Enchemica

Enchemica, LLC
2335 Buckingham Circle
Loveland, CO 80538 USA
1-970-481-9338

TECHNICAL MEMORANDUM

TO: Greg Ghidotti, Resolution Copper Mining

FROM: Ted Eary, Enchemica

DATE: July 8, 2020

SUBJECT: Nitrogen Chemical Loads and Concentrations in the Geochemical Models used for the Resolution Copper Project

1 INTRODUCTION

During the Water Working Group Meeting held on June 25, 2020, there was a request for more details about how nitrogen (N) chemical loads and concentrations were estimated in the block cave geochemistry and tailings solute models. The purpose of this memo is to provide these details and to serve as clarification to action item WR-20.

2 NITROGEN ESTIMATION METHOD

An example of the calculation method used to estimate chemical loads and concentrations for N compounds is shown in Figure 1. The numerical values in this example are specific to year 20 of the mine life, and the explanations and example calculations are for total N. The assumption was made in the models that any NH_4-N produced by explosives would be converted to NO_3-N during exposure to air and ore processing so that total N is equivalent to NO_3-N.

Additional details about the calculations shown in Figure 1 are given in the following sections.

2.1 Block Cave

There are two types of water expected to exit the block cave and enter the West Plant:

- Ore moisture
- Sump water

The methods to estimate total N concentrations in these two water types is provided below.

2.1.1 Ore Moisture

The use of ammonium nitrate-fuel oil (ANFO) explosive is expected to be the primary source of N compounds (NO_3 and NH_4) in the block cave mine. In the block cave geochemistry model, the rate of N production (N_p) in kg/yr from use of explosives was calculated from:

$$N_p = P_f \cdot E \cdot N_{anfo} \cdot N_{residual} \cdot B_m \qquad \text{Eq. 1}$$

The variables in Eq. 1 are:

P_f = Powder factor = 0.72 kg ANFO/tonne. This value was provided by RCM.

E = Fraction of ANFO in the ammonium nitrate-fuel oil mixture = 85%. This value was based on an example from Golder (2008). Liquid fuel makes up the remaining 15%.

N_{anfo} = Fraction of N in ANFO = 35%. This value is from the molecular formula of NH_4NO_3 for ANFO:

$$N_{anfo} = \frac{2 * 14}{14 + (4 * 1) + 14 + (3 * 16)} = 0.35$$

$N_{residual}$ = Fraction of residual N after blasting = 5%. The other 95% is converted to gases during explosions. The value of 5% is from Ferguson and Leask (1988) who estimated a residual amount of about 15% less than the 6% residual estimated by Pommen (1983). For comparison, estimates for Diavik waste rock test piles are reported to range from 0.1 to 6% but generally less than 3% (Bailey et al. 2011). All the residual N was assumed to be readily leachable in the block cave model.

B_m = Blasted mass of rock per year (Table 1). These data were provided by RCM. The rate of blasted rock is substantially less than the ore production rate because once draw-points are established, ore is produced by fracturing. No additional blasting is normally needed except for plugged draw-points.

In the block cave geochemical model, the rate of N production from use of explosives according to Eq. 1 was assumed to be transported to the West Plant in ore moisture. For example in Figure 1, the load of 14958 kg/yr from blasting divided into the ore moisture flow rate of 1.824 x 10^9 L/yr (917 gpm) gives a concentration of 8.2 mg/yr for total N in ore moisture.

2.1.2 Sump Water

Sump Water was expected to be comprised of inflows to the mine from the deep groundwater system and Apache Leap Tuff (ALT) and also blowdown water generated from cooling systems. In the block cave model, these water types were mixed in proportion to their flow rates and concentrations to give total N concentrations for Sump Water. In the example shown in Figure 1, Sump Water has a total N concentration of 0.7 mg/L based on the proportional mixing calculation.

2.2 West Plant and Tailings

Ore and water will enter the West Plant where they will be converted to tailings slurry after removal of ore concentrate. The types of water entering the West Plant include the following (concentrations and flows from the example shown in Figure 1):

- Ore moisture: 8.2 mg N/L at 917 gpm
- Sump water: 0.7 mg N/L at 2305 gpm
- Freshwater: 1.1 mg N/L at 6778 gpm
- Reclaim from the TSF: 3 mg/L at 5260 gpm

Total flow through the West Plant for the example in Figure 1 is 15260 gpm. In the tailings solute model, the concentration of total N in the water portion of the slurry exiting the West Plant was determined by proportional mixing of the above water types. This mixing calculation results in a total N concentration of 2.1 mg/L.

Ore processing was expected to be an additional source of total N for tailings slurry. Based on hydrometallurgical testing, the rate total N (NO_3-N + NH_4-N) release during processing was estimated at 0.2305 mg N/kg. For the production rate at year 20 shown in Figure 1, ore processing yields 9706 kg N/yr, which is equivalent to adding about 0.3 mg N/L to the water portion of the tailings slurry exiting the West Plant. This concentration is obtained by dividing the amount of 9706 kg N/yr by the total flow through the West Plant of 15260 gpm (3.0358×10^{10} L/yr). After these calculations, the total N concentration in tailings slurry is estimated at 2.4 mg/L (2.1 mg/L from mixing + 0.3 mg/L from release during ore processing).

At this point in the system, the details of the calculation of total N for all the other parts of the tailings system are too complex to be shown in a simple diagram due to the number of feedback and re-cycling loops between the various parts of the tailings management systems, such as seepage collection, reclaim pumping, cyclones, thickeners, bleed water, etc.

A general description of the system is that the West Plant generates pyrite tailings and scavenger tailings. Scavenger tailings are deposited on and behind the embankment. Pyrite tailings are deposited in the pyrite cells. Excess water is collected and stored in the TSF Reclaim Pond, which is the source of re-cycled water going back to the West Plant. For the year 20 scenario shown in Figure 1, the flows into the TSF Reclaim Pond have total N concentrations of about 2.5 mg/L. Evaporation increases the concentration to about 3 mg N/L. As a result, reclaim water is predicted to have a higher concentration than the sum of its inflows.

Table 1. Estimated yearly amounts of blasted rock for the block cave (RCM).

Year	Blasted Rock (tonne)	Year	Blasted Rock (tonne)
0	1198169	21	1154733
1	1557855	22	1237728
2	1562950	23	1313284
3	1545919	24	1170403
4	1440694	25	1245590
5	1370244	26	1413816
6	1349188	27	1417001
7	1450438	28	1111821
8	1393639	29	919555
9	1498381	30	928255
10	1393349	31	1056501
11	1496716	32	785491
12	1487802	33	1026423
13	1478907	34	825335
14	1497886	35	479661
15	1500293	36	103822
16	1532227	37	51911
17	1459195	38	25956
18	1301478	39	12978
19	1584847	40	6489
20	1396593		

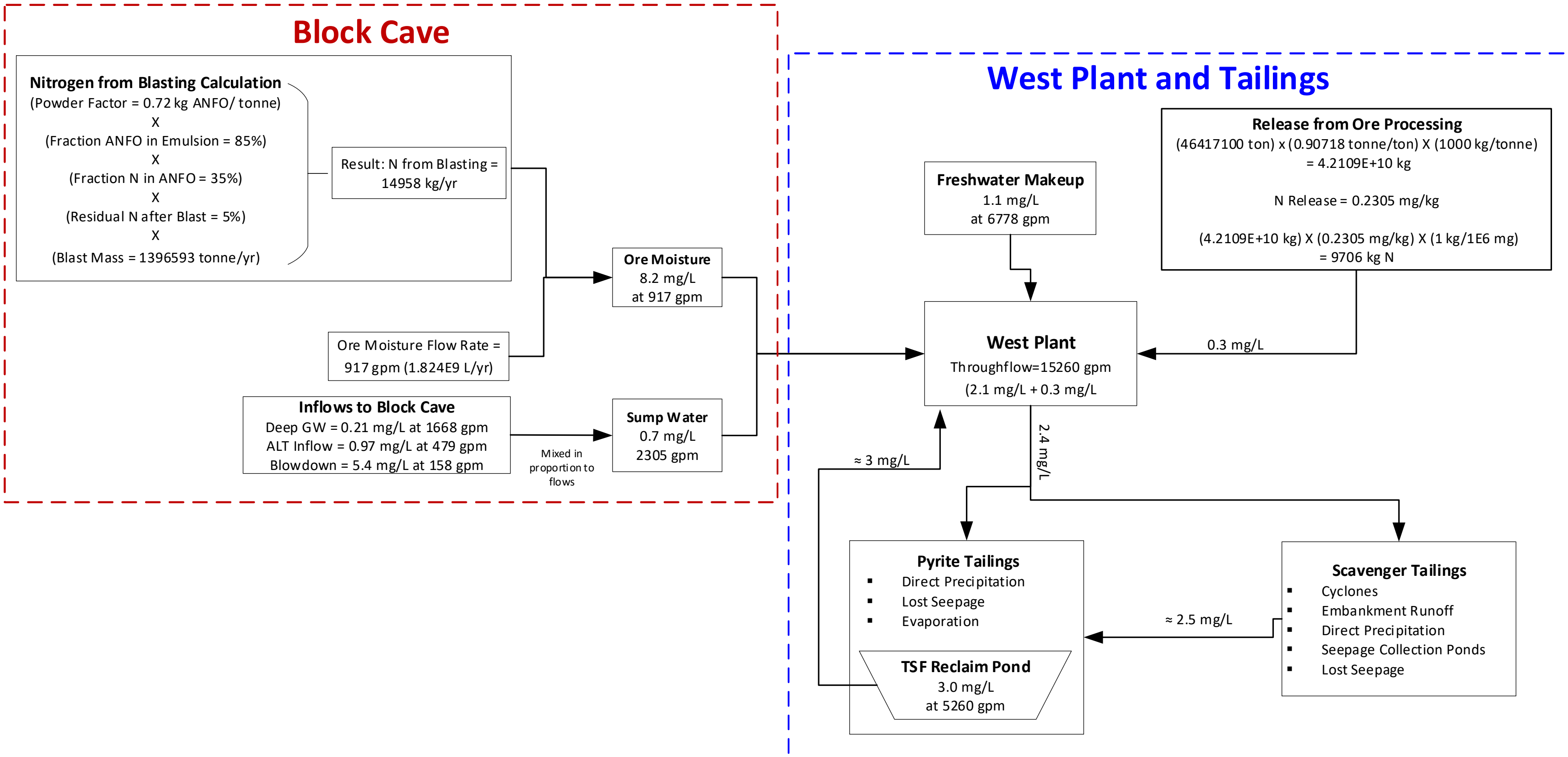

Figure 1. Example calculation for nitrogen for a single year of the mine life (year 20)

3 REFERENCES

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