Sulfide Mining and Health

A Primer for Family Docs

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Minnesota Academy of Family Physicians
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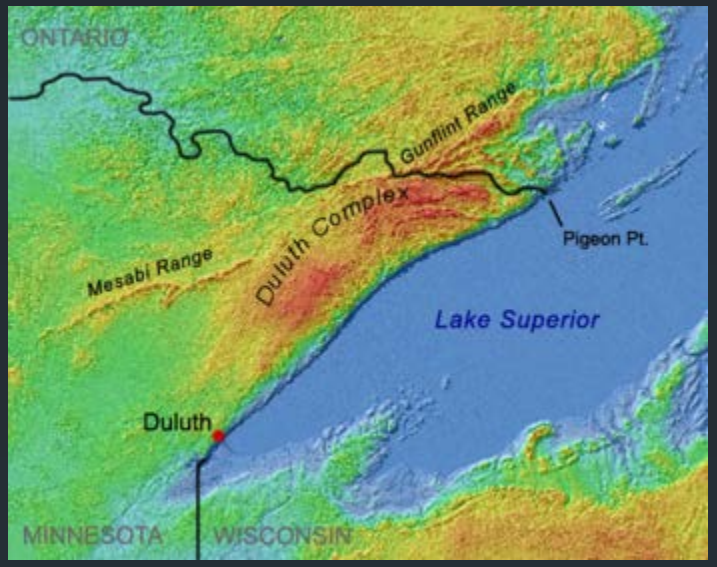
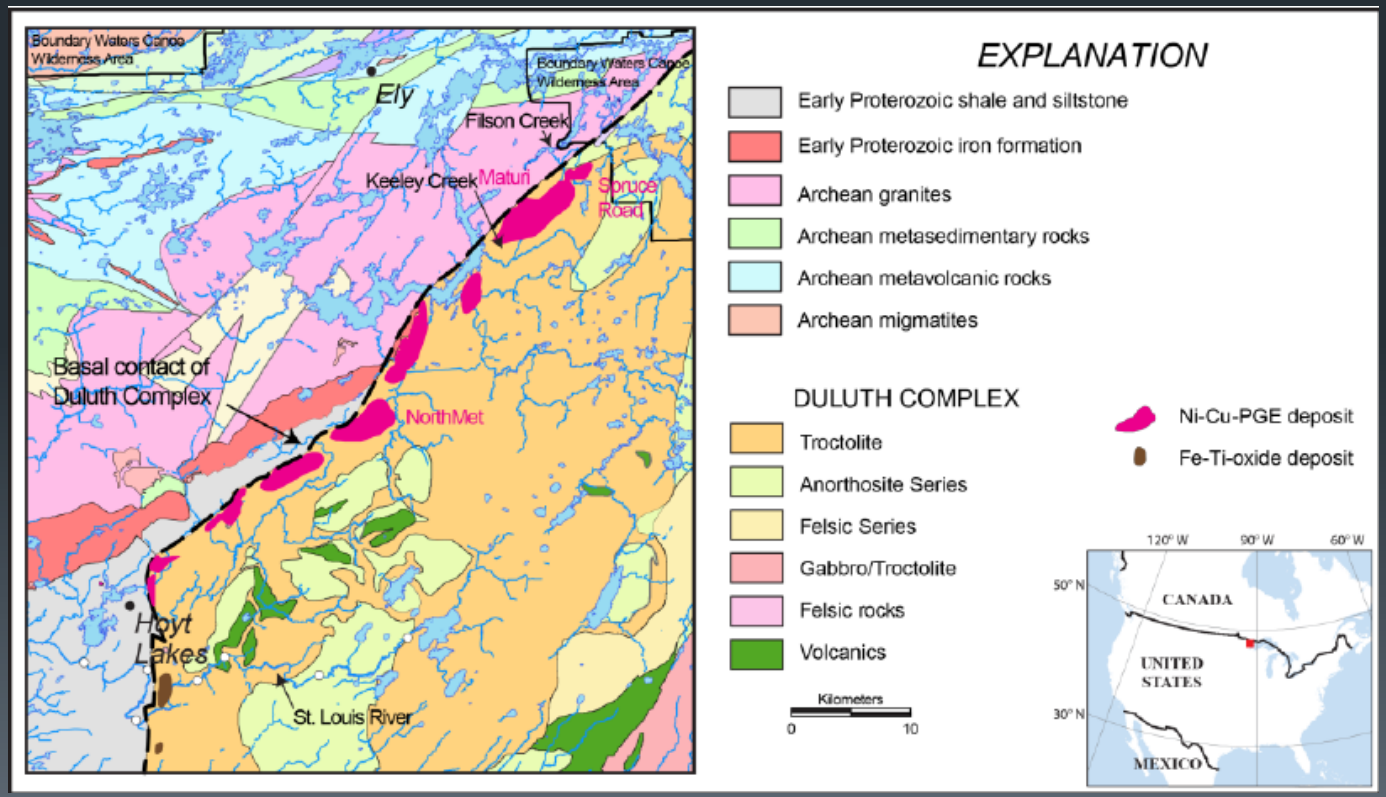
Sulfide Mining and Human Health: A Primer for Family Docs

Objectives:

- Recognize how sulfide and taconite mining differ
- Identify major toxins associated with sulfide mining
- Review how these toxins can impact human health
- Review MAFP's human health advocacy efforts

Sulfide Mining





How sulfide and taconite mining differ

Iron ore (taconite) mining

Photo courtesy of http://rvingbeachbums.blogspot.com/2014/11/iron-ore-mines-of-hibbing-mn.html, accessed on March 7th, 2017

Sulfide (copper-nickel) mining

Photo courtesy of https://toursofutah.com/kennecott-utah-bingham-canyon-copper-mine-tour/, accessed March 7th, 2017

Sulfide Mining

Desired metals in a mining operation, such as copper, nickel, palladium group metals, can be bound to sulfur in rock. Because of this sulfur bond, they are described as *sulfide minerals*. There are many chemical compounds within this category.

Mining these *sulfide minerals* is referred to as sulfide mining.

Jacobs JA, Lehr JH, Testa SM.
Acid Mine Drainage, Rock Drainage and Acid Sulfate Soils: Causes, Assessment, Prediction, Prevention and Remediation. Hoboken, NJ: John Wiley & Sons; 2014.

How sulfide and taconite mining differ

Iron ore (taconite) mining

- Desired ore lacks significant sulfur content; the chief iron-bearing minerals include iron oxides and iron carbonate
- Reaction with air/water = rust
- Mining rock & waste less likely to produce acid

Sulfide (copper-nickel) mining

- Ore body contains sulfur
- Mining activity can produce acid
- Reaction with air/water = H^+, SO_4^{2-} (sulfate), H_2SO_4 (sulfuric acid)
- Potential for release of heavy metals in ore

Poveromo JJ. Iron ores. In: Wakelin DH, Fruehan RJ, eds. The Making, Shaping and Treating of Steel. 11th ed. Pittsburgh, PA: The AISE Steel Foundation; 1999:547-642.

How sulfide and taconite mining differ

Pyrite Oxidation Sequence:
An example of how sulfide-bearing rock reacts with oxygen and water to create sulfuric acid

(1) $2\ FeS_{2\ (solid)}$ (pyrite) $+ 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-}{}_{(aq)}$ (sulfate) $+ 4\ H^+{}_{(aq)}$

(2) $4\ Fe^{2+}{}_{(aq)} + O_2 + 4\ H^+{}_{(aq)} \rightarrow 4\ Fe^{3+}{}_{(aq)} + 2\ H_2O$

(3) $2\ Fe^{3+} + 6\ H_2O \leftrightarrow 2\ Fe(OH)_{3(solid)}$ (ferric hydroxide) $+ 6\ H^+{}_{(aq)}$

(4) $14\ Fe^{3+} + FeS_{2(solid)} + 8\ H_2O \rightarrow 15\ Fe^{2+}{}_{(aq)} + 2\ SO_4^{2-} + 16\ H^+{}_{(aq)}$

(5) $FeS_{2(solid)} + 7\ Fe_2(SO_4)_{3(aq)} + 8H_2O \rightarrow 15\ FeSO_{4(aq)} + 8\ H_2SO_4$ (sulfuric acid)

Jacobs JA, Lehr JH, Testa SM. Acid mine drainage, rock drainage, and acid sulfate soils: causes, assessment, prediction, prevention, and remediation. Hoboken, NJ: John Wiley & Sons; 2014, p. 24.

How sulfide and taconite mining differ:
ACID MINE DRAINAGE

Iron hydroxide precipitating in a stream can be seen as the yellow-brownish discoloration, sometimes referred to as ‘ochre’ or ‘yellowboy’.

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/.

Identify Major Toxins Associated with sulfide mining: potential metals

Ore that contains the commercially desired metals often contains other metals like mercury, lead and arsenic, similarly bound to sulfur. Examples include:

- Lead (galena or PbS)
- Arsenic (arsenopyrite or FeAsS)
- Zinc (sphalerite or [(ZnFe)S])
- Mercury (cinnabar or HgS)
- Copper (chalcopyrite or $CuFeS_2$)
- Cadmium sulfide (CdS)
- Manganese sulfide (MnS)

Jacobs JA, Lehr JH, Testa SM.
Acid mine drainage, rock drainage,
and acid sulfate soils: causes, assessment, prediction,
prevention, and remediation.
Hoboken, NJ: John Wiley & Sons; 2014.

Microorganisms can speed up the oxidation reactions significantly

Acidithiobacillus ferrooxidans magnification 30,000 times.

Photo courtesy of Henry Lutz Ehrlich, Geomicrobiology, 2nd edition, (New York: Marcel Dekker, 1990)

Identify major toxins associated with sulfide mining

World Health Organization's Chemicals of Major Public Health Concern:

- **Air pollution***
- **Arsenic***
- **Asbestos***
- Benzene
- **Cadmium***
- Dioxin & Dioxin-like substances
- Inadequate or excess Fluoride
- **Lead***
- **Mercury***
- Highly hazardous pesticides
- **Cadmium***

JWorld Health Organization. Preventing disease through healthy environments: Action is needed on chemicals of major public health concern. Geneva: World Health Organization; 2010. Available at: www.who.int/ipcs/features/10chemicals_en.pdf?ua=1.

Review how these toxins can impact human health

Goodman & Gilman's: The Pharmacological Basis of Therapeutics, 12e, 2011 > Environmental Toxicology: Carcinogens and Heavy Metals

Laurence L. Brunton, Bruce A. Chabner, Björn C. Knollmann

Table 67-3
Toxic Metals with Frequent Environmental or Occupational Exposure[a]

METAL	CERCLA PRIORITY	COMMON SOURCE OF EXPOSURE	ORGAN SYSTEMS MOST SENSITIVE TO TOXICITY	IARC CARCINOGEN CLASSIFICATION
As	1	Drinking water	CV, skin, multiple other	Group 1, carcinogenic to humans—liver, bladder, lung
Pb	2	Paint, soil	CNS, blood, CV, renal	Group 2A, probably carcinogenic
Hg	3	Air, food	CNS, renal	Group 2B, possibly carcinogenic ($MeHg^{+}$); group 3, not classifiable (Hg^{0}, Hg^{2+})
Cd	7	Occupational, food, smoking	Renal, respiratory	Group 1, carcinogenic to humans—lung
Cr^{6+}	18	Occupational	Respiratory	Group 1, carcinogenic to humans—lung
Be	42	Occupational, water	Respiratory	Group 1, carcinogenic to humans—lung
Co	49	Occupational, food, water	Respiratory, CV	Group 2B, possibly carcinogenic
Ni	53	Occupational	Respiratory, skin (allergy)	Group 1, carcinogenic (soluble Ni compounds); group 2B, possibly carcinogenic (metallic Ni)—lung

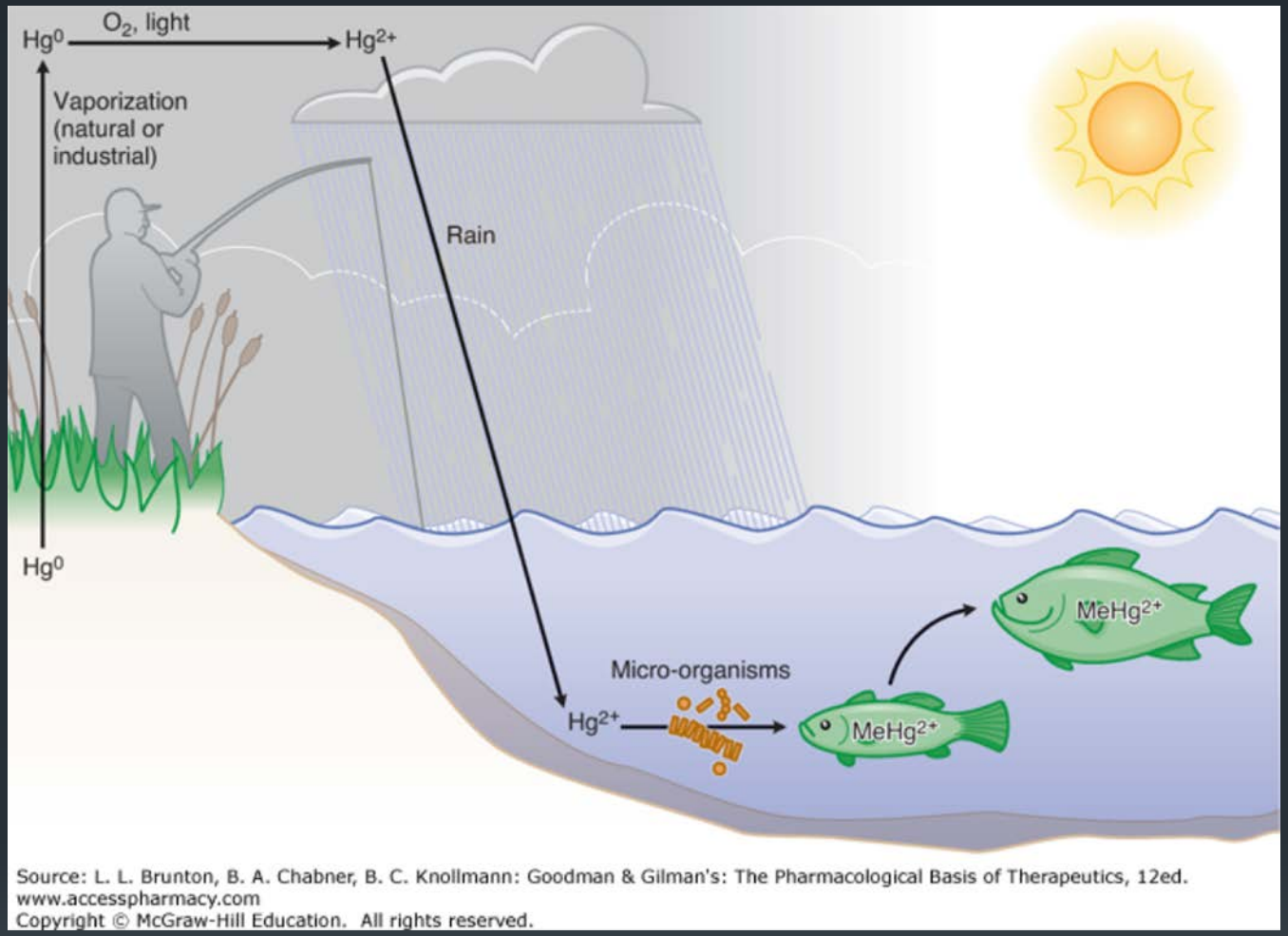
[a]The Agency for Toxic Substances and Disease Registry (ATSDR) has both detailed monographs and brief summaries for each of these compounds, available at http://www.atsdr.cdc.gov. The International Agency for Research on Cancer (IARC) also has monographs available at http://monographs.iarc.fr. CERCLA, Comprehensive Environmental Response, Compensation, and Liability Act. CNS, central nervous system;CV, cardiovascular.

Identify major toxins associated with sulfide mining: Mercury (Hg)

Mercury methylation by microorganisms occurs in sediments, wetlands, ombrotrophic (“cloud fed”) bogs and peat lands that are found in Minnesota’s water rich environment.

Jeremiason JD, Engstrom DR, Swain EB, et al. Sulfate addition increases methylmercury production in an experimental wetland. Environ Sci Technol. 2006;40(12):3800-6.

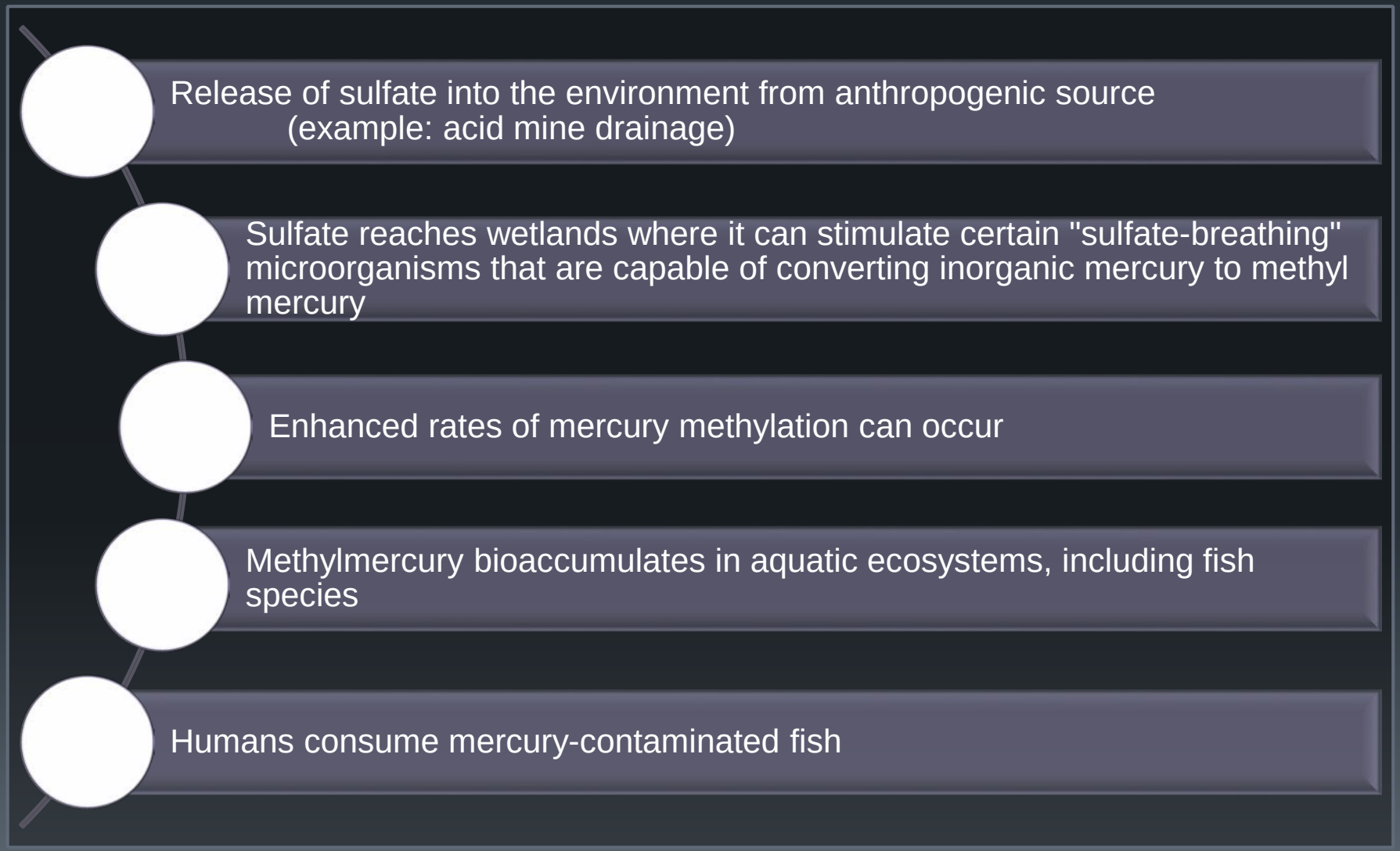
Branfireun BA. Of the NorthMet mining project and land exchange: Final environmental impact statement 2015. Expert Report. Available at: http://waterlegacy.org/sites/default/files/u42412/Branfireun_Expert_Opinion_PolyMet_FEIS_(FinalDraftDec.2,2015)(1).pdf. Accessed August 14, 2016.



Source: L. L. Brunton, B. A. Chabner, B. C. Knollmann: Goodman & Gilman's: The Pharmacological Basis of Therapeutics, 12ed.
www.accesspharmacy.com

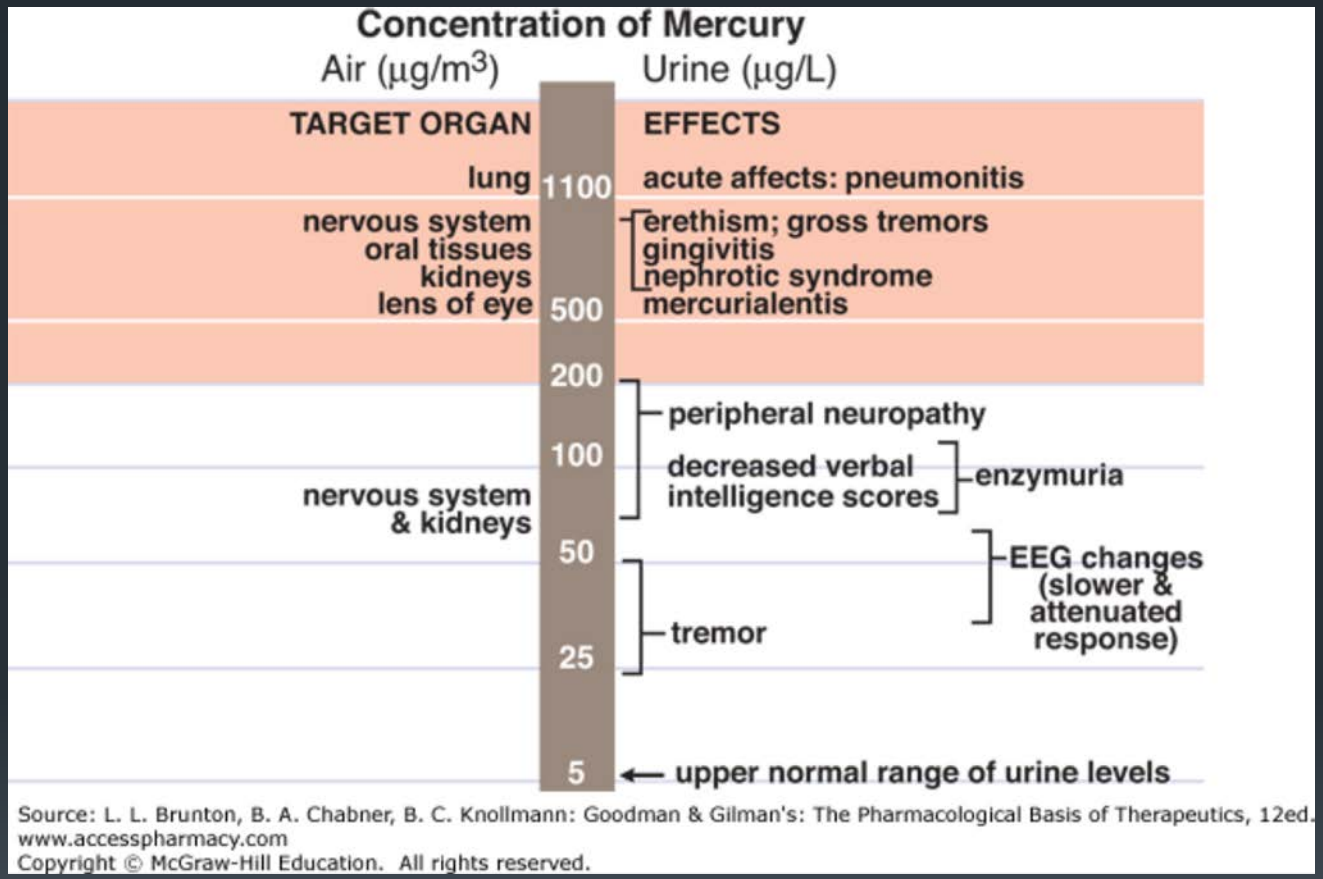
Mobilization of mercury in the environment. Metallic mercury (Hg^0) is vaporized from the Earth's surface both naturally and through human activities such as burning coal. In the atmosphere, Hg^0 is oxidized to form divalent inorganic mercury (Hg^{2+}). Hg^{2+} then falls to the surface in rain. Aquatic bacteria can methylate Hg^{2+} to form methyl mercury ($MeHg^+$). $MeHg^+$ in plankton is consumed by fish. Because of its lipophilicity, $MeHg^+$ bioaccumulates up the food chain.

Sequence of events by which release of anthropogenic sulfate can result in increased mercury levels in fish, and ultimately humans.



1. Jeremiason JD, Engstrom DR, Swain EB, et al. Sulfate addition increases methylmercury production in an experimental wetland. Environ Sci Technol. 2006;40(12):3800-6.
2. Branfireun BA. Of the NorthMet mining project and land exchange: Final environmental impact statement 2015. Expert Report. Available at: http://waterlegacy.org/sites/default/files/u42412/Branfireun_Expert_Opinion_PolyMet_FEIS_(FinalDraftDec.2,2015)(1).pdf. Accessed August 14, 2016.

Review how these toxins can impact human health



The concentration of mercury vapor in the air and related concentrations of mercury in urine are associated with a variety of toxic effects.

Source: Environmental Toxicology: Carcinogens and Heavy Metals, *Goodman & Gilman's: The Pharmacological Basis of Therapeutics, 12e*

Citation: Brunton LL, Chabner BA, Knollmann BC. *Goodman & Gilman's: The Pharmacological Basis of Therapeutics, 12e*; 2011 Available at: http://accessmedicine.mhmedical.com/content.aspx?sectionid=102164854&bookid=1613&Resultclick=2 Accessed: March 04, 2017

Review how these toxins can impact human health

The causes of neurodevelopmental disorders, including ADD, learning disorders, autism spectrum disorder, language disorders and intellectual disabilities are complex and multifactorial, but the connection to exposures to heavy metals, particularly methyl mercury, is known.

Bennett D, Bellinger DC, Birnbaum LS, et al. Project TENDR: Targeting environmental neurodevelopmental risks the TENDR consensus statement. Environ Health Perspect. 2016;124(7):A118-22.

Photo by Scott Housely, 2015 courtesy of the Center for Disease Control, content provided byJulia Whitney, Stephen Griffin

Identify major toxins associated with sulfide mining: other considerations

- Airborne particulates including fugitive dust, silica dust
- Additional air pollution (directly from mining activity as well indirect impacts from electrical power generation with fossil fuel source)
- Other considerations:

- unanticipated interruption of water treatment
- extreme weather event that overwhelms operation
- catastrophic event such as tailing dam breach

Image of truck with fugitive dust accessed from https://www.thermofisher.com/blog/mining/is-your-fugitive-dust-control-plan-effective-enough/ on March 7th, 2017.

Dam breach at Mount Polley Mine in British Columbia, Canada, August 4, 2014. Image taken by NASA's Operational Land Imager on Landsat8 satellite. Available courtesy of NASA Earth Observatory at http://earthobservatory.nasa.gov/IOTD/view.php?id=84202&src=ve.

Review MAFP's human health advocacy efforts: Why the concern?

Scale of initial proposed project

- 500 football fields 20 stories high of excavated rock now exposed to air and water
- This would only be the first in likely multiple much larger mines to be developed in the water rich environment of northern Minnesota.

Length of time water will need to be either contained or treated

- Hundreds of years

History

- Never has a sulfide mine been developed, operated and closed without producing polluted drainage.

History of Healthcare Profession Involvement

- MPHA (October 2014): letter representing over 400 public health professionals.
- MN Nurses Association (March, 2014): letter representing over 20,000 nurses.
- Health Providers Letter (March, 2014): letter of 46 doctors and nurses.
- Individual Health Professionals letter (Oct. 2014): 94 individuals plus Healthy Food Action and Food and Water Watch for a total of 153 health professionals (October 2014).
- MMA (Sept. 25th, 2014): letter representing over 10,000 physician members
- Physician meetings with MN Dept. of Health (May 2014) and DNR officials (July 2014)

Review MAFP's human health advocacy efforts:

- Fall of 2014 Four physicians were invited to present information on the proposed PolyMet project at Lake Superior MAFP chapter meeting

- ? Our place as physicians to take a stand?

  Conclusion was yes , absolutely. It was our responsibility as protectors of the health of our community to help raise awareness of a very significant potential public health problem.

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STRONG MEDICINE FOR MINNESOTA

History of MAFP and Physician Involvement

- Lake Superior Chapter Minnesota Academy of Family Physicians April 2015 resolution to statewide MAFP requesting a Health Impact assessment be completed prior to permitting of PolyMet

- Resolution adopted *unanimously* at House of Delegates meeting and subsequent letter sent

- September, 2015 nine physicians invited to meet with Commissioners of Health, MPCA, DNR and representatives from Governor Dayton's Office to advocate for HIA.

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History of MAFP and physician involvement, continued

MINNESOTA ACADEMY OF FAMILY PHYSICIANS
STRONG MEDICINE FOR MINNESOTA

July 2016 meeting in Duluth MN
between EQB leadership and MAFP members,
MAFP 2016 president and MAFP Executive Director

- April 13th, 2016 MAFP House of Delegates passed a resolution asking for a rule change to Minnesota Administrative Rules, Chapter 4410 to require a comprehensive and independent HIA be prepared for all sulfide mining projects requiring and EAW or EIS.
- On May 25th, 2016, this petition was sent to the Minnesota Environmental Quality Board.
- July 19th, 2016 the Chair and staff of the EQB came to Duluth to discuss the MAFP petition.
- Oct. 19th 2016 members of the MAFP, including the current state president met with the EQB to further discuss the request for an HIA rule change

History of MAFP physician involvement, continued

October 2016 MAFP members and leadership advocate for MAFP's request for a MN Rule change to require Health Risk and Health Impact Assessments as part of the Environmental Review process. Pictured, left to right: John Ipsen MD, Jennifer Pearson MD, Maria Huntley MAFP Executive Director, Dania Kamp MD MAFP 2016 President, Emily Onello MD, Deborah Allert MD, and Kristan Wegerson MD.

To date, Environmental Quality Board has not ruled on MAFP's petition.

Are Current Regulatory Bodies are Adequate to Protect us?

Sulfide mines invariably produce polluted drainage from their operations despite their plans that predict that there will be no pollution.

USEPA

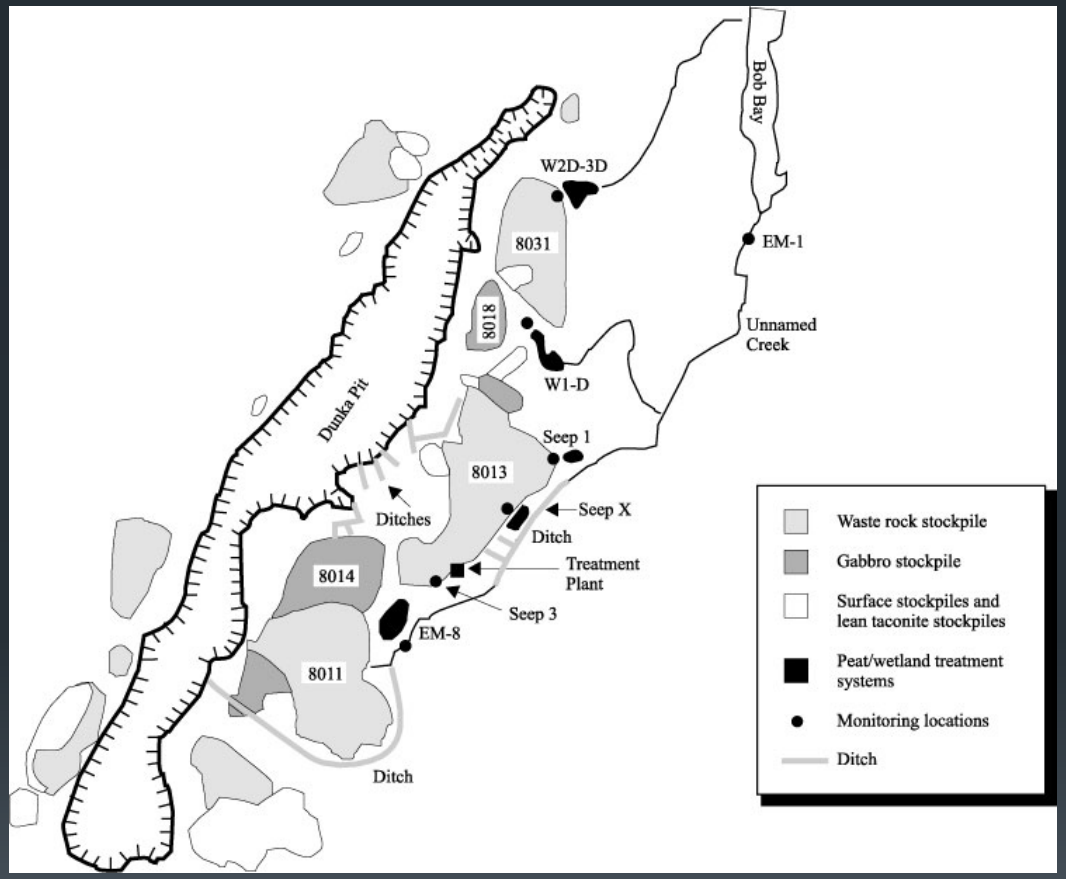
- The USEPA is involved in the production and approval of Environmental Impact Statements and tasked with enforcing violations of Federal law
- Major violations are not uncommon
  - In situations (such as Superfund sites) the USEPA tries to hold those responsible for the cleanup liable for damage costs, however, they are often thwarted in this attempt
- Toxic release information

Are Current Regulatory Agencies able to protect us?--continued

- MPCA
- The MPCA issues permits for actions related to the discharge of pollutants to surface waters. They must also certify compliance with state water standards
  - Variances
  - Inability to enforce regulations
  - Example: Dunka Mine (next slide)

Dunka Mine Example

- The Dunka pit is being considered by Twin Metals for use as a tailings disposal area
- This area was the location of an iron mining operation that exposed sulfide ore which produced acid drainage.
- For decades, the site has discharged heavy metals and acidic runoff into Birch Lake through an unnamed creek.
- There has been little action against those responsible and the runoff problem continues.



Source: Interstate Technology Regulatory Council
http://www.itrcweb.org/miningwaste-guidance/cs_dunka_mine.htm

Are Current Regulatory Bodies are Adequate to Protect us?

- MDNR

  The Minnesota DNR grants mining permits but has a conflicting mission. On the one hand, they are tasked with investigating potential environmental consequences. On the other hand they are tasked with promoting economic interests through the extraction of Minnesota's mineral resources.

- Minnesota State Health Department (MDH)

  This agency helps regulate groundwater quality through permitting processes related to water supplies and wells.

Public Risk vs. Private Reward

Taxpayer Risk

- It is taxpayers who are left with large bills to pay for the cleanup of abandoned sulfide mines. (Superfund sites)
- US EPA estimates the cost of mine cleanup for sites listed as national priorities at $20 billion. The most significant cost for this is ling-term water treatment and management.
- Tailings dam failures

Call to Action for Physicians

AMA Code of Ethics: Chapter 8:

Opinions on Physicians & the Health of the Community

Excerpt from Section 8.11 Health Promotion and Preventative Care

Although physicians' primary ethical obligation is to individual patients, they also have a responsibility to protect and promote public health.

“Medicine and public health share an ethical foundation stemming from the essential and direct role that health plays in human flourishing. While a physician’s role tends to focus on diagnosing and treating illness once it occurs, physicians also have a professional commitment to prevent disease and promote health and well-being for their patients and the community.”

Available at https://www.ama-assn.org/sites/default/files/media-browser/code-of-medical-ethics-chapter-8.pdf, accessed March 3, 2017

The Times Are Changing

- Rollbacks on clean water and mining regulations
- Fewer environmental protections
- It is more important than ever for physicians to be the voice of the community

Making a Difference

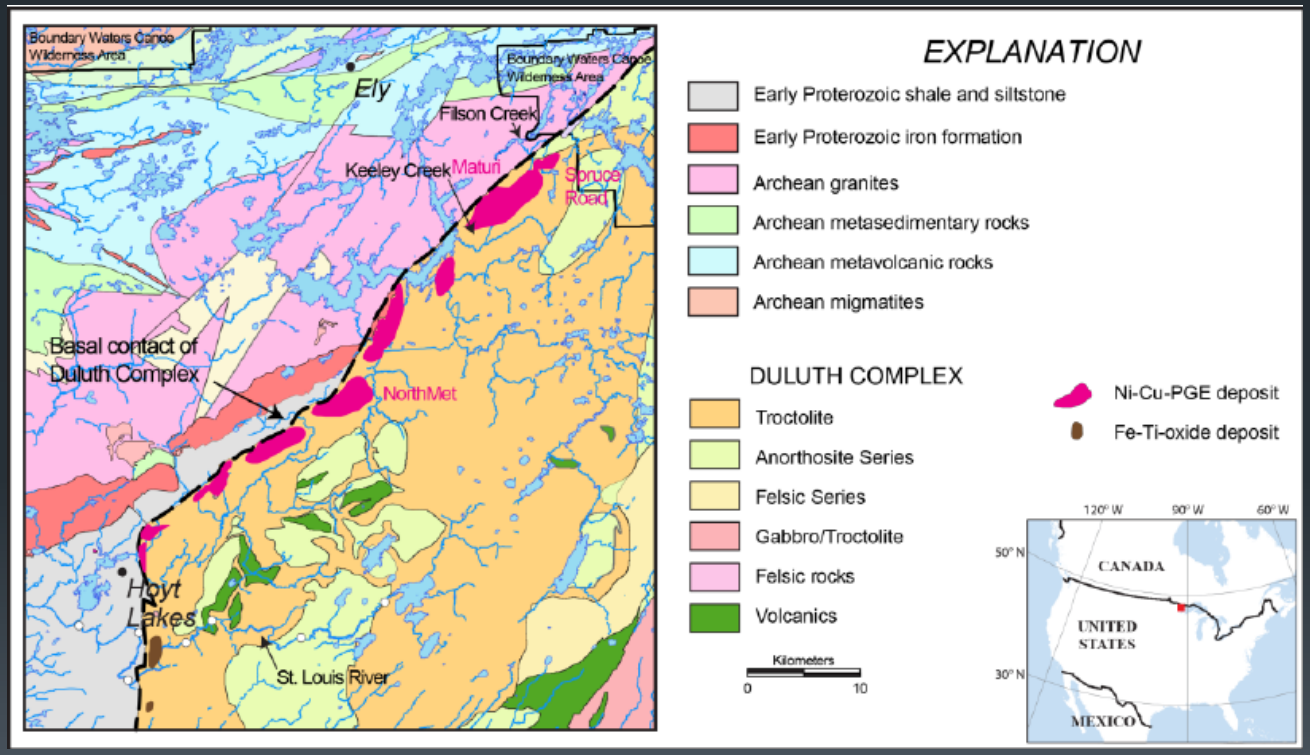
- Be involved
- Be informed
- Be willing to use your resources and partner with others
- Be an educator of public officials
- Be willing to leverage your history of caring for your community
- Most of all, be willing to stand up and be counted

Willingness to be Involved

"Every year I live I am more convinced that the waste of life lies in
the love we have not given,
the powers we have not used,
the selfish prudence that will risk nothing….
No one ever yet was the poorer in the long run for having
once in a lifetime "let out all the length of the reins."

- Mary Cholmondeley, Quotations from Women on Life

Questions?


Boundary Waters Canoe Wilderness Area
Ely
Filson Creek
Keeley Creek
Maturi
Spruce Road
Basal contact of Duluth Complex
NorthMet
Hoyt Lakes
St. Louis River
EXPLANATION
Early Proterozoic shale and siltstone
Early Proterozoic iron formation
Archean granites
Archean metasedimentary rocks
Archean metavolcanic rocks
Archean migmatites
DULUTH COMPLEX
Troctolite
Anorthosite Series
Felsic Series
Gabbro/Troctolite
Felsic rocks
Volcanics
Kilometers
0
10
Ni-Cu-PGE deposit
Fe-Ti-oxide deposit
120° W
90° W
60° W
50° N
30° N
CANADA
UNITED STATES
MEXICO

Supplemental Reading

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- Trasande L, Landrigan PJ, Schechter C. Public health and economic consequences of methyl mercury toxicity to the developing brain. Environ Health Perspect. 2005;113(5):590-6.
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Thank you