precip. on Tail. Basin^a (NET)	4800	0	0	0	0	0	10,000	0	0	0	0	0
Σ Mass: $mg*10^{-8}$ (A)		180	560	26	23	46,000		360	1400	65	59	120,000
Σ Mass: $mg*10^{-8}$ (B)		16	370	21	22	43,000		40	970	56	57	110,000
Σ Vol: $l \times 10^{-8}$		120	120	120	120	120		260	260	260	260	260
C_f: mgl^{-1} (A)		1.5	4.7	0.22	0.19	380		1.4	5.4	0.25	0.23	460
C_f: mgl^{-1} (B)		0.13	3.1	0.18	0.18	360		0.15	3.7	0.22	0.22	420

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[a] Precipitation-Evaporation

[b] Volumes by method I, Level II Water Budget Report

Table 3: Predicted volumes (1×10^{-8}) and Concentrations (in mgl^{-1})

Collection Criterion	Pit Model	Average Year						Wet Year					
		Vol $1*10^{-8}$	[Cu]	[Ni]	[Co]	[Zn]	[SO_4]	Vol $1*10^{-8}$	[Cu]	[Ni]	[Co]	[Zn]	[SO_4]
Total Runoff from Subsystem A	A	120	1.5	4.7	0.22	0.19	380	260	1.4	5.4	0.25	0.23	460
	B	120	0.13	3.1	0.18	0.18	260	260	0.15	3.7	0.22	0.22	420
Minimum runoff of impacted water and precipitation	A	75	2.4	7.5	0.35	0.31	610	170	2.1	8.2	0.38	0.35	710
	B	75	0.21	4.9	0.28	0.29	570	170	0.24	5.7	0.33	0.34	650
Results for basin water on impermeable base	A	80	2.2	7.0	0.32	0.29	580	80	4.5	18	0.81	0.74	1500
	B	80	0.20	4.6	0.26	0.28	540	80	0.50	12	0.70	0.71	1400
Results for basin water on semi-permeable base	A	90	2.0	6.2	0.29	0.26	510	90	4.0	16	0.72	0.66	1300
	B	90	0.18	4.1	0.23	0.24	480	90	0.44	11	0.62	0.63	1200
Results for basin water on permeable base	A	180	1.0	3.1	0.14	0.13	260	180	2.0	7.8	0.36	0.33	670
	B	180	0.089	2.1	0.12	0.12	240	180	0.22	5.4	0.31	0.32	610