A Review of the PolyMet NorthMet Supplementary Draft Environmental Impact Statement and Selected Supporting Documents Related to the Predictions of Solute Levels in Discharge

Review Conducted for WaterLegacy

Bruce Johnson, Chemist, Retired Regulator

March 2014

Introduction

My review is based on 30 years of experience in environmental research, NPDES enforcement, and resolving contamination and waste management issues for a regulated party. I have extensive experience with mining in Northeast Minnesota. This experience includes extensive metal sulfide field research. I have authored/coauthored eight publications on waste management procedures and copper/nickel metals leachate research. I was a member of the National Academy of Sciences, Transportation Research Board.

This review evaluates the predicted chemical inputs and assumptions used to predict the quality of wastewater/leachates that will be generated.

Reviewed as a whole, the PolyMet NorthMet Supplementary Draft Environmental Impact Statement (SDEIS) fails to adequately address major ions and trace elements. The document ignores aquatic toxicity and possible synergistic impacts from waste rock leachates. The SDEIS fails to evaluate parameters in a scientifically defensible manner.

As a result, predictions of impacts to surface and ground water are understated. Parameters that are minimized or not analyzed may also impair the ability of installed water quality treatment to meet surface and groundwater standards.

Mine Site Assumptions Regarding Rock Characterization

Mine Site water quality assessment is based on improper assumptions about rock characterization and chemistry. Category 1 waste rock pile will create acidic pore water and leach high volumes of sulfates and toxic metals.

1. The SDEIS improperly uses small sample size and averaging to design waste rock humidity cell tests.

The discussion of Category 1 waste rock sulfur cutoff of 0.12% sulfur (SDEIS, p. 3-45) contains faulty model inputs from the results and conclusions of PolyMet 2013l Waste Characterization Data Package.

Mathematical modeling of environmental conditions is a tool that can be used to provide rough estimates when significant field data results parameters are not adequate to provide a basis for predictions. The use of high quality chemical input data (both laboratory and field) to mathematical models is critical to the accuracy of models predictions. Poor quality data inputs and assumptions in models produce predictions that are inaccurate, the result of which is unanticipated contamination and/or under-designed wastewater treatment systems.

The SDEIS humidity cell testing lacks the rigor necessary to predict sulfur content of the waste rock stockpiles. It is very well documented in the geologic open literature that the Duluth Complex mineralogy is highly disseminated. This variation is demonstrated in both reports and drill core analyses [1]. In this reference, Patelke and Severson discuss a report on a bulk sample operated by Tec Cominco, site B1-321:

> Thus, one lesson to be learned here is that if the grade is important it is imperative to conduct detailed drilling of a site to establish the boundaries of the future bulk sample! The extreme variability of the Unit 1, both in geology and mineralization style, can produce dramatic changes within a few tens of feet (both horizontally and vertically).

The report documents the Duluth Complex contains inclusions of Virginia formation.(*Id.*) An inclusion is defined as "A fragment of older rock within an igneous rock to which it may or may not be genetically related" (Bates, 1983). The Virginia formation contains high sulfur and other metals [2]. The inclusions vary from large ones, that may be identified by coring, to rather small inclusions (a few inches to multiple feet in size) that are environmentally significant and are easily missed with drill cores. [3]

This Partridge River intrusion, where the proposed PolyMet mine site is located is highly disseminated as well. As a result, both the mineralogy and the concentrations from an environmental standpoint vary extensively throughout the deposit.

Sulfur concentration variation can be observed in drill cores[4] ,(SRK, RS53/RS42 – Waste Rock Characteristics/Waste Water Quality Modeling – Waste Rock and Lean Ore - NorthMet Project. Draft 01. Prepared for PolyMet Mining Inc. March 9, 2007, SDEIS reference SRK 2007b, Appendix c.2.) and in the open literature [5]. The SRK RS53/RS42 document describes the humidity cell process, stating 89 samples were used to categorize waste rock, a total of 309 million tons of waste rock (NorthMet Project Waste Characterization Data Package V. 9, March 7, 2013, SDEIS reference PolyMet 2013l, section 4.3). This sample size is scientifically inadequate for characterization of such a massive pile of waste rock.

The humidity cell test rock was separated by rock type (geological units); in describing the process for the selection of the test cores, the document states cores were determined by "knowledge" to select representative samples of each unit (SRK, RS78 – Block Ore and Waste March 2, 2007, SDEIS reference SRK 2007a, p. 8). In such an important evaluation an accepted statistical protocol, such as use of a random number generator, must be used to select cores. The cores used in the testing were not selected using a scientifically valid statistical procedure. This likely skews the predicted sulfide metals in the tests.

---

[1] *A History of Copper-Nickel and Titanium Oxide Test Pits, Bulk Samples, and Related Metallurgical Testing in the Keenawan Duluth Complex, Northeastern Minnesota*, Richard L. Patelke and Mark J. Severson, Jan 2005, Technical Report NRRI/TR-2005/01, p. 74.

[2] *Geology and Mineral Potential of the Duluth Complex and Related Rocks of Northeastern Minnesota*, James D. Miller, Jr; John C. Green; Mark J. Severson; Val W. Chandler; Steven A. Hauck; Dean A. Peterson; Timothy E,.Wahl. Report Investigations 58 ISSN0076-9177, University of Minnesota, St Paul, 2002. pp. 85, 87, 89.

[3] *Geology and Mineralization in the Dunka Road Copper-Nickel Deposit, St Louis County, Minnesota*, Stephen Geerts, Randal J. Barnes and Steven A. Hauck. March 1990, NRRI/GMIN-TR-89-16, p. 17.

[4] *Ibid.* 1, p. 74.

[5] *Mineral Potential of the Duluth Complex and Related Intrusions*. Chapter 8. Mark J. Severson, James D. Miller, Jr., Dean M. Peterson, John C. Green, and Steven A. Hauck. p. ix, 74, 78, 165, 167.

The selected cores segments were divided into their geological units. Each unit was combined and the sulfur content for each unit was averaged. The average concentration was used for the humidity testing. Averaging conceals the effect of actual isolated high sulfur concentrations within the waste rock, and by default assumes all waste rock sulfur concentrations will be as well mixed within the Category 1 waste rock stockpile as it is in the test cells. Only under these waste rock well mixed conditions would the resultant leachate be similar to the humidity cell results.

From an environmental standpoint, average concentrations fail to adequately address environmental impacts. High sulfur "seed" inclusions[6] are of environmental concern (SDEIS reference SRK 2007a, p. 6.). This procedure, by default, assumes all waste rock sulfur concentrations will be as well mixed within the stockpile as they were in the test cells. Thus, in theory, the leachate observed in the field will be similar to the humidity cell results. However, in practice the waste rock will not be well mixed and numerous seed quantities of sulfur much greater than 0.12% will be within the stockpile. These seeds will initiate acid and leach both its high sulfur waste rock and also the lower sulfur rock in its drainage path. The acid may exit the stockpile or may be neutralized before exit, but either way it will carry out a load of dissolved metals [7].

Thus the ore block model, excellent for assessing the economic value of a resource for production purposes, will not upscale adequately to meet environmental, chemical and toxicological requirements. Separation of the very heterogeneous waste rock containing high sulfate inclusions[8] using an average concentration block model will not prevent higher concentration sulfur rock from being placed in lower concentration waste rock stockpiles [9].

The up-scaling of theoretical modeling to field operations will unavoidably result in high concentration inclusions (seed quantities) of sulfur being placed in lower sulfur stockpiles [10]. These high sulfur inclusions will produce pockets of acid leachates within the piles. These acid leachates will drain and leach other low sulfur materials below. If neutralizing rock is not sufficiently present, over time the leachate will be acid and contain metals and other contaminants. Even if the acid were to be neutralized to some degree before discharge exits the stockpile, the drainage will carry out a load of dissolved metals influenced by the higher acidity of the disseminated sulfates. [11]. Leached metals will not be adsorbed by the host rock in the pile and will result in much higher leachate values than predicted by the model. The higher the stockpile, the higher concentration of leachate will be produced.[12]

---

[6] *Geology and Mineralization in the Dunka Road Copper-Nickel Mineral Deposit St. Louis County, Minnesota,* Stephen Geerts, Randal J. Barnes, and Steven A. Hauck, March 1990, NRRI/GMIN TR-89-16; p. 11.
[7] *Alternative Acid Mine Drainage Abatement Measures*, Dr. A. MacG. Robertson, Steffen Robertson, and Kirsten (B.C.) Inc., Vancouver B.C. Canada, p. 4.
[8] Ibid 8, p. 11.
[9] *Environmental Leaching of Duluth Gabbro Under Laboratory and Field Conditions: Oxidative Dissolution of Metal Sulfide and Silicate Minerals.* Paul Eger, Kim Lapakko, Minnesota Department of Natural Resources, Division of Minerals 1980, p. 12.
[10] Ibid 9, p, 4.
[11] Ibid 9, p. 4.
[12] Ibid 11, p. 188.

2. Sorting waste rock stockpiles will not be possible to the degree presumed in the SDEIS.

The SDEIS proposes to use block modeling to separate heterogeneous waste rock into four classes based on the sulfur concentrations in block modeling (SDEIS, p, 3-44). This modeling cannot be consistently duplicated in the physical action of loading trucks from the windrowed blast rock. Since the deposit is disseminated and the blocks are averaged, high levels of sulfur can be unidentified and unaccounted within a block, and/or adjacent block averages could vary in sulfur concentration significantly. The permanent unlined Category 1 waste rock stockpile is classified as less than or equal to 0.12% sulfur (SDEIS, p. 3-45). In practice the block model sorting process will result in blocks or portions of blocks with high concentrations placed into the Category I pile.

The block model was designed to estimate ore resources for production purposes. It averages the nearest 10-foot drill core analyses to the 20 foot height of the block, and then averages all nearby drill core averages adjusted to distance to determine a number for sulfur content in the 50 x 50 x 20 feet block (PolyMet Rock and Overburden Management Plan V. 5, December 28, 2012, SDEIS reference PolyMet 2012s, Section 2.3). There are 436 drill cores in the mine area. The economic portion of the mine is 528 acres. This calculates to an average of less than one drill core per acre. The mine area is divided into 133,000 blocks (SDEIS, pp. 3-39, 40).

This process determining the block's average sulfur number will not reflect the highest concentration of an element such as sulfur found in the nearest drill core. As noted previously, mine site drill core logs demonstrate large variability of sulfur, even between analyses completed at 10 foot intervals [13],and waste rock will contain "seed quantities" of sulfur much greater than 0.12% that will initiate acid and leach metals both from the high sulfur seed and from other rock in its drainage path. Any block may contain rock portions with much higher sulfur than what is calculated as the average.

This process of waste rock characterization is further adulterated by the gross separation of waste rock by category during the extraction process. Consider that over 13 years, the Category 1 stockpile will contain 167,922,000 tons of waste rock (SDEIS p. 3-43). Each blast will remove 250,000 to 300,000 tons of rock (SDEIS, p. 3-41). Thus each blast will remove approximately 85 blocks. A block weighs 3,518 tons (PolyMet, Rock and Overburden Management Plan, SDEIS reference PolyMet 2012s, p 39.) and each truck holds 240 tons of rock. Therefore each block contains approximately 15 truckloads. It is likely that blocks or portions of blocks with higher sulfur seed concentrations will be transported to the Category I pile. Without a tight system, if one block from a blast is mis-characterized and transported to Category I, more subsequent trucks moving the blasted rock may replicate this error. The Plan discusses the possibility of GPS tracking that "can be" used to assist in separating rock types (SDEIS Reference PolyMet 2012s, p. 34) but the SDEIS fails to commit to implementing such practices In any case, GPS use cannot resolve the issue of averages missing higher concentration seed rock.

[13] Ibid.1, Fig. 24, p. 66 .

Consequences of Analysis:

As a result of these practical constraints, the proposed block evaluation process will result in stockpiles that will not uniformly meet proposed cutoff concentrations resulting in much higher concentrations of leachate production than predicted in the SDEIS. If neutralizing rock is not sufficiently present, the leachate will be acid and contain metals and other contaminants. Leached metals will not be adsorbed by the host rock in the pile and will result in much higher leachate values than predicted by the model. These elevated concentrations will impact surface and/or groundwater. Unpredicted elevated concentrations will also adversely affect the removal efficiency of the mine site wastewater plant (SDEIS Reference PolyMet 2012s, p. 39).

The SDEIS states its plan to use Category 1 waste rock for construction material (SDEIS, Table 3.2-8). However, this material should be considered reactive waste (SDEIS PolyMet 2013l, p. 2). It has a high potential for leaching beyond surface water standards and should not be used as construction material.

Although the SDEIS acknowledges that much higher rates of leachates would result if waste rock piles were to become acidic, up to a factor of 8.2 with the onset of acidic conditions (SDEIS, p. 5-51), predictions of leachates from the permanent Category 1 waste rock stockpile are based on an assumption that this waste rock does not become acidic.

Approaches to determining stockpile sorting were considered in SDEIS Reference SRK 2007b. While discussing models, this document noted on page 4: "Northwest Geochem (1991) comprehensively reviewed modeling methods to predict the chemistry of waste rock stockpile drainage and concluded that 'no model exists which can even generally simulate the most critical physical, geochemical, and biological processes in waste-rock piles'. Subsequently, MEND (2000) concluded that 'If assessments of the behavior of waste rock stockpiles are required, it should be realized that no reliable modeling approaches are available. Advances have been made in understanding and modeling the various processes (e.g. flow in unsaturated materials, pyrite oxidation) but reliably coupling the models remains primarily a topic of research.'" Other theoretical and empirical approaches were discussed, and the decision was made to use the current block model approach, but the block model cannot escape the faults enumerated in both the SDEIS Reference SRK 2007b and this review.

Analysis of water quality outcomes must be revised based on a reasonable range of predictions about disseminated sulfates and localized acidic conditions.

Improper Characterization of Waste Rock Parameters

The use of a block model intended to predict the amount of profitable resource to determine concentrations of other parameters does not accurately predict potentially toxic waste rock leachates. This error will compound the inaccuracies resulting from the averaging of the sulfate mineralogy from the humidity testing.

The SDEIS uses block modeling, originally used to predict the amount of profitable resource, to separate very heterogeneous waste rock into four classes based on the sulfur concentrations.

Elements both of economic and non-economic interest within the Duluth Complex are disseminated (heterogeneous). Copper, nickel, cobalt, zinc, mercury, lead, arsenic, sulfur, chlorides and others vary in both economic metallurgical interest and in environmentally significant concentrations within the host rock. Waste rock will not be blended to an average concentration, as it can be for the beneficiation process.

The humidity testing sampling focused only on the presence of sulfide heavy metals in its core and geologic unit selection process, so the sample selection focused only on parameters closely associated with the sulfide bearing minerals. (SDEIS Reference PolyMet 2013l, pp.7-21). This process fails to address concentrations of other parameters that exist within the non-sulfide host rock. Some non-sulfide parameters are also of environmental concern.

During the humidity cell testing numerous parameters from the PolyMet test rock demonstrated metals release at near neutral to basic pH (SDEIS Reference SRK2007b, App. H.2.).These metals can be expected to be at environmentally elevated concentrations in the leachate of all stockpiles.

As discussed previously, high concentration inclusions (seed quantities) of sulfur will produce pockets of acid leachates within the piles, leaching metals in the drainage path. If neutralizing rock is not sufficiently present, the leachate will be acidic and contain metals and other contaminants. If neutralizing rock is sufficiently present, circumneutral leachate will still contain metals, especially nickel which is very environmentally mobile, and other contaminants. As in the humidity testing to predict sulfates, use of the block modeling averages underestimates metals leachate production.

Unlike many other copper (Cu) deposits in the nation, the PolyMet Duluth Complex deposit also includes significant quantities of nickel, cobalt, and zinc (Ni, Co, Zn) ore. Rock from the Duluth Complex in this area contains disseminated (unevenly distributed) mineralization, that may or may not produce acid leachate, and will still leach heavy metals far above surface water standards at potentially toxic levels.[14] The release of Cu can be reduced with circumneutral pH (pH 6.7 to 7.2), such as limestone additions to waste rock piles, but this is not true for Ni, Co, and Zn, which are readily released in near neutral pH (+/- pH 7).[15] Unlike the PolyMet SDEIS, which did not discuss this issue, the Regional Cu-Ni Study states that leachate impacts of nickel, cobalt and zinc are of great significance.[16]

Acid rock drainage related to copper and sulfur is not a sufficient indicator for leaching of toxic metals, since there are numerous reports on the Duluth Complex in the area demonstrating

---

[14] K. Lapakko and P. Eger, *Environmental Leaching of Trace Metals from Waste Rock and Lean Ore Stockpiles*, p. 3 (1980)("Lapakko 1980") *available from author on request*; MDNR 1980, *supra*, pp. 195-196.

[15] *Id*; *see also* M.J. Rinker, R. V. Nicholson, M.A. Venhuis, & B. Swarbrick, *Implications of Non-Acid Metal Leaching on Mine Rock Management at a Nickel Mine in Permafrost Terrain: 1-Mine Rock Evaluation* (1999), *available from author on request*; Minn. Envt'l Quality Bd., *Spruce Road Bulk Sample Site & Spruce Road Bulk Sample Site Monitoring Results*, Reports to Minnesota Regional Copper-Nickel Study, p. 19 (1977)("MEQB 1977") *available at* http://archive.leg.state.mn.us/docs/pre2003/other/CN148.pdf; S. J. Eisenreich, M.R. Hoffman & I. Iwasaki, *Metal Sulfide Leaching Potential in the Duluth Gabbro Complex*, Report to Minnesota Regional Copper-Nickel Study (1976)("Eisenreich 1976"); Lapakko 1980, *supra*, pp. 3-4.

[16] Minnesota Regional Copper-Nickel Study, Executive Summary, p. 45, 48-49, *available at* http://www.leg.state.mn.us/docs/pre2003/other/792632.pdf

significant releases of Ni, Co, and Zn at circumneutral pH.[17] Toxic metal releases at near neutral pH of Cu, Ni, Co, Zn have occurred from the Duluth Complex stockpiles and test plots at the LTV Dunka Taconite Mine (a.k.a. Cliffs Erie Dunka Mine), Amax test site and Spruce Road Bulk Sample Site. Cliffs Erie required a variance from Minnesota water quality standards with respect to acute toxicity for its 2001 NPDES permit[18] and continues to request variances from toxicity water quality standards for metals releases from the Dunka Mine.

Minnesota's Cu-Ni Study data showed that Duluth Complex waste rock leachates have a high probability of aquatic toxicity.[19] The median trace metal concentrations (Ni, Cu, Zn and Co) from Dunka Mine stockpiles with circumneutral pH had leachate seepages that ranged from ten to 10,000 times the natural background levels of streams in the area.[20] In August 1988 MPCA determined all of these discharges to be acutely toxic. The leachates were found toxic to *Ceriodaphnia dubia* in as low as 3 to 14 percent dilutions. These discharges are the most acutely toxic discharges known in the state.[21] Copper, nickel, cobalt and zinc metals are all highly toxic to aquatic life at low levels (micrograms per liter), and may have negative human health effects at marginally higher levels. For example, ATSDR has stated Ni to be a potential carcinogen.[22]

The average annual precipitation for the Project area is 28.4 inches. The 855.9 acres of stockpiles projected for the PolyMet mine site can be expected to receive 660,008,592 gallons of precipitation in an average year. Uncovered AMAX test plots indicated 50 to 60 percent of precipitation was released as leachate.[23] In an *average* year, a rough estimate would predict Polymet stockpiles will produce 330,000,000 to 396,000,000 gallons of leachate, containing metals and sulfides.

Acid and circumneutral leaching must be anticipated from all stockpiles of mineralized Duluth Complex waste rock.[24] This leaching would far exceed surface water standards and should be expected to be acutely toxic.[25] Experience suggests that toxic metal releases of Ni, Co and Zn exceeding surface water standards can be expected indefinitely, if not in perpetuity, in the Partridge River Watershed.

Mineralized mine pit sidewalls will also leach acid and metals orders of magnitude above surface water standards. This was documented in the Cu-Ni Study sampling of the U.S. Steel bulk sample pit at the Filson Creek bulk sample site. A 33-day laboratory test of the Duluth Complex Rock resulted in elevated metals releases in water, with increased release as the water's oxygen

---

[17] S.J. Eisenreich, M.R. Hoffman, K. Lapakko, *Mechanism and Control of Metal Sulfide in Gabbro Mining-Related Solids*, Report to Minnesota Regional Copper-Nickel Study, p, 27 (1977); Lapakko 1980, *supra*, p. 3; MDNR 1980, *supra*, *see e.g*. pp. 9-10. Pilot testing has demonstrated only a 10 percent reduction in Ni release by the use of limestone in a Dunka Mine Duluth Complex waste rock seepage.
[18] Dunka Mine NPDES Permit MN0042579, pp. 11, 12, 15.
[19] MDNR 1980, *supra*, see e.g. p. 197.
[20] Lapakko 1980, *supra*, p. 3.
[21] MDNR, *Bob Bay Study* (1983)("MDNR 1983"); B. Johnson, J. Strudell, MPCA Proposed Dunka Memorandum to Russell Felt (Mar. 28, 1989) ("Johnson 3/28/89") *available from author on request*; MPCA Dunka Reports, *supra*.
[22] Agency for Toxic Substances and Disease Registry ("ATSDR"), Nickel ToxFAQs CAS # 7440-02-0 *available at* http://www.atsdr.cdc.gov/tfacts15.pdf
[23] P. Eger, B. Johnson, G. Hohensteen, DNR/*AMAX Leaching and Reclamation* (Jan. 29, 1979).
[24] *See* MDNR 1980, *supra*; MEQB 1977, *supra*; Eisenreich 1976, *supra*, p. 27; Lapakko, 1980, *supra*.
[25] *See* MPCA Dunka Reports, *supra*; MDNR 1983, *supra*; Johnson 3/28/89, *supra*.

content increased.[26] In the Cu-Ni Study, the MDNR also expressed concerns over mine pit sidewall leaching.[27]

Consequences of Analysis

Predictions of metals leachates in the SDEIS are likely to be understated and additional mass balance analysis of non-production metals should be required, particularly for environmental parameters of concern, especially but not limited to mercury, cobalt, zinc, lead, chlorides and arsenic.

SDEIS Failure to Adequately Evaluate Chlorides

Summary: The SDEIS fails to adequately evaluate chlorides. Chlorides will be much higher than predicted, impacting wastewater treatment performance and surface and groundwater quality.

1. Basic Information Regarding Chlorides

Background regarding chlorides is important for the chloride discussion below. Chloride compounds do not biodegrade, readily precipitate, volatilize, or bioaccumulate. Chloride ions do not adsorb readily onto mineral surfaces and therefore concentrations remain high in surface water and sediment pore water, and low in sediment (Health Canada, 1999).

Chloride in fresh water has many environmental impacts. Low levels of chlorides are toxic to invertebrates and aquatic plants (USEPA, 1988). Chlorides in low concentrations are documented to impact aquatic plants and amphibians, and fish shifts in aquatic populations have been observed (Sadowski; Karraker 2008).

As early as 1980 the MDNR reported results of laboratory studies where chloride solutions as low as 140 mg/l (.005 M) increased nickel leachate[28]. Later reports agree that elevated levels of chloride at approximately 2000 mg/l (0.1M) have been demonstrated to increase the dissolution of sulfide metals for ore processing (Lin,1988; Doner,1978).

Chloride in water can only be treated through dilution or high performance treatment such as by reverse osmosis. Elements like chloride cannot be created or destroyed; treatment simply concentrates chlorides into another media.

In 1979 the baseline average of chloride from 462 samples from streams in the Lake Superior and Rainy River watersheds had a median average of 2.0 mg/l (n=462), and in 94 lake samples chloride averaged 1.6 mg/l (n= 94). In 1979, in impacted sites (Bob Bay, St. Louis River and Partridge River) chlorides ranged from 2.8-38 mg/l with a median average of 29 mg/l (n= 55).

---

[26] MDNR 1980, *supra*, pp. 108, 110.
[27] *Id*., p. 263.
[28] Ibid 11, Fig. 3.41.

The same report identifies fluoride in unimpacted streams (group c) ranging from 0.2-1.5 mg/l (n=347) [29]. The Partridge River, adjacent to the proposed mine pit, has a 7-day ten-year low stream flow (7Q10) of near zero. According to Minn. R. 7050.0210 negligible mixing of wastewater will be allowed and any discharge limit will be near the in-stream standard of 230 mg/l.

2. The SDEIS incorrectly assumes the occurrence and concentrations of chlorides are few in number and only in fractures containing water.

The SDEIS (SDEIS, p.5-113) discusses chlorides. The discussion mis-states referenced articles, and ignores other more recent peer-reviewed literature regarding the sources of chlorides in the Duluth Complex.

The SDEIS (p. 5-113) cites Morton and Ameel 1985 for the conclusion "saline ground water is encountered sporadically in deep (greater than 1000') bedrock wells in northeastern Minnesota."

The cited reference was an attempt by the authors to evaluate if there was a relationship between brackish water and metals of economic interest. This was stated in their objectives on p. 2 : "1) locate saline wells within the North Shore Volcanic Group and Duluth Complex, 2) sample and analyze waters from these wells and if feasible to establish base-line values of trace metals, 3) sample and analyze saline wells associated with known areas of economic mineralization, 4) compile analyses of potable and non-potable wells from the literature, and 5) establish if there were any relationship between rock type and the incidence of saline wells." The objective was not to determine the origin, depth or the frequency of wells located with saline water. The authors had trouble finding saline wells, not because of the frequency of occurrence, but as a result of poor reporting in drill logs, and the fact that unusable saline wells are required to be sealed.

2. The SDEIS incorrectly assumes chlorides are mostly found in fractures exceeding PolyMet's mine pit depth.

The SDEIS (SDEIS, p. 5-113; Barr, John Swenson and Jeré Mohr Memorandum to Bill Johnson. Response to questions on saline groundwater, September 7, 2012, SDEIS Reference Barr 2012v) further assumes if brackish, high chloride water occurs it will found very deep -- 1,200 to 1,400 feet. The SDEIS further states that PolyMet's pit will not be deep enough to hit saline water if it exists. They reference the Amax shaft produced brackish water, and attribute its production of brackish water to location of shafts at depths of approximately 1,200 to 1,400 ft.

Reviewing cited Amax data[30] this assumption is also in error. The Table indicates sampling locations by elevations not in depth. Thus converting the elevation data to feet from the surface one finds the samples were taken at the surface, at 406 feet, 512 feet, 554 feet. These samples are all well within the proposed depth of the PolyMet pit.

---

[29] *Water Quality Characterization of the Copper-Nickel Water Quality Research Area*, Daryl Thingvold, Nancy Sather, Peter Ashbrook December 1979, Table 5, Appendix 2.

[30] *Analysis of Groundwater From shaft and Drill Holes at the MinnAmax Site Near Babbit, MN*, T. Hargy, Kennocott Copper,Table 5.

In addition the table indicates three borings encountered extremely high chlorides (11,000, 6,300 and 3,900 mg/l). The depth of a boring is not related to the chloride concentrations since the borings are only cased to bedrock, below which the boring is not cased. Brackish water can enter at any location within the un-cased borehole.

Furthermore, the Morton and Ameel 1985 report cited by PolyMet clearly indicates that high levels of chloride occur at shallower depths. On p. 35 the authors conclude: "The saline and brackish waters in the Duluth Complex and N.S.V.G. occur at shallower depths than those in most occurrences in the Canadian Shield tabulated by Fritz and Frape (1982)." Morton and Ameel 1985, Figure 16, chloride concentration vs well depth, demonstrates that chloride, in their study, does not increase with depth. This figure demonstrates little difference between Duluth Complex 100 and 600 feet wells. Table 7 of the report shows results of chlorides in bedrock wells less than 400 feet.

PolyMet's statement on SDEIS page 5-113, "In general, the potential for encountering saline water increases with depth, such that briny groundwater (defined as TDS greater than 35,000 mg/L) may be nearly ubiquitous in bedrock at depths greater than approximately 3,000 ft throughout the Lake Superior Basin in northeastern Minnesota (Morton and Ameel,1985)." mis-represents the conclusions drawn by Morton and Ameel (1985).

4. The SDEIS incorrectly assumes that the Amax site chlorides are localized to the Amax site.

The SDEIS (SDEIS, p, 5-113) and Barr (SDEIS Reference Barr 2012v) also state that the Amax test shaft that encountered saline water was 3.2 miles northeast of PolyMet, thus the appearance of chlorides is likely not to be present at the PolyMet mine pit. The PolyMet pit will be 2.6 miles long, 528 acres (SDEIS, pp.3-39, 40), with its closest point approximately 2.93 miles from the Amax shaft.

PolyMet assumes but does not substantiate that chlorides are localized to Amax. Such an assumption is not consistent with scientific evidence. Chlorides are known to be in inclusions in the "dry" troctolite. PolyMet's mine will be located primarily in troctolite. Furthermore, the SDEIS, p. 3-33, contradicts this assumption, stating, "All of the mineral deposits share a broadly similar geologic setting to the NorthMet Deposit."

PolyMet has hundreds of borings with thousands of feet of core available. A thorough analysis of these cores would help to determine the presence or absence of chloride inclusions.
The U.S. Forest Service recently tested for chlorides in the water of five exploratory borings in the area of the drill site southwest of PolyMet near the South Kawishiwi River. The water testing found the following chloride concentrations in the 5 borings tested contained the following chloride concentrations: 38 mg/l, 3460 mg/l, 440 mg/l, 476 mg/l, 1,500 mg/l[31]. Thus high

[31] Superior National Forest, *Federal Hardrock Minerals Prospecting Permits Project, Final Environmental Impact Statement*, Appendix G. 04/09/2012 (rev).
http://www.fs.usda.gov/wps/portal/fsinternet/!ut/p/c5/04_SB8K8xLLM9MSSzPy8xBz9CP0os3gDfxMDT8MwRydLA1cj72BTUwMTAwgAykeaxRtBeY4WBv4eHmF-YT4GMHkidBvgAI6E

chlorides were found in 4 of the five borings tested. This recent U.S. Forest Service testing further demonstrates high chloride have been found both to the North and South of PolyMet's proposed pits**.**

5. The SDEIS incorrectly assumes chlorides are found only on the rock surface and in inundated fracture zones.

The SDEIS (SDEIS, pp. 5-113, 114) incorrectly assumes that brackish water is contained only in fractured rock, rather than in inclusions within the rock. Because the SDEIS contends both that brackish water is only in fractures and that fractures at the mine site are insignificant; the SDEIS then assumes that the brackish water will not be a continuing source of pollutant. These assumptions are inaccurate.

Reports from the MDNR, NRRI, and Washington University geologists contradict the SDEIS assumption. The first report is a publication by Eduard H. Dahlberg, a geologist employed by Minnesota Department of Natural Resources (DNR), Division of Minerals and the University of Minnesota[32]. His report identified that drill cores from Duluth Complex contain high chloride and fluoride concentrations in serpentinized ultramafic rocks. Within drill cores at distances ranging from 11.3 to 917.5 meters (37 to 3009 feet) from the footwall of the Duluth Complex, the chlorides were present as salts. "The phase occurs as vein-filling material in grains up to 200 pm (picometer, one trillionth part of a meter) long and 20 pm wide... Analyzed rock cores also contain very high concentrations of chlorides (up to 3200 ppm) and fluoride (up to 760 ppm)."

The Dahlberg report continued, "This effect has been observed over intervals ranging in thickness from 30 cm (about 12 inches) to a few meters and occurs within "zones" up to 44 meters (144 feet) thick. The drill cores bearing the alteration product come from drill holes located in troctolitic rocks in the area of the Maturi, Minnamax, Water Hen, Dunka Road, and Dunka Pit Cu-Ni sulfide occurrences." The form of salt was identified as an iron chloride.

In 1991, an NRRI report identified chloride encrustations in crisscrossing hairline fractures giving the rock a "cracked" appearance. These were found in parts of the Local Boy area[33]. In 1995, a paper by Pasteris, Harris, and Sassani analyzed the mineralogy of the Duluth Complex and further documented that drill core samples of troctolite contained high concentrations of both calcium chloride and sodium chloride in fluid inclusions. These concentrations ranged from 0 to 48% (0 to 480,000 ppm) [34].

---

dIeDXIvfdrAJuM3388jPTdUvyA2NMMgyUQQAyrgQmg!!/dl3/d3/L2dJQSEvUUt3QS9ZQnZ3LzZ fS000MjZOMDcxT1RVODBJN0o2MTJQRDMwODQ!/?project=18155

32 *A Chlorine-bearing Phase in Drill Core of Serpentinized Troctolitic Rocks of the Duluth Complex, Minnesota*, Eduard H. Dahlberg, Bernhardt Saini-Eidukat; Canadian Mineralogist Vol. 29, 1991, pp. 239-244.

33 *Geology, Mineralization, and Geostatistics of the MinnAmax/Babbitt Cu-Ni Deposit (local Boy Area),Minnesota, Part II:Mineralization and Geostatistics,* Mark J.Severson, Randal J.Barnes, NRRI Technical Report NRRI/TR-91/13b, June 1991, pp. 55-57.

34 *Interactions of Mixed Volatile-Brine Fluids in Rocks of the Southwestern Footwall of the Duluth Complex, Minnesota: Evidence from Aqueous Fluid Inclusions,* Jill Dill Pasteris, Teresa N. Harris, David C. Sassani, American Journal of Science, Vol.295, February 1995, pp. 125-172.

All three publications also determined that brackish liquids are contained in fluid inclusions. Fluid inclusions are defined as "a tiny cavity in a mineral 1.0-100.0 microns in diameter, containing liquid and/or gas formed by the entrapment in crystal irregularities of fluid, commonly that from which the rock is crystallized" (Bates, 1983). These inclusions are microscopic, less than 20 um (micrometers) in length. The inclusions contain chlorides from NaCl, CaCl2-H20, FeCl2. The inclusions have been reported in the troctolite rock. Troctolite is a major constituent of the PolyMet pit rock.

The SDEIS also ignores data from the Amax site that demonstrates years of elevated chlorides in the mine dewatering and a DNR three-year field study of MinnAmax tailing leachate[35] that demonstrated very high chloride leachates (averaging 433 mg/l with a max of 4,690 mg/l).

The DNR at that time simply speculated that the high level of chlorides was an unidentified error in tailing processing. In the same leachate, sodium averaged 467 mg/l, with a maximum of 2500 mg/l. Literature and field experience demonstrates that the SDEIS assumption that the brackish water is solely on the surface of rock in fracture pockets is in error.

This error affects the presumption in the SDEIS (p. 5-114) that if saline water were encountered discharging in the pit, it would be quickly diluted with fresh water and then be a discharge of a one-time nature that would be diluted by incoming freshwater. The SDEIS modeling predicts with 90% confidence that between $7.67x10^{-20}$ to 46 mg/l of chlorides will be input into the WWTF west and east basin respectively (PolyMet 2013g, Large Table1).

The SDEI- predicted basin influent numbers reflect concentrations found in Bob Bay, the St. Louis River, and Partridge River after in-stream dilutions. [36] The modeled chloride numbers cannot be justified. Elevated concentrations of chloride will be found in the leachates of the waste rock and even at higher levels in the tailing leachate, since the tailing exposed surface area is much larger.

Consequences of Analysis
The SDEIS fails to accurately evaluate the impacts of high levels of chlorides on the inundated meromictic east, central, and west pits water at closure (Novotny, 2007). Meromictic impacts from chlorides to ground and potentially surface water and wetlands must be addressed.

The SDEIS fails to address impacts of high chloride that is not captured from the seepage and liner leaks; potential impacts on surface water, groundwater and wetlands quality must be addressed.

The SDEIS fails to discuss how chlorides may affect reject concentrate and sludge chemistry, potentially impacting waste storage.

The SDEIS fails to discuss how any passive treatment systems proposed for closure would control chlorides.

---

[35] *Drainage from Copper-Nickel Tailings: Summary of a Three Year Field Study,* Minnesota Department of Natural Resources, Division of Lands and Minerals, July 2004.
[36] Ibid, 2.

REFERENCES:

Amrhein, 1992*, Effect of deicing salts on metal and organic matter mobilization in roadside soils*, Christopher Amrhein , James E. Strong , Paul A. Mosher, *Environ. Sci. Technol.*, 1992, 26 (4), pp. 703–709.

Bates,1983, *Dictionary of Geologic Terms*, Robert L. Bates and Julia A. Jackson, American Geological Institute, Third Edition,1983.

DNR, 2007, An Evaluation of the Ecological Significance of the Headwaters Site Northern Superior Uplands Ecological Land Classification System Section; Laurentian Uplands Subsection Lake and St. Louis Counties, Minnesota Department of Natural Resources Minnesota County Biological Survey Division of Ecological Services, March 2007.

Doner*,* 1978*, Chloride as a Factor in Mobilities of Ni(II), Cu(II), and Cd(II) in Soil,* H. E. Doner, Soil Science Society of America Journal, Vol. 42 No. 6, pp. 882-885.

Health Canada 1999, *Priority Substances List Assessment Report For Road Salts*, Health Canada, 1999.

Karraker, 2008, *Impacts Of Road Deicing Salt On The Demography Of Vernal Pool-Breeding Amphibians,* Nancy E. Karraker, James P. Gibbs, and James R. Vonesh, Ecological Applications, 18(3), 2008, by the Ecological Society of America. pp. 724–734.

Lin, 1988, *Ferric Chloride Leaching Of The Delta Sulfide Ores And Gold Extraction From The Leaching Residue*, H.K.Lin and P.D. Rao, Library of Congress Catalog Card Number 88-061592 ISBN0-911043-08-X, May 1988.

Novotny, 2007, *Road Salt Effects on the Water Quality of Lakes in the Twin Cities Metropolitan Area*, Eric Novotny, Dan Murphy and Heinz Stefan, ST. ANTHONY FALLS LABORATORY Engineering, Environmental and Geophysical Fluid Dynamics, Project Report No. 505, December 2007.

Sadowski, *The Impacts of Chloride Concentrations on Wetlands and Amphibian Distribution in the Toronto Region*, Eva Sadowski, Brandon University, Prairie Perspectives, p. 144-162.

USEPA, 1988, *Ambient Aquatic Life Water Quality Criteria For Chloride,* Office of Research and Development, Environmental Research Laboratory, Duluth, Minnesota, EPA 440/5-88-301,February 1988.

Bruce Johnson
6763 253rd Ave. N.E.
Stacy, Minnesota 55079
763-444-4579
bmjohnson@sprintmail.com

Chemist, retired regulator with extensive field and technical experience with environmental impacts of copper-nickel sulfide mining and peat mining, remediation of water quality impacts, compliance with state and federal regulations.

Employment

(1990-2004) Minnesota Department of Transportation

- Supervisor of Environmental Investigations and Compliance Unit
- Supervised all the Department's Superfund, Petrofund, Hazardous and Solid Waste Management;
- Developed a waste management and environmental audits program to reduce environmental liabilities;
- Developed a unique method to compost petroleum contaminated soils;
- Developed environmentally safe methods to remove and legally dispose hazardous lead based paint from bridges within the state;
- Reduced the Department's hazardous waste production 84%, from a large quantity generator to a small quantity generator;
- Developed a program to safely and legally remove abandoned hazardous waste from state administered transportation properties;
- Eliminated use of lead and chromium based paints as roadway striping while maintaining US/DOT requirements for reflectivity.
- Drastically reduced the use of treated wood in highway guard rails;
- Developed a chemistry baseline for heavy metals concentrations in high way rights-of-way in the Twin Cities metropolitan area;
- Assessed the potential environmental chemical and biological impacts from using waste tires as a light-weight fill in roadway construction;
- Developed chemical and biological procedures to test new products for potential environmental impacts prior to full-scale implementation.

(1984-1990) Minnesota Pollution Control Agency – Pollution Control Specialist Intermediate, Industrial Enforcement Team Leader

- Technical leader for the NPDES industrial enforcement unit staff;
- Enforced NPDES industrial permit requirements for all state industries;
- Enforced all NPDES Mining Permits;
- Developed statewide permit conditions for the land application of cannery wastes;
- Water quality lead staff to enforce environmental crimes.

(1979-1984) Minnesota Department of Natural Resources
Minerals Supervisor, Peat Mining Study of the environmental impacts from a test peat mining operation near Cotton, Minnesota.

- Researched potential water quality impacts from a pilot fuel peat mining operation;
- Developed sampling protocols to assess impacts from the state's test fuel peat mining program;
- Analyzed project chemical data from study;
- Co-author of the study report.

Hydrologist II, Peat Mining Research

- Developed and designed monitoring and methods to comply with regulations
- Developed plan and quality assurance for compliance with NPDES permit

Land Reclamation specialist for MinnAmax test piles construction

Field Chemist in charge of the MinnAmax metal pathways field study of environmental impacts from sulfide mining.

- Researched metal sulfide metal leaching mechanisms;
- Developed sampling protocols to assess impacts from sulfide waste rock and tailing field test plots;
- Insured chemical quality control quality assurance is maintained;
- Analyzed project chemical and water volume data;
- Assisted in developing project reports.

(1976-1979) State of Minnesota - Regional Copper Nickel Study

Field Chemist in charge of metal pathways portion of analysis, including:

- Researched sulfide metal leaching mechanisms;
- Assessed chemical data;
- Assessed water quality impacts from Erie Mining Company's Dunka mine sulfide waste rock leachates;
- Developed sampling protocols to assess potential water quality impacts
- Develop sediment sampling protocols to assess ambient metal concentrations in lake sediments;
- Surveyed existing lake sediments for ambient heavy metal concentrations;
- Surveyed selected bulk sample sites for leachate impacts;
- Assisted in developing project reports.

(1973-1976) U.S. Environmental Protection Agency

Shagawa Lake Eutrophication Project.

Assisted in assessment of remediation of a lake impacted from municipal sewage resulting in hyper-eutrophic conditions. Operated a carbon-14 primary productivity laboratory; developed in situ sediment sampling procedures; analyzed data.

(1972-1979) U.S. Army

First Lieutenant, Chemical, Biological, and Radiological Staff Officer.

Education & Certifications

1969 **B.A. - Biology/Chemistry** - Winona State University

1972 **B.S. - Education** - Winona State University

Hazardous Waste Investigations Training, U.S. Department of the Treasury, Federal Law Enforcement Training Center, Glencoe GA.

Certified Hazardous Materials Manager - Masters level. Certified by: Academy of Hazardous Materials Managers

Professional Recognition:

2000 MPCA Award for Northern Minnesota Abandoned Hazardous Waste Pilot Project,

1990 MPCA Meritorious Service Award

1990 Letter of Appreciation, Attorney General Office State of Minnesota

1990 Letter of Recognition, Attorney General State of Minnesota

Publications:

Decision Support Model for Assessing Net Public Benefits of Reuse of Waste Materials in Highway Maintenance and Construction, Hyman, Johnson, 2001.

Hazard Analysis And Risk Management Of Road Subbase Materials Using The Comparative Risk Bioassay Methodology, Johnson Belluck, Melby, 1997.

Comparative Risk Bioassays for Determining the Relative Hazards of Recycled Materials, Johnson, Belluck, Melby 1996.

A Comparative Study of the Toxicity of Shredded Tires and Wood Chips using the Biological and Chemical Comparative Risk Methodology, Johnson, Belluck, 1996.

Program review of Environmental Analysis Technology and Water Resources Technology at Vermilion Community College, Sept. 1986.

DNR/AMAX Field Leaching and Reclamation Program: Progress report on Leaching Study. Minnesota Department of Natural Resources, Division of Minerals. Eger P., Johnson B., 1979.

Field studies: Leaching-Metal transport and Metal Pathway. Progress report to the Minnesota Environmental Quality Board Regional Copper Nickel Study, Eger, P., Johnson, B. and Otterson, P, 1977.

Hydrologic and Water Quality Monitoring of a Fuel Peat Mine Near Cotton, Minnesota, Eger, Lapakko, Johnson, 1985.

Environmental Leaching of Duluth Gabbro Under Laboratory and Field Conditions: Oxidative Dissolution of Metal Sulfide and Silicate Minerals, Eger, 1980. (Contributor)

Additional Professional Activities:

2006 - present. Chairperson, Isanti County Water Board that sets policy for surface and ground water management in the County.

2002 – present. Owner of bandsaw mill and hardwood specialty sales business, designed and installed solar panels, solar hot water wood kiln and two wind generators.

1996 – 2000 National Academy of Sciences, Transportation Research Board member of the Environmental Maintenance Subcommittee.

1990 Republic of Germany - 5-week working internship with the Umwelt Bundes Amt (German Federal EPA) to share environmental scientific expertise.

1979 –1981, Owned, designed and engineered a unique, energy efficient 7000 sq. ft. hydroponic greenhouse that included designing the nutrients used in the facility.