Summary Analysis of
PolyMet NorthMet Modeled Tailings Chemistry
and MinnAMAX Site Tailings Leachate
Prepared for Water Legacy

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I am a chemist/biologist and retired regulator with extensive field and technical experience in environmental impacts of copper-nickel sulfide mining and peat mining, remediation of water quality impacts, and compliance with state and federal regulations. I was the field chemist in charge of metals pathway analysis for Minnesota's Regional Copper-Nickel Study, the field chemist researching metal sulfide leachates from the MinnAMAX (AMAX) waste rock and tailings piles, and the land reclamation specialist responsible for construction of these AMAX test piles.

In reading various versions of the PolyMet NorthMet (PolyMet) environmental impact statement and its supporting documents, I have been troubled both by the low solute concentrations predicted by PolyMet for the tailings seepage and by the fact that the documents used the AMAX waste rock pile leachate as a reference source, but drew no data from the AMAX tailings test pile, an appropriate reference for the PolyMet tailings.

It is my opinion that the PolyMet final environmental impact statement and underlying documents, including the Water Management Plan for the Plant (PolyMet 2015i) underestimates the likely concentrations of solutes in NorthMet tailings toe seepage, in some cases by more than an order of magnitude.

In response to Comment ID 17802, FEIS p. A-112, it is stated, "The FEIS relies on AMAX-derived data in a variety of circumstances." Examples were listed, such as scaling humidity cell results with AMAX waste rock leachate data. Yet, PolyMet does not use the AMAX tailing data to scale their tailing seepage modeling predictions. Instead the Co-Lead Agencies discount the value of the MDNR's own AMAX tailings data to predict PolyMet seepage concentrations, by stating the AMAX shaft is "many miles away" (FEIS p. 5-131), (It is 3.2 miles away only half a mile more than the length of the PolyMet mine, and the closest actual copper–nickel sulfide tailings data) and, "it is uncertain if geologic units and structures penetrated by the shaft are similar to those in the location of the NorthMet Project Proposed Action" as in the response to Comment 17800, p. A-111 (It is in the same Partridge River Formation rock).

I briefly summarize the conditions under which AMAX tailings leachate was produced and the results of my comparison of AMAX data to PolyMet tailings seepage modeling predictions. Modeling loses it credibility when there is no field verification from appropriate field source data.

The AMAX tailing leachate data was derived from tailings that were processed by the Twin Cities Research Center of the U.S. Bureau of Mines from crude ore samples collected from the Duluth Complex formation at the AMAX site (Schluter and Mahan 1981). The tailings were processed using a bulk flotation process. Sodium isopropyl xanthate and MIBC (methyl isobutylcarbonol) were used in the flotation circuit, as collector and frother, respectively. An unspecified conditioner was also added to the circuit. The mineralogy of the tailings was not analyzed, but it would be expected to be similar to that of the initial ore. This is very similar to the process chemicals proposed by PolyMet. The ore was approximately 40 to 70 percent plagioclase, with about 15 to 40 percent combined olivine, pyroxene and amphibole (Stevenson et al. 1979).

Chlorite, biotite and smectite have each been found in ore at levels less than 5 percent (Stevenson et al. 1979). Some of the trace metals in the Duluth Complex do not occur as discrete metal sulfides, but are included within olivine, pyroxene and plagioclase (Iwasaki et al. 1982).

In November 1978, a tailings plot approximately 20' x 30' x 2' deep, was constructed. A 30-mil Hypalon synthetic liner was placed beneath the tailings to prevent seepage and provide an impermeable base for a drainage collection system. The AMAX tailing processed by the U.S. Bureau of Mines were placed on top of the liner and final grading was done using hand tools to smooth the surface and provide a depth of approximately 50 cm. Leachate from the plot was collected for three years. Data was reported in 2004 by MDNR in a report entitled *Drainage from Copper-Nickel Tailings: Summary of a Three-Year Field Study*, July 2004, a copy of which is attached. The report notes that a short-circuiting of the liner allowed some rainwater to avoid traveling totally through the tailing producing some very low results that would not be representative. However the mean and median averages are likely to be representative of copper-nickel tailings leachate. Many values are elevated as compared to values from taconite ore tailings in Northeast Minnesota mines.

Tables 1 and 2 of this report, compare PolyMet's Estimated Tailings Basin Seepage Water Quality from the North Toe, (PolyMet 2015i, Large Table 2, Attachment A) with the values from the AMAX tailing. Both AMAX and PolyMet are in the Partridge River Duluth Complex Formation. PolyMet found it reasonable to use the AMAX waste rock test plots to provide a source calibration for their waste rock humidity tests. Thus comparing AMAX tailing from the same source is reasonable; yet it has not been done.

Table 1 provides the AMAX maximum, mean and median of the observed data and the P10, P50, and P90[1] predictions for maximum concentration levels in seepage at the North Toe of the PolyMet tailing basin for the first five years of production in PolyMet modeling (PolyMet 2015i, Large Table 2). Even the AMAX mean and median data for many solutes far exceeds PolyMet's probability predictions, keeping in mind AMAX measurements occurred in just 3 years of testing versus PolyMet's 5-year model predictions.

Table 2 compares the PolyMet P90 maximum predicted concentrations of the tailing leachates in the first 5 years of production (from PolyMet 2015i, Large Table 2) with the AMAX tailing test plot maximum observed concentrations. Even if the chloride ratio is considered to be an anomaly, an assumption that may be inaccurate (See Johnson opinion on the SDEIS, 2014), maximum levels of metals and salts in the AMAX tailings leachate are far higher than what was modeled for the PolyMet project. Leachate from AMAX tailings contained maximum levels of cobalt more than 30 times the P90 maximum predicted for the NorthMet project, levels of nickel more than 21 times the P90 predicted PolyMet concentrations, levels of sodium 35 times the P90 predicted PolyMet concentrations, and levels calcium, magnesium and sulfate more than 11 times higher than predicted P90 maximum PolyMet concentrations.

PolyMet's predictions affect the conclusions in the FEIS regarding biological impacts and ecological impacts of changes in water quality. Data from the existing AMAX three-year tailing field study calls into question assumptions in the FEIS that tailings seepage would not adversely affect water quality or violate Class 2B standards to protect aquatic life.

[1] P90 is defined in the FEIS Glossary as "90th percentile probability, which means that there is at least a 90 percent probability that a constituent would not exceed the evaluation criteria."

TABLE 1 MinnAMAX Tailing Leachate Data and PolyMet Tailing Leachate Modeling Predictions							
		AMAX* Measured Leachate (3 year field study)			PolyMet Prediction NorthMet Tailings Seepage (mine year 5 North Toe)**		
Parameter	**Units**	**Max**	**Mean**	**Median**	**P10 Max**	**P50 Max**	**P90 Max**
Calcium	mg/l	600	329.06	388	45.65	45.93	46.32
Magnesuim	mg/l	954	243.48	212	79.78	80.29	80.66
Sodium	mg/l	2500	467.3	277.5	70.29	70.79	71.21
Potassium	mg/l	102.2	45.8	40.5	10.12	10.21	10.31
Sulfate	mg/l	3,950	1752	1750	335.79	338.29	340.16
Chloride	mg/l	4,690	890	433	22.26	22.45	22.65
Manganese	ug/l	920	198	70	368.82	391.24	415.29
Nickel	ug/l	430	172	170	8.24	12.42	20.47
Copper	ug/l	170	59	60	16.03	21.79	29.75
Cobalt	ug/l	90	35	35	2.32	2.55	2.99
Zinc	ug/l	30	19	20	14.53	15.01	15.74
Iron	ug/l	80	38	40	3,838.08	3,869.43	3,893.63

TABLE 2 Comparison - MinnAMAX Leachate Data and PolyMet 5-year Predictions				
Parameter	**Units**	**AMAX Tested Maximum**	**PolyMet Modeled P90 Max**	**Ratio AMAX/ PolyMet**
Calcium	mg/l	600	46.32	12.95
Magnesuim	mg/l	954	80.66	11.83
Sodium	mg/l	2,500	71.21	35.11
Potassium	mg/l	102.2	10.31	9.91
Sulfate	mg/l	3950	340.16	11.61
Chloride	mg/l	4960	22.65	218.98
Manganese	ug/l	920	415.29	0.50
Nickel	ug/l	430	20.47	21.01
Copper	ug/l	170	29.75	5.71
Cobalt	ug/l	90	2.99	30.10
Zinc	ug/l	30	15.74	1.91
Iron	ug/l	80	3,893.63	0.02

* MDNR, Drainage From Copper-Nickel Tailings:Summary of a Three-Year Field Study, 2004, Table 7

**Water Modeling Data Package, Vol. 2 - Plant Site, PolyMet 2015i, Large Table 2

ATTACHED REFERENCES

Attachment A	PolyMet 2015i Large Table 2.
Attachment B	MDNR, Drainage from Copper-Nickel Tailings: Summary of a Three-year Field Study, July 2004.

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Chemist/biologist, 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.

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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.