Dangers of Sulfide Mining

https://tamarackwateralliance.org/

tamarackwateralliance.org/docs/SulfideMining-details.pdf

Nov 6, 2025

Context – Taconite Mining

- Taconite mining is **NOT** considered a high sulfide operation (but there are small amounts of sulfur in the ore – see later)
  - The first ore shipped from the Vermilion Range in 1884, the Mesabi Range in 1892, and the Cuyuna Range in 1911
  - The mines on the Mesabi Range historically extracted ore with 50–70% iron and could be dug out of the ground and shipped right out to be made into steel.
  - Starting in the mid-50's, production shifted to a lower grade ore called taconite, which has about 20–30% iron - finished pellets may contain up to 60-65% iron
- In 2024, eight open pit iron ore mines (with pelletizing plants) in Michigan, Minnesota, and Utah shipped 98% of domestic usable iron ore
  - 73% of US Iron Ore comes from Minnesota in 2024
  - 1.4% of world wide iron ore comes from Minnesota
  - Steel from recycled iron and steel scrap provided 65% of US Steel production (iron ore from MN accounted for about 26% of steel production)
- 2024 Minnesota DEED data indicates mining represents 0.7% of MN GDP and 0.198% of all jobs

Mining in Minnesota is Culturally Significant but Economically Nonconsequential

Wikipedia - Former AHM blast furnace in Port of Sagunt, Valencia, Spain

https://eros.usgs.gov/earthshots/taconite

https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-iron-ore.pdf

https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-iron-steel-scrap.pdf

https://www.revenue.state.mn.us/sites/default/files/2025-10/2025-mining-guide.pdf

Context – Taconite Mining

- Currently, the taconite is shipped to fossil fuel based blast furnaces
  - But blast furnaces are very quickly losing market share to electric arc furnaces to gain efficiency and greatly reduce carbon footprint
  - Blast furnaces are very expensive to rebuild so are often decommissioned rather than maintained
- Electric arc furnaces (EAFs) can't use the taconite pellets that Minnesota currently produces because their iron content is too low (about 60-65%)
  - EAFs consume recycled iron and steel scrap which currently make up 72% of the steel market including high grade steel
  - EAFs require higher grade source material
  - 93% of new steelmaking capacity announced in 2024 promises to use lower emission electric arc furnaces (EAFs)
  - 49% of the world's steelmaking capacity in development now uses EAFs
  - New plants must be built in the Mesabi range that can turn the low-grade ore into high grade iron for further processing
- Mesabi Metallics is operating a direct-reduced iron (DRI) plant in Nashwauk, Minnesota, to produce higher grade iron ore

- Fossil fuel-based blast furnaces which rely on coal/coke are increasingly being replaced by electric arc furnaces (EAFs) and direct reduced iron (DRI) technology
  - The steel and iron industry is responsible for 7% of greenhouse gas emissions and 11% of carbon dioxide emissions globally
  - This is more than the total emissions from all the world's cars and vans.
- EAFs offer a lower-carbon alternative (from sustainable power grid) to blast furnaces that rely on coal,
- DRI technology can utilize various fuels, including hydrogen, to produce iron

https://www.carbonbrief.org/significant-shift-away-from-coal-as-most-new-steelmaking-is-now-electric/

Iron Industry faces serious challenges as it struggles to compete with new added costs of DRI plants and iron ore prices $100-$110 per tonne.

Taconite is **NOT** a High Sulfide Mining Operation

Taconite (Iron)

- **Grade**
  - Taconite is 20-30% iron
- **Found With**
  - Iron is bound in silica minerals (SiO_2 like quartz, … asbestos, …) and iron oxides
- **Price -> about $100-120 per tonne (metric)**
- **Ownership -> Mostly US (except for US Steel)**

Unlike iron mining, copper and nickel mining in Minnesota is characterized by:

- Very high sulfur content (toxic impacts)
- Very low grades but high value
- Very large amounts of waste due to the low grade (sulfide contaminated)
- Exclusively Foreign Owned

High Sulfide Mining (Copper and Nickel)

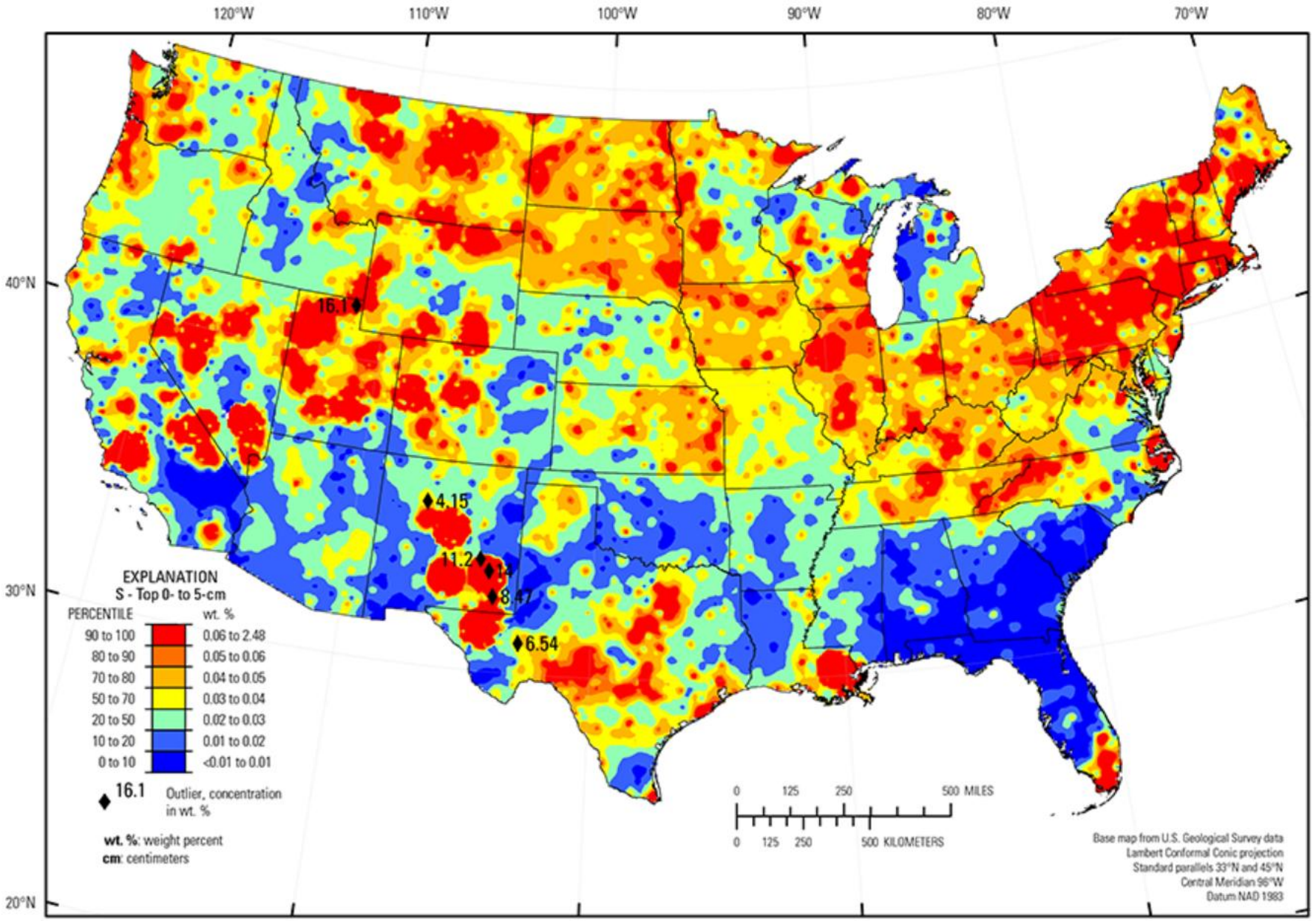
- **Grade**
  - Nickel from underground mines is generally in the range of 1.5-3% nickel (to be feasible) … some underground mines report much lower (0.19% numbers)
  - Nickel from open pit mines can be very low from 0.08% upward toward 0.5%
  - Copper from open pit mines can be 0.3% - 0.79% (Polymet)
- **Found With (in the Midwest)**
  - **Sulfides** -> Highly variable, e.g. the Arkansas Geological Survey, indicated ore with sulfur ranging from 6.5 to 32.4%
  - Deposits of up to 70% sulfur have been reported in MN
  - A high sulfide mine can have more than 10 times as much sulfur than the mineral being mined
- **Price -> Nickel $15,500, Copper $9,800 per tonne (sulfur is less than $100 per tonne)**
- **Ownership -> Mostly Foreign companies (Rio Tinto, Glencore, Talon from Canada, …)**

Sulfur

Sulfur is an essential plant nutrient - **sulfur** cycling in soil is complex.

Sulfur is essential to all organisms, including humans, and is considered to be nontoxic - **EXCEPT**

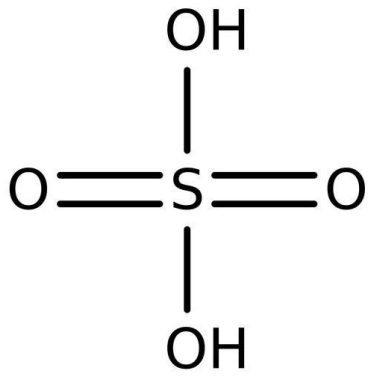
Sulfur compounds, such as carbon disulfide (CS_2), hydrogen sulfide (H_2S rotten eggs), sulfur dioxide (SO_2), and of course, sulfuric acid (H_2SO_4) are toxic.



https://pubs.usgs.gov/sir/2017/5118/sir20175118_element.php?el=16

Sulfides and Extractive Industries

- Petroleum and natural gas - hydrogen sulfide (H_2S) gas is often present
  - Hydrogen sulfide is a colorless gas, and is poisonous, corrosive, and flammable, with trace amounts in ambient atmosphere having a characteristic foul odor of rotten eggs
  - Exposures generally should not exceed 20 parts per million (ppm)
  - At higher and more dangerous concentrations of around 100 ppm, neurotoxicity occurs with olfactory paralysis
- Coal - typically coal contains anywhere from 0.2 to 5 percent sulfur by weight
  - Burning coal puts both sulfur dioxide and nitrogen oxide into the air
  - These gases mix with water droplets and oxygen to make sulfuric acid and nitric acid
  - So called (Acid Rain) that has affected large areas
  - SO_2 and NO_X also can react in the atmosphere to form fine sulfate and nitrate particles that people can inhale into their lungs potentially causing increased risk of heart disease, and effects on lung function including breathing difficulties



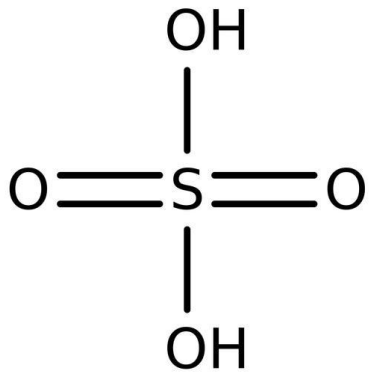
Sulfuric Acid
A very strong acid

Sulfide Mine Dust Can Have the Same Effect as Coal based Acid Rain

https://www.epa.gov/acidrain/effects-acid-rain

Sulfides and Extractive Industries

- Sources of Sulfur in Minnesota
  - Taconite mines and coal plants (particularly from ND as well as MN) are the largest dischargers of sulfates today in Minnesota (DNR)
  - Nickel-Copper-Cobalt minerals in MN are bonded to sulfur mined as high sulfide ores
- High Sulfide concentrations occur in Minnesota copper and nickel deposits
  1. When these ores are exposed to air and moisture, a chemical reaction occurs that generates **sulfuric acid** that migrates into the surrounding environment and, through leaching, releases heavy metals present in the waste rock, pit walls, and tailings basins of mining operations.
  2. The sulfuric acid along with dissolved heavy metals released onto the land will seep intc the rich aquifers below and then into streams and lakes at levels that are toxic to fish and other aquatic life
  3. Sulfates interact with sulfate-reducing bacteria to produce the more bio-toxic form of mercury, methylmercury, a known neurodevelopmental toxin

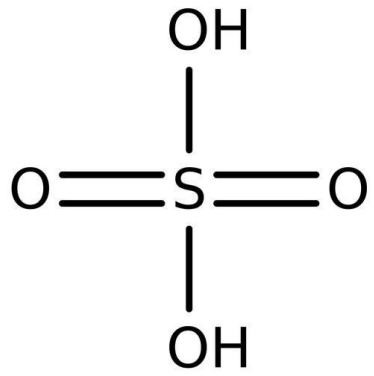


Sulfuric Acid
A very strong acid

The chemical reaction of sulfide ore / tailings to sulfuric acid can happen over long periods of time – many 100's of years

Sulfur Related Dangers of High Sulfide Mining

- Acid Mine Drainage - Nickel-Copper-Cobalt minerals are bonded to sulfur mined as sulfide ores
  - When these ores are exposed to air and moisture, a chemical reaction occurs that generates **sulfuric acid** that migrates into the surrounding environment and, through leaching, releases toxic heavy metals present in the drill cuttings, waste rock, pit walls, and tailings basins of mining operations – highly toxic to fish and aquatic life
- Sulfur reducing bacteria convert free mercury in the environment to methyl-mercury which is highly toxic and accumulates in fish creating fish consumption limits
  - Free elemental mercury can be toxic but is not the concern – mercury must be methylated to accumulate in the environment
  - Sulfur is the primary methylator for mercury
  - Methylmercury is very toxic
- Wild rice is very sensitive to sulfate levels and require an environment where sulfate levels are less than 10ppm – thus even relatively low levels of sulfates can decimate wild rice crops



Sulfuric Acid

A very strong acid

Extracted Sulfur is Toxic in the Environment

Acid Mine Drainage (AMD)

- For the 20 years that Wisconsin had a “Prove It First” law in place, the mining industry **could not find a non-polluting sulfide mine**. The law was repealed in 2017.
  - https://www.sierraclub.org/wisconsin/prove-it-first-law
- Kuipers et al (2006) studied 25 operating hard rock mines and their EISs:
  - All predicted compliance with water quality standard within their EISs
  - However pollution from 85% of mines near surface water and 93% of mines near ground water exceeded water quality standards
  - 89% had inaccurately predicted that they would not create AMD.
  - CLEARLY – EXISTING MINING REGULATION IS NOT SUFFICIENT!

Photo courtesy of the U.S. Geological Survey. 1998. Status and trends of the nation’s biological resources. Vol. 1. Reston, VA: U.S. Department of the Interior. Available at: http://www.nwrc.usgs.gov/sandt/.

According to the EPA, sulfide ore mining is the most toxic industry in the US - metal mining industry releases the most toxic chemicals by weight compared to any other industry

https://earthworks.org/releases/epa_metal_mining_most_toxic_industry_in_america/

Acid Mine Drainage (AMD)

- AMD is primarily the result of sulfur from mine waste (e.g. sulfide dust from blasting / digging / crushing the ore) interacting with air/water to create sulfuric acid
- A literature review on acid mine drainage concluded that “no hard rock surface mines exist today that can demonstrate that acid mine drainage can be stopped once it occurs on a large scale.”
- Acid runoff from the Summitville Mine in Colorado killed all biological life in a 17-mile stretch of the Alamosa River. The site was designated a federal Superfund site, and the EPA has spent over $210 million on clean-up.
- Zortman Landusky mine in north central Montana filed for bankruptcy in 1998 leaving the state of Montana with the liability for $33 million in long-term water treatment and reclamation costs

- Torch Lake in Houghton County, MI is a superfund site
  - Copper mining activities in the area from the 1890s until 1969 produced mill tailings that contaminated lake sediments and the shoreline
  - Fish were found with cancerous tumors and high levels of copper, arsenic, mercury and PCBs
  - Remediation efforts started in 1998 and continued through 2006 – EPA updated cleanup plan Nov 2024

Environmental Damage Not Recognized until nearly 20-30 years after mine closed!

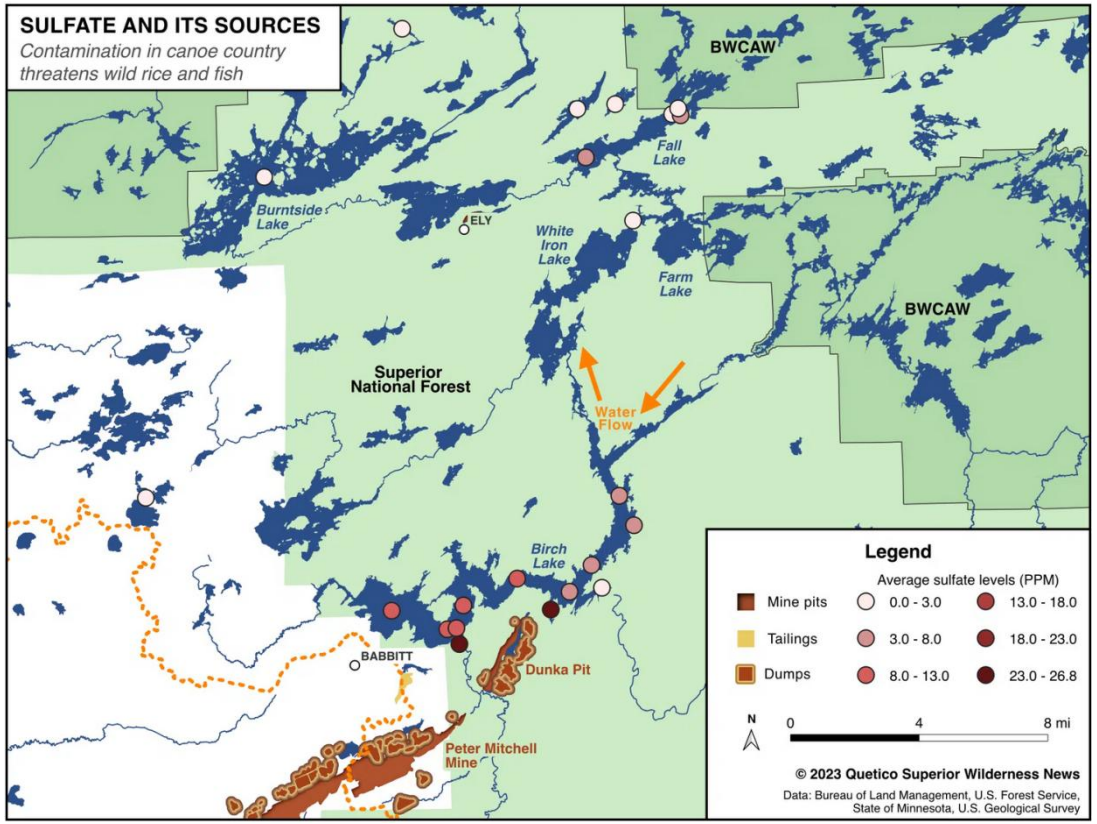
Why Do We Need To Use Taxpayer $$$ To Clean Up Mining Industry Messes!

SOURCES:

- https://earthworks.org/issues/acid_mine_drainage/
- https://www.usgs.gov/mission-areas/water-resources/science/mine-drainage
- https://www.epa.gov/nps/abandoned-mine-drainage-additional-resources

Acid Mine Drainage (AMD)

- MPCA recently announced that Birch Lake has excessive sulfate in its water (impaired)
- The Dunka taconite mine (closed in 1991) waste rock piles, which are 80–100 feet high and extend for almost a mile, have been leaching metals into the streams and wetlands that flow into Birch Lake.
- Several lakes and rivers upstream of the Boundary Waters Canoe Area Wilderness are contaminated with sulfate, which causes more mercury in fish and kills manoomin (wild rice), according to the Minnesota Pollution Control Agency and several citizen-led sampling efforts.
- Waters downstream of past and present iron mines exceed standards for sulfate levels designed to protect the environment.

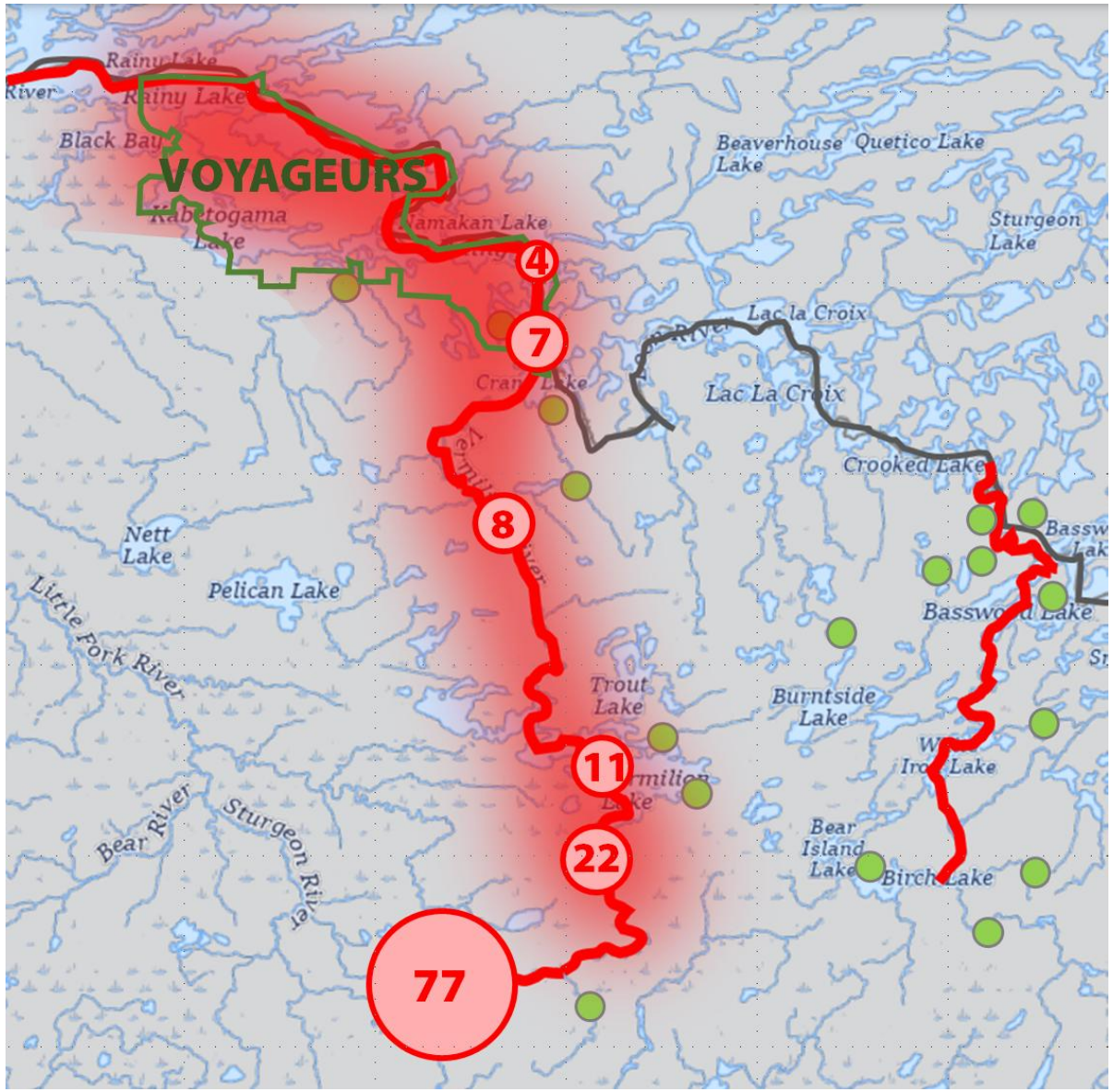


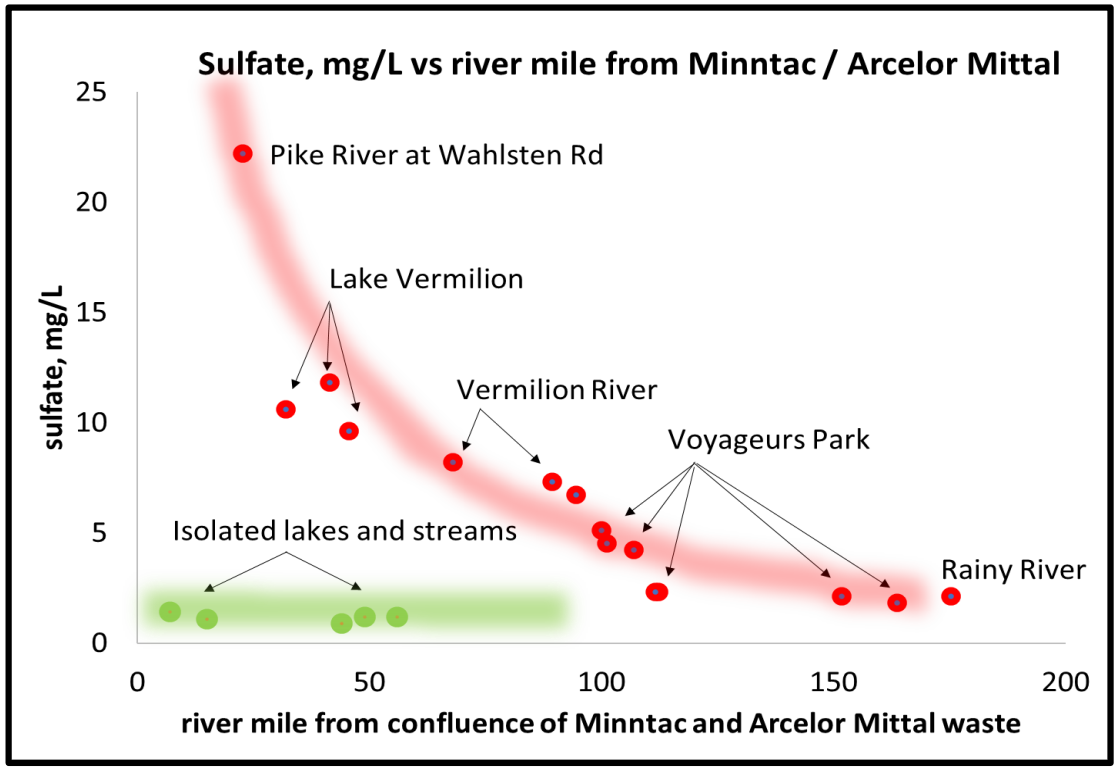
https://www.youtube.com/watch?v=ZW8p640wNno

The Northern Lakes Scientific Advisory Panel, or NLSAP, monitors (sulfate based) water pollution in Voyageurs Park and the BWCA in cooperation with the Minnesota Pollution Control Agency and have measured high levels of sulfate

https://queticosuperior.org/birch-lake-near-bwcaw-polluted-by-sulfate-advocates-blame-taconite-mines/

BWCA/Voyageurs Pollution





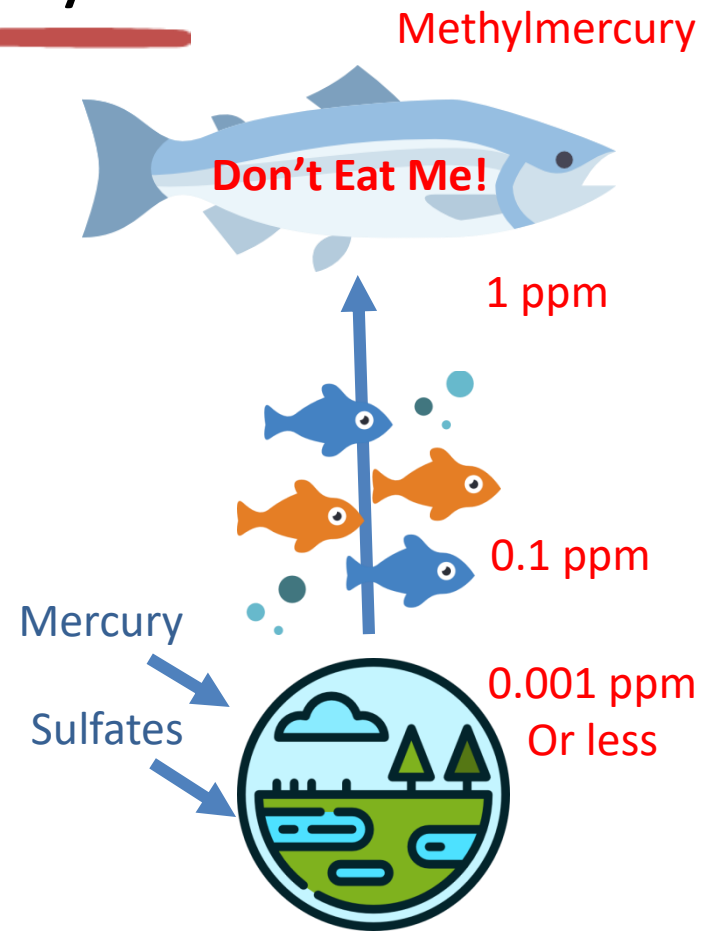
- **LEFT**: Sulfate pollution from Minntac and Arcelor Mittal mines in Virginia, through Voyageurs Park
- **RIGHT**: Sulfates from Northshore Mine in Babbit though BWCA
- Red bubbles show the sulfate concentrations dropping steadily from 77 parts per million (PPM) in Virginia to 2.5 PPM in International Falls
- Background sulfate concentrations in unpolluted lakes and streams is less than 2 ppm as indicated by small green bubbles.
- Six PPM is enough to quadruple concentration of mercury in fish.
- Voyageurs Park walleyes are severely contaminated with mercury because of sulfates - WORSE than 64 of 65 commercial seafood species monitored by the US FDA

Courtesy of Northern Lakes Scientific Advisory Panel (NLSAP)

More Info at: tamarackwateralliance.org/docs/2025_04June_NLSAP-TWA_meeting.pdf

Sulfate Reducing Bacteria Produces Methylmercury

- Atmospheric mercury (Hg) is the dominant source of Hg in northern Minnesota.
  - Taconite plants, are the largest industrial source of mercury pollution in Minnesota, have vented the toxic metal for years into the air without enforced limits.
  - https://www.startribune.com/epa-rule-targets-taconite-industry-mercury-polluter-minnesota-coal-regulation-earthjustice-tribe/600274349
  - Coal-fired power plants are another significant source of mercury
- Atmospherically derived Hg must be methylated prior to accumulating in fish
- Sulfate-reducing bacteria are the primary methylators of Hg in the environment
  - Sulfur + Mercury creates methylmercury
  - Sulfur historically comes from coal plants (e.g. Acid Rain), mine waste and to a much lesser extent fertilizers and some soaps
- Methylmercury is a highly toxic substance that is fat soluble and thus can "bio-magnify" up the food chain (in fatty tissues), primarily in fish and shellfish.

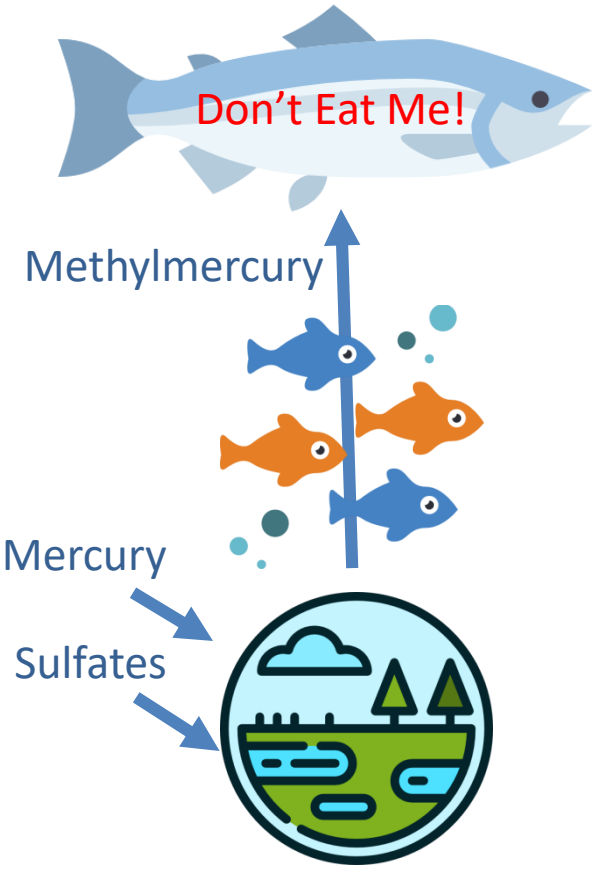


Methylmercury Presents a Serious Health Threat And is Created by Sulfate Reducing Bacteria

https://www.fs.usda.gov/nrs/pubs/jrnl/2006/nc_2006_jeremiason_001.pdf
https://www.pca.state.mn.us/pollutants-and-contaminants/mercury
https://pmc.ncbi.nlm.nih.gov/articles/PMC3514465/
https://www.ucsfhealth.org/medical-tests/methylmercury-poisoning
Fish icons created by Freepik, Smashicon and monkik - Flaticon

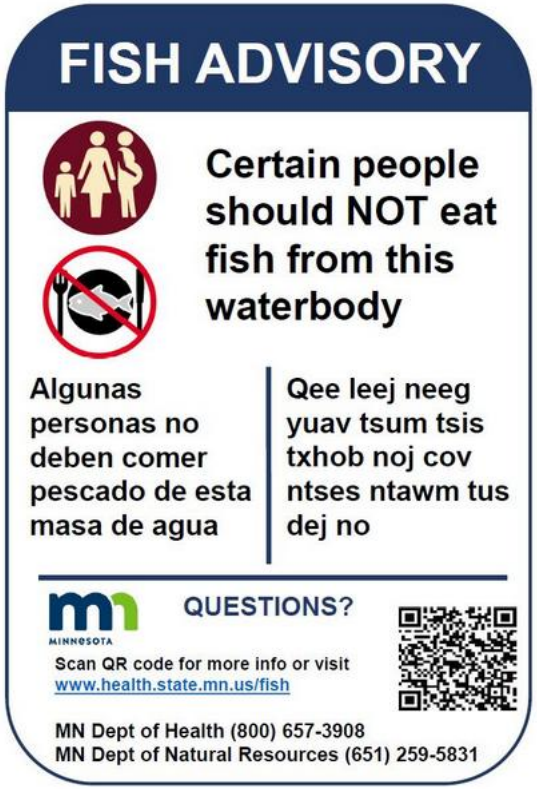
Methylmercury is VERY Toxic

- Methylmercury can cause a wide range of health effects, including:
  - Neurological damage (e.g., tremors, seizures, memory loss)
  - Kidney damage
  - Cardiovascular problems
  - Developmental problems in children (e.g., brain damage, motor coordination difficulties)
- "Mercury in Newborns in the Lake Superior Basin" study showed that ten percent of tested newborns in MN had concentrations of Mercury above EPA reference dose
  - 3% of Wisconsin and 0% of Michigan samples were above the U.S. EPA dose limit.
  - Babies born during the summer months were more likely to have an elevated mercury level suggesting that increased consumption of locally caught fish during the warm months is an important source of pregnant women's mercury exposure in this region
  - www.health.state.mn.us/communities/environment/fish/techinfo/newbornhglsp.html
- Karen Wetterhahn, a chemistry professor at Dartmouth College, died from mercury poisoning in 1997 due to accidental exposure to methylmercury
  - A few drops of the highly toxic compound seeped through her gloves
  - This led to her death about a year later
  - https://en.wikipedia.org/wiki/Karen_Wetterhahn



Local Lakes Are Already Impaired (mercury levels in fish)

- Many recreational lakes in MN lakes have fish consumption limits due to mercury levels
- See list of Minnesota Impaired Waters: https://www.pca.state.mn.us/air-water-land-climate/minnesotas-impaired-waters-list
- Minnesota Lake Finder for more detail: https://www.dnr.state.mn.us/lakefind/lake.html
- Fish consumption guidance can be found once the lake is identified



High Sulfide Mining Operations Will Only Make Lake Conditions MUCH, MUCH Worse, Further Compromising Water Quality and Fish Consumptions Limits

Sulfide Mining Threatens Tribal Wild Rice Resources

- Minnesota ranks #1 in the United States for wild rice production, both naturally grown and cultivated
- Wild rice is very sensitive to sulfide contamination
- Anishinaabe seasonally harvest tens of thousands of acres of wild rice in Northeastern Minnesota's undisturbed watersheds
- Manoomin is sacred to their way of life.
- Pristine water quality must be maintained for wild rice to germinate, grow, and survive.
- Sulfates bound in glacial/bedrock geology are released when the water is disturbed due to mining, endangering wild rice fields.
- Many lakes and streams around the Great Lakes have already lost their wild rice.
- Wild rice is hard to restore once it is gone.

Minnesota's wild rice sulfate standard limits sulfate to 10 parts per million (ppm or mgL) in wild rice waters.

Research Confirms 10/mg/L Still Sound Scientific Standard

- Research at the Univ. of MN NRRI (Dr. John Pastor, et. al.) determined that the 10 mg/L standard was still a sound scientific standard for the protection of wild rice
  - Later, they determined that inputs of iron with sulfate formed iron-sulfide (FeS) plaques on the root of the wild rice, slowly starving the plant of nutrients.
  - This resulted in small seeds with low reproductive viability, or no viable seed at all.
  - Repetitive growing seasons under these conditions led to a loss of wild rice, and eventually, stands of wild rice disappearing.
- Industry proponents continue to throw out red-herrings, stating that sulfate, in some combination of carbon and iron (to be determined on an individual basis for each waterbody) can allow wild rice to thrive
  - They do not point out that this has never been observed and documented in natural waterbodies, and is considered an artifact of a laboratory experiment completely detached from a repeatable natural environment
- This argument has largely been rebuffed by independent research findings
  - Administrative Law Judge's (ALJ) findings and conclusions, and a subsequent ALJ review process, and Minnesota's courts.
  - They also fail to cite from the Governor's Task Force report, pg. 34, para. 2, where it states "Ultimately, the MPCA found that high levels of sulfide in the porewater – the water in the sediment where the wild rice roots – has an adverse impact on wild rice.

Research Confirms 10/mg/L Still Sound Scientific Standard

1. Ecological Applications - Dr. John Pastor, et.al., "Effects of sulfate and sulfide on the life cycle of Zizania palustris in hydroponic and mesocosm experiments" - Oct. 4, 2016;
2. Journal of Geophysical Research: Biogeosciences - "Increase in Nutrients, Mercury, and Methylmercury as a Consequence of Elevated Sulfate Reduction to Sulfide in Experimental Wetland Mesocosms" by A. Mybro, E. B. Swain, N. W. Johnson, D. R. Engstrom, J. Pastor, B. Dewey, P. Monson, J. Brenner, M. Dykhuizen Shore, and E. B. Peters;
3. Journal of Geophysical Research: Biogeosciences - "The Evolution of Sulfide in Shallow Aquatic Ecosystem Sediment: An Analysis of the Roles of Sulfate, Organic Carbon, and Iron and Feedback Constraints Using Structural Equation Modeling" by Curtis D. Pollman, Edward B. Swain, David Bael, Amy Mybro, Philip Monson, and Marta Dykhuizen Shore;
4. Journal of Geophysical Research: Biogeosciences - "Sulfide Generated by Sulfate Reductions Is a Primary Controller of the Occurrence of Wild Rice (Zizania palustris) in Shallow Aquatic Ecosystems" by A. Mybro, E.B. Swain, D. R. Engstrom, J. Coleman Wasik, J. Brenner, M. Dykhuizen Shore, E. B. Peters, G. Blaha;
5. Ecological Applications Vol. 27, Issue 1, Jan. 2017 pp. 321-336 - "Effects of sulfate and sulfide on the life cycle of Zizania palustris in hydroponic and mesocosm experiments" by John Pastor, Brad Dewey, Nathan Johnson, Edward B. Swain, Philip Monson, Emily B. Peters, and Amy Mybro;

Health Impacts of High Sulfide Mining

Airborne particulates including dust from mine operations / venting

- Inhaled, small particles lead to oxidative stress and inflammation with numerous health impacts:
  - Increased risk cardiovascular event
  - Long term increased risk of hardening of arteries
  - Increased risk of blood clots
  - Increased tendency toward metabolic imbalances
  - Emerging evidence if increased dementia risk
  - Higher risk for lung disease
- Across the environment
  - Effects on Acid Rain damage (plant kill)
  - Serious impacts on wild rice (very intolerant of sulfides)

Water based contamination in ground water, lakes and streams

- Impacts on aquatic life and wetland plants including wild rice
- When the release of sulfur (e.g. from mining operations) reaches wetlands, it can stimulate "sulfate breathing" microorganisms that convert inorganic mercury to methyl mercury
- Highly toxic methyl mercury is fat soluable and accumulates in aquatic ecosystems including fish
- As sulfuric acid migrates into the surrounding environment heavy metals present in the waste rock, pit walls, and tailings basins is released further polluting the environment

Documented Health Risks of Sulfide Mining in Minnesota

- Sulfide Mining and Human Health in Minnesota
  https://pubs.royle.com/publication/?i=352462&article_id=2624726&view=articleBrowser
- Risks and costs to human health of sulfide-ore mining near the Boundary Waters Canoe Area Wilderness
  https://www.tandfonline.com/doi/abs/10.1080/10807039.2019.1576026
- Sulfide-ore mining AND human health in Minnesota - WHERE ARE WE NOW?
  https://www.savetheboundarywaters.org/sites/default/files/resource-file/MNMedicine2022.pdf
- Human Health and Sulfide Mining
  https://www.tamarackwateralliance.org/docs/HumanHealthAndSulfideMining.pdf
- Fond du Lac Band of Lake Superior Chippewa Health Impact Assessment. Expanding the Narrative of Tribal Health: The Effects of Wild Rice Water Quality Rule Changes on Tribal Health. Published online October 2018. Available at http://www.fdlrez.com/RM/downloads/WQSHIA.pdf

Can Toxic Affects of High Sulfide Mines be Mitigated?

THINGS THAT HELP:

- Mine nickel in laterite deposits (iron and silica based) NOT high sulfide deposits
- Mine in arid / low vegetation areas
- Use liners for operational areas (e.g. processing …) and for any storage and tailings piles
- Aggressive dust mitigation and vent shaft filtering
- Aggressive water collection and treatment

WHAT YOU CAN DO:

- Call and/or write your legislative representatives and the DNR / MPCA about the importance of clean water and strong regulation
- Recycle (everything and compost the rest)
- Support organizations that work for clean water including Waterlegacy, MCEA, Tamarack Water Alliance, CURE, Friends of Boundary Waters, … and others
- Take care not to use sulfur in fertilizers near lakes, rivers or wetlands.

Fundamentally, Minnesota (and most US states) need much better regulatory framework to **require and enforce** mitigations

Additional References

- Gestring B. U.S. Copper Porphyry Mines: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures and Water Collection and Treatment Failures. EARTHWORKS; 2012. https://earthworks.org/cms/assets/uploads/archive/files/publications/Porphyry_ Copper_Mines_Track_Record_-_8-2012.pdf
- World Health Organization. Ten chemicals of major public health concern. Published 2020. Accessed Oct. 2023. https://www.who.int/news-room/photo-story/photo-story-detail/10-chemicals-of-public-health-concern
- Grandjean P, Landrigan PJ. Neurobehavioural effects of developmental toxicity. Lancet Neurol. 2014;13(3):330- 338. doi:10.1016/S1474-4422(13)70278-3
- Kuipers JR, Maest AS, MacHardy KA, Lawson G. Comparison of Predicted and Actual Water Quality at Hardrock Mines: The Reliability of Predictions in Environmental Impact Statements. EARTHWORKS; 2006. https://earthworks.org/resources/comparison_of_predicted_and_actual_water_quality_at_hardrock_mines/
- Stock JH, Bradt JT. Analysis of proposed 20-year mineral leasing withdrawal in Superior National Forest. Ecol Econ. 2020;174:106663. doi:10.1016/j.ecolecon.2020.106663


Thank You!

Iron Mining Has Other Environmental and Health Risks

- Iron/Taconite ore and tailings can contain high levels of silica
  - Managing and storing these tailings is a major environmental concern because they can release silica dust and other contaminants, when not properly contained or treated
  - Silica dust, when airborne and inhaled, can pose serious health risks to miners and nearby communities
  - Exposure to respirable crystalline silica (silica dust) can lead to lung diseases such as silicosis, lung cancer, and other respiratory problems. (https://www.consumernotice.org/environmental/silica-dust/ and https://www.consumernotice.org/environmental/silica-dust/silicosis/)
- Studies have shown that workers in the Minnesota taconite mining industry have a higher risk of developing mesothelioma, a rare cancer of the lung lining, compared to the general population, according to the University of Minnesota School of Public Health
  - cancer.umn.edu/news/connection-between-iron-range-miners-and-asbestos-related-disease
- Taconite plants, are the largest industrial source of mercury pollution in Minnesota, have vented the toxic metal for years into the air without enforced limits (https://www.startribune.com/epa-rule-targets-taconite-industry-mercury-polluter-minnesota-coal-regulation-earthjustice-tribe/600274349)
- Other contaminates include sulfides and heavy metals like arsenic, cobalt, manganese
  - These metals can dissolve from the tailings and enter the environment, especially when exposed to rain and water sources
  - Heavy metals contaminate soil, surface water, and groundwater, potentially harming human health and the environment

But Shouldn't We Mine Nickel Here Because of Poor Labor Practices in Indonesia?

- Using US nickel has absolutely no affect on the Indonesian market which supplies 60% of worldwide production
  - Only 0.22% of the world's supply of Nickel comes from the US (Michigan Eagle Mine)
  - US only possesses 0.24% of the worldwide reserves of Nickel
- US based companies do not import appreciable amounts of nickel from Indonesian nickel (into the US).
  - See https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-nickel.pdf.
  - USGS primary nickel is from Canada, 46%; Norway, 9%; Finland, 7%; Russia, 7%; and Nickel-containing scrap, including nickel content of stainless-steel scrap: Canada, 40%; Mexico, 26%; United Kingdom, 9%; Russia, 5%. Note that recycled nickel in all forms accounted for approximately 54% of consumption.
  - Indonesian nickel goes to China where it is primarily used for stainless steel
- Indonesian nickel is predominately in iron deposits (NOT SULPHUR) so no high sulfide pollution effects
  - Deforestation is a main concern but the primary cause of deforestation in Indonesia is agriculture not mining
  - People in glass houses should not throw rocks - in 1850, Minnesota's old-growth forests covered approximately 16.1 million acres ... Now down to 44,000 acres
- Nickel based EV batteries supports the use of African cobalt and associated slave labor.
  - Africa / Congo is known to use poor practices and slave labor in their cobalt mines
  - Congo supplies 74% of the world wide supply of cobalt and nickel based EV batteries use cobalt.
  - Much better to STOP using nickel and cobalt EV batteries but to switch to other chemistries such as Ferrous Phosphate (LFP) and eventually non-Li chemistries.

But Don’t We Need Nickel Mining for a Green/Sustainable Future?

But don’t we need nickel for solar panels, cell phones and all our electronic toys?

NO – Solar panels and electronic devices use silicon … from chips to solar cells … made from sand

- NOTE that mining by its very nature is NOT sustainable – minerals do not grow back like trees
- **What we NEED is more recycling** to create a sustainable economy
  - In 2024, recycled nickel in all forms accounted for approximately 54% of apparent consumption (USGS)
  - Around 68% of all nickel available from consumer products is recycled (from the Nickel Institute)
- US Nickel Mining Will Make NO difference in the Global Supply of Nickel
  - **Only 0.22% of the world’s supply of nickel** comes from the US (Michigan Eagle Mine)
  - **US only possesses 0.24% of the worldwide reserves of nickel** (Michigan and Tamarack)

Price of nickel falling to pre-EV days … making Tamarack nickel too pricey for stainless steel

https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-nickel.pdf
https://markets.businessinsider.com/commodities/nickel-price

Why Mine High Sulfide Minerals When Alternatives Exist

- Nickel laterite ores make up about 54% of the world's nickel reserves (some estimate as high as 70%)
  - But they may require more complex processing than sulfide ores
  - Laterite ores are rich in aluminum, magnesium, iron, and nickel.
- High sulfide nickel ores make up the remaining 35% of reserves
- Why sacrifice Minnesota with high sulfide mining when environmentally safer options exist worldwide?
  - https://natural-resources.canada.ca/minerals-mining/mining-data-statistics-analysis/minerals-metals-facts/nickel-facts
  - https://feeco.com/processing-of-nickel-laterite-ores-on-the-rise/
  - https://nickelinstitute.org/en/blog/2024/august/nickel-industry-part-2-processing-nickel-laterites-and-smelting/

Copper Mining (High Sulfide or Oxide)

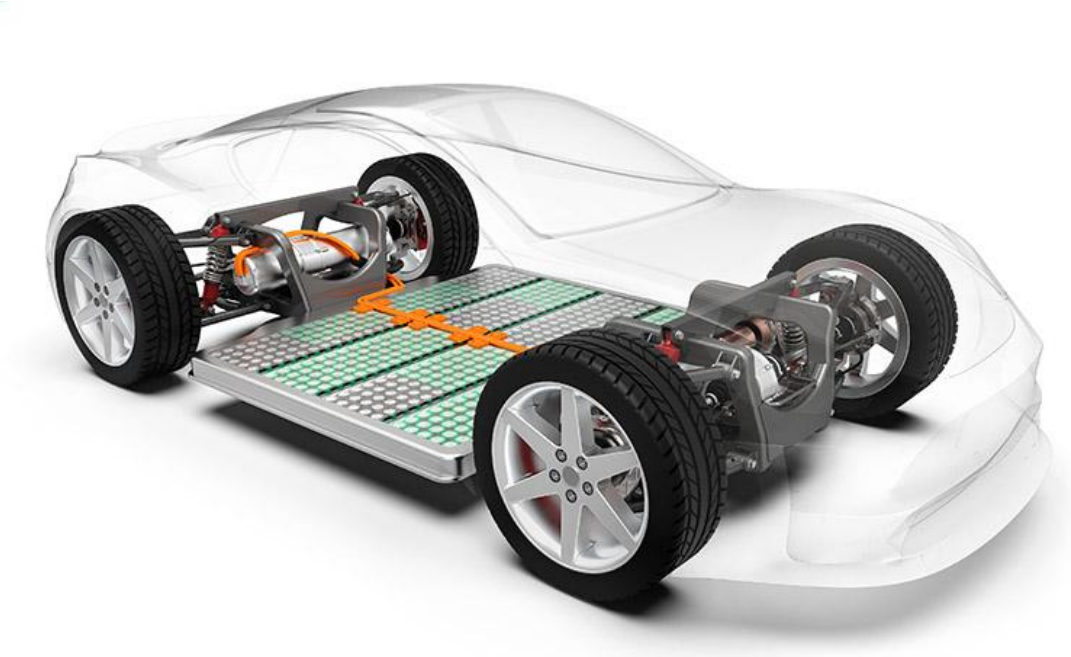
- Not all copper ores are high sulfide (highly polluting)
  - There are two main copper ore types of interest, copper oxide ores and copper sulfide ores
  - The **most common source of copper ore is the sulfide ore** mineral chalcopyrite, which accounts for about 50 percent of copper production
  - But oxide based ores are more abundant (https://www.visualcapitalist.com/sp/coppers-supply-chain/)
- Copper oxide ores are not as attractive of an exploration target as the copper sulfide ore types due to their lower grade
  - However low-grade copper oxide deposits can be economically extracted because they can be processed at lower cost than the copper sulfide ores.

Not all copper mining need be from high sulfide (high polluting) mines
Copper Oxide ore is more abundant and can be processed at lower costs

https://www.nasdaq.com/articles/copper-ore-types-sulfides-versus-oxides-2011-04-23

But Don’t We Need Nickel for EVs?

- EV Batteries - Nickel costs $15,000 per tonne (1/2025) and its use makes EVs unaffordable for most people
  - EV batteries using Li-Ion technology can cost $20,000 when nickel was $10,000 per tonne … now battery costs have sky rocked!
  - Nickel batteries can never be a solution to affordable EVs
- Tesla has announced a long term shift to (LFP) Lithium Ferrous Phosphate EV batteries – safer and longer life
  - Tesla 1Q22 quarterly report – nearly 50% of their vehicles in that quarter were already shipping with LFP (no nickel) batteries and
  - Tesla is transitioning their fixed battery product line to LFP
- Gotion and CATL unveiled a lithium manganese ferrous phosphate (LMFP) battery, with an energy density comparable Li-Ion (nickel based) batteries
- CATL is trialing a Sodium Ion EV battery – no nickel but made with locally sourceable inexpensive materials
- Lyten Corp and others are trialing a Lithium-Sulphur battery (no nickel) that has 2-3 times the energy density of the old Nickel based Lithium-Ion batteries – for much longer range vehicles.



Industry is moving away from Nickel & Cobalt based EV batteries due to the high cost of these materials

Recycling is a MUST for a Sustainable Future

- Copper Nickel Mining is FUNDAMETALLY Unsustainable – Sustainability Requires Recycling!
- Copper Usage – EVs
  - EV copper usage is primarily in the motor and power bus connecting the battery to the motor
  - Cars in general are already nearly all recycled (crushed) so in the future, we would expect battery and motor extraction for recycling
  - Thus EV (mined) copper demand slowly rises then falls to a small quantity once the large majority of vehicles are electric
  - **US 2024 EV sales used 0.517% of world wide copper production (global copper growth is 2.76%)**
- Copper Usage – HVAC Goes Green – Heat Pumps for Heating
  - https://www.eia.gov/todayinenergy/detail.php?id=52558 indicates that 88% of US households have AC as of 2020.
  - These over time will convert to heat pumps with a very small increase in copper needed when compressor and air exchange units are recycled
- Copper recovered from scrap contributed 35% of the U.S. copper supply in 2024

Just by Recycling EV Batteries and Appliances with Motors Could Address the Majority of Copper Needs in the US

Recycling is a MUST

- Copper Usage – Power Grid
  - Almost all power distribution uses aluminum cables NOT copper (check out the power cable coming into your breaker box).
  - According to NREL (https://www.nrel.gov/docs/fy17osti/66861.pdf) the National Renewable Energy Lab, only 1 metric ton of copper per Mw of capacity is needed for a large wind turbine
    - Other sources estimate 4x this amount but don't provide the detailed analysis that NREL has done … seems they are "making it up"
  - 2023 US growth of turbine capacity then uses 0.04% of world wide supply https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php)
  - Solar Cells – high estimates abound BUT Navigant Research (https://www.copper.org/publications/pub_list/pdf/a6197-na-solar-pv-analysis.pdf on page 6) indicates that the very large majority of copper attributed to solar cells is in the power distribution which has been going down with new technology and can be replaced by aluminum cable if needed.

Many information sources on this topic GREATLY over-estimate both need for energy as well as the % copper used AND do not account for recycling!

Minnesota Census of Employment and Wages (QCEW)

Minnesota had 2,931,419 total jobs in 2024

Minnesota Industry Employment in 2024

NAICS	Industry Title	Employment	Establishments	Avg. Annual Wage	Total Payroll
11	Agriculture, Forestry, Fishing and Hunting	23,446	3,295	$51,948	$1,220,137,914
21	Mining	5,803	253	$112,164	$649,733,863
22	Utilities	14,655	560	$130,364	$1,909,867,535
23	Construction	145,047	18,605	$88,296	$12,801,250,165
31	Manufacturing	320,253	8,573	$83,252	$26,671,060,408
42	Wholesale Trade	134,030	15,855	$106,392	$14,256,523,859
44	Retail Trade	285,244	18,053	$39,312	$11,222,391,537
48	Transportation and Warehousing	116,545	6,338	$68,848	$8,030,613,696
51	Information	46,715	7,407	$114,088	$5,329,522,069
52	Finance and Insurance	138,236	11,300	$136,084	$18,824,754,910
53	Real Estate and Rental and Leasing	35,853	7,071	$68,900	$2,470,389,710
54	Professional, Scientific, and Technical Servic..	167,468	30,181	$121,940	$20,423,898,427
55	Management of Companies and Enterprises	86,680	2,537	$145,184	$12,598,881,256
56	Administrative and Support and Waste Man..	123,346	10,433	$56,160	$6,927,305,471
61	Educational Services	234,549	5,392	$61,984	$14,559,634,458
62	Health Care and Social Assistance	532,896	25,901	$66,976	$35,703,542,200
71	Arts, Entertainment, and Recreation	54,524	3,997	$46,020	$2,497,135,612
72	Accommodation and Food Services	229,453	12,900	$27,300	$6,265,198,772
81	Other Services (except Public Administration)	91,777	20,724	$47,580	$4,369,367,689

From:
https://mn.gov/deed/data/data-tools/qcew/
Select the **Employment Details** tab