Arthur Baldwin

Must enforce standard. MPCA must enforce Minnesota's wild rice sulfate standard of 10 parts per million (ppm) under the Clean Water Act and decisions of the Minnesota courts. MPCA has no discretion to continue to delay or deny enforcement. The 10 ppm sulfate standard is the "effects threshold" for wild rice impairment.

>Degradation prohibited. Both the Clean Water Act and Minnesota law prohibit degradation of water quality in Minnesota lakes, streams, and wetlands. MPCA must not allow polluters to degrade high quality, low-sulfate wild rice waters.

>Protect low-sulfate waters. Many of Minnesota's most abundant wild rice stands in the Boundary Waters, the Lake Superior watershed, and north central Minnesota (including the Big Sandy Lake area) have far less than 10 ppm of sulfate. MPCA permitting should not allow sulfate in these wild rice waters to increase even if the degraded level of sulfate remains just below the standard.

>Sulfate and mercury. Sulfate pollution increases toxic mercury contamination of fish due to release of mercury from sediments and increased mercury methylation. MPCA must consider the effects of lax sulfate standard enforcement on mercury and methylmercury.

>Health threat of sulfate and mercury. MPCA lax enforcement of the wild rice sulfate standard and increased mercury contamination of fish will damage the developing brains of fetuses, infants, children, and people who rely on fish for subsistence, and will impair the exercise of tribal Treaty-reserved rights.

>Need proof to consider "site-specific standard." The wild rice sulfate standard is not advisory. Any discharger asking for MPCA even to consider of a "site-specific standard" sulfate standard must prove that wild rice beneficial use will be protected long-term.

>High iron does not protect wild rice. Peer-reviewed scientific evidence does not support allowing more sulfate when there is also a high level of iron in sediments. Adding sulfate to waterbodies with high levels of iron coats wild rice roots with iron sulfide and interferes with wild rice seed quality, production, and sustainability.

>MPCA's "equation" is not valid science. MPCA's "equation" method to determine if wild rice production would be protected without the 10 ppm standard was debunked in contested case proceedings in 2018. The "site-specific standards" loophole should not be used to resurrect this scientifically unsupported theory.

>Current discharge – historic proof. Before a "site-specific standard" can be considered for wild rice waters that currently exceed the wild rice sulfate discharger, the proponent (discharger or MPCA) should have to prove based on independent research—from the time historic sulfate discharge began to the present—the absence of harm to wild rice beneficial use, including harm to wild rice abundance, seed productivity, genetic diversity, and nutritional quality.

>New or expanded discharge – research required. Before a "site-specific standard" can be

considered for a new or expanding discharge to wild rice waters, the proponent (discharger or MPCA) should have to prove based on at least 5 years of independent research using site-specific wild rice seeds and sediment that the proposed sulfate levels would not cause harm to wild rice beneficial use, including harm to wild rice abundance, seed productivity, genetic diversity, and nutritional quality

>Tribal and public process. No "site-specific standard" for discharge of sulfate to wild rice should be approved by MPCA without tribal consultation and tribal consent and a formal and public rulemaking process.

>Enforcement without further delay. Unless and until a "site-specific standard" has been formally approved as required under state law and the Clean Water Act, the MPCA must apply the 10 ppm wild rice sulfate standard in setting and enforcing permit limits and in preparing TMDL studies and implementation plans to restore wild rice waters listed as impaired due to excessive sulfate. MPCA must neither delay or assume a less stringent will at some point be approved.

Clean up the legacy pollution from taconite mining before the taxpayer gets sacked for the bill!

Sulfide Mining and Human Health in Minnesota

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Sulfide Mining and Human Health in Minnesota

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Sulfide mining (specifically copper-nickel sulfide mining) represents a significant departure from Minnesota's iron mining tradition. Sulfide mining can produce acid waste and sulfates that mobilize the release of heavy metals into the environment. These metals include known neurotoxins such as lead and mercury. Mining activities also create airborne fibers and pollutants that can contribute to increased morbidity. The short- and long-term effects of exposure to these substances on human health should be considered in present and future sulfide mining proposals. In addition, Minnesota physicians need to understand the potential adverse mental and physical health effects of sulfide mining on mine workers and residents of communities near mining operations.

The Duluth Complex is a geological formation that contains deposits of copper, nickel and palladium group metals. It is located at the eastern end of the Mesabi Iron Range in northeastern Minnesota.[1] PolyMet Mining plans to build an open-pit mine in the northeastern part of the state to recover those valuable metals. Other mining companies are also exploring mineral deposits and preparing proposals for extracting them.

During the past three years, multiple organizations representing health care professionals have voiced concern about the potential effects of copper-nickel mining on human health. The Minnesota Medical Association, Minnesota Public Health Association, Minnesota Nurses Association and Minnesota Academy of Family Physicians have each endorsed deeper inquiry into the potential health effects of sulfide mining, and specifically of copper-nickel mining. Although the majority of debates about sulfide mining in our state have been framed as "environment versus jobs," the impact on human health needs to be a part of these discussions.

Sulfide mining has significant potential for the release of toxic chemicals into the environment. These include a number of chemicals identified by the World Health Organization as being of major public health concern: arsenic, asbestos, cadmium, lead and mercury.[2] Given this ominous list, and the possible synergistic effects of co-exposure to more than one of these chemicals, it is important that physicians understand why concerns are being raised about this type of mining.

FIGURE 1

Metal sulfide oxidation sequence using pyrite as an example

Pyrite (FeS_2) is exposed to air (O_2) and water (H_2O)

A sequence of reactions occur creating sulfate, ferric hydroxide and hydrogen ions.

Additional chemical reactions occur involving pyrite, iron sulfate and water, resulting in the release of sulfuric acid.

Sulfuric acid promotes release of other metals from rock and causes harm to aquatic ecosystems.

Source: 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 Acid Mine Drainage is Generated

Sulfide mining differs significantly from iron ore (taconite or ferrous) mining because it has the potential to generate acidic pH. Copper and nickel typically are bound to sulfur in rock. Because of this sulfur bond, they are described as sulfide minerals.[3] The chief iron-bearing minerals in iron mining are iron oxides and iron carbonate,[4] neither of which are sulfide minerals. Typical iron ore in Minnesota is relatively poor in sulfide minerals and contains minerals that actually buffer acid generation. Minnesota has not experienced large-scale release of toxic metals from iron mine waste into the environment.

However, both iron and sulfide mining operations do involve the excavation of millions of tons of rock in order to acquire a fractional amount of desired product. The ore is then processed to yield the desired metal. The surface mine site as well as mining wastes (overlying material, waste rock and "tailings"—fine-grained materials left over after the metals of interest are extracted) are exposed to moisture and atmospheric oxygen. When the sulfide mineral ore and wastes come into contact with air and water, chemical reactions occur that result in seepage of sulfuric acid, sulfate and toxic metals into surface and ground water. The general concept is as follows:

Metal sulfide + air + water →
Mobilized metal + salts + acid
(including sulfuric acid)

An example of the metal sulfide reaction is outlined in Figure 1. It demonstrates how sulfuric acid is generated in the presence of unearthed sulfide mineral rock.

Copper-nickel ore frequently contains iron sulfide minerals such as pyrite (FeS_2), one of the world's most common sulfide minerals. The atmospheric oxidation of pyrite ultimately results in the release of sulfuric acid.[3] Under certain conditions, ferric iron (Fe^{3+}) remains soluble in acidic outflows and forms the reddish-orange to yellow ferric hydroxide ($Fe(OH)_3$), a precipitate often recognized as the hallmark of waters containing acid mine drainage[3] (Figure 2).

FIGURE 2

Acid mine drainage

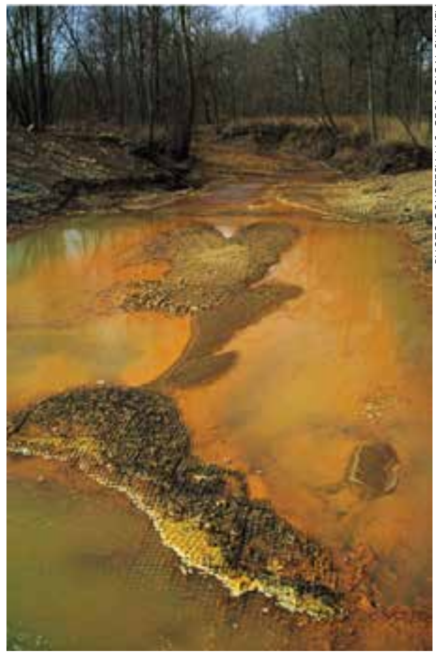
PHOTO COURTESY U.S. GEOLOGICAL SURVEY

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

Aqueous sulfuric acid is released into the surrounding environment and leaches heavy metals from the rock. The release of sulfuric acid and heavy metals into surface and ground water, and eventually into streams and lakes, is called "acid mine drainage." Many of the copper sulfide mines currently operating in the United States are located in the Southwest, a region that receives little rain and snow; thus, communication between surface and groundwater resources is limited. In wetter climates like Minnesota's, surface and shallow groundwater are more vulnerable to the negative effects of sulfide mining.[5]

Ore that contains commercially desired metals often contains other metals including mercury, lead and arsenic, which are similarly bound to sulfur. Studies of the Duluth Complex formation suggest that leachate will likely include copper, nickel, cobalt and zinc.[6]

By understanding the general concept of sulfide mineral oxidation (Figure 1), one can see how toxic metals are mobilized from solid rock into the environment and can generate sulfuric acid.[7] This reaction can result in ongoing leaching of metals from mine ore and waste rock, which can continue for centuries.

The Role of Microorganisms

Microorganisms are critical to acid mine drainage, as they accelerate the release of metals. These include extremophilic, sulfur-oxidizing and iron-oxidizing bacteria and archaea. One model organism is *Acidithiobacillus ferrooxidans*, which has been well-studied in the context of sulfide mining because it catalyzes ferrous iron to ferric iron. The regeneration of ferric iron exponentially increases the rate of breakdown of pyrite and sulfide minerals, increasing acid mine drainage.[3]

Select anaerobic microorganisms carry a gene that allows them to add a methyl group to inorganic mercury to create the most toxic form of mercury, methyl mercury. The environmental conditions that promote mercury methylation are complex and not completely understood, but they often are associated with bacterial sulfate reduction (anaerobic organisms that "breathe" sulfate as an alternative to oxygen).[8] Methylation occurs in the sediments, wetlands, ombrotrophic ("cloud fed") bogs and peat lands that are found in Minnesota's water-rich environment.[9]

Multiple variables affect the methylation reaction that creates methyl mercury including pH, temperature and concentrations of carbon, iron and sulfate. It appears that higher levels of sulfate (SO_4^{2-}) can enhance the rates of mercury methylation because they can stimulate bacterial sulfate reduction.[8] Since acid mine drainage includes sulfate, it is important to understand that increases in sulfate can increase the amount of methylated mercury released into the environment, primarily when that sulfate stimulates bacterial sulfate reduction in anoxic environments.

Mercury Already an Issue in Minnesota

Mercury can be found in the air, sediment, water, soil and living organisms. Humans acquire mercury in two ways: by breathing gaseous mercury or ingesting methyl mercury, notably by eating fish and shellfish. Methyl mercury is found throughout fish tissue, including muscle, and is not removed by trimming the fat, avoiding certain parts of fish or using special cooking methods.[10] Figure 3 shows the sequence of events by which release of anthropogenic sulfate can result in increased mercury levels in fish.

Mercury contamination of fish is a significant public health concern in Minnesota because of its neurotoxicity. In 2011, the Minnesota Department of Health found that one out of 10 infants in Minnesota's Lake Superior region were born with unsafe levels of mercury in their blood.[11] Many of Minnesota's northern waters are already legally classified as impaired because of the presence of mercury in fish tissue. This predates any potential mercury increases resulting from acid mine drainage.

Precise predictions of methyl mercury increases that would result from an influx of sulfate caused by mining can be challenging. However, concern is warranted because fishing remains important to Minnesotans,[10] and fish is an important food source for both indigenous and non-indigenous residents. Rural and tribal residents may be at greater risk of mercury exposure than urban or suburban residents because of their higher rates of self-caught fish consumption.[12]

Mercury toxicity as a result of ingesting heavily contaminated fish can result in a range of neuropsychiatric issues including abnormal brain development and sensory distortions (paranoia and hallucinations). The developing brains of fetuses and children can experience the most profound and devastating consequences of exposure to mercury and other heavy metals.

Many illnesses of the brain and central nervous system are categorized as neurodevelopmental disorders. These include attention deficit hyperactivity disorder, learning disorders, autistic spectrum disorders, language disorders and intellectual disabilities. The causes of neurodevelopmental disorders are multifactorial, but the connection to exposures to heavy metals, particularly methyl mercury, is known.[13]

FIGURE 3

Connection between anthropogenic sulfate release and human mercury exposure

Release of sulfate into the environment from anthropogenic source (example: acid mine drainage)

Sulfate reaches wetlands where it can stimulate certain "sulfate-breathing" microorganisms that are capable of converting inorganic mercury to methyl mercury.

Enhanced rates of mercury methylation can occur.

Methylmercury bioaccumulates in aquatic ecosystems, including fish.

Humans consume mercury-contaminated fish.

These conditions cannot be cured, and they come with significant personal, familial and societal costs. A small increase in incidence resulting from increased mercury exposure may result in large costs to society on a population level.[14] A recent consensus statement by Project TENDR issued a strong call for "recommendations to monitor, assess and reduce exposures to neurotoxic chemicals."[15]

Air Quality Considerations

The ore complex that contains copper, nickel and precious metals may also contain amphibole fibers. Amphibole fibers are often described as elongated mineral particles (EMPs). EMP fibers are crystals with similarities to asbestos. When ore is mined and processed, EMPs can be released. Currently, EMPs pose an uncertain risk to human health. Because of this uncertainty, longitudinal biomonitoring of people and communities exposed to EMPs is needed.

"Fugitive dust" is a term applied to dust that escapes mining operations. This can include dust that mining trucks generate on the road or dust that escapes as ore is transported in open train cars. Although levels may be difficult to quantify, fugitive dust may have health effects on both mineworkers and residents of nearby communities. Fossil fuel combustion, which is needed to generate electric power for mining, is another source of air pollution, the effects of which need to be considered.

Worker Exposures and Concerns

Safe workplace guidelines are important for people employed in the mining industry. Mine workers require protection from the airborne particulates and dust that are associated with mining operations. Sulfide mining, by virtue of its novel ore composition, presents new environmental safety questions.

The Mine Safety and Health Administration (MSHA) oversees mine safety and releases guidelines for worker protection. MSHA-allowable exposure levels for airborne exposures other than to asbestos are tied to the 1973 American Conference of Governmental Industrial Hygienists (ACGIH) guidelines. The MSHA guidelines do not reflect current science on the health consequences of airborne exposures in mining. The National Institute of Occupational Health and Safety (NIOSH), MSHA and the Occupational Safety and Health Administration (OSHA) have all proposed reduction of the allowable exposure by 50% from the 1973 ACGIH guidelines. In order to better protect Minnesota's miners, the threshold for allowable airborne exposures should be based on more contemporary science. Both NIOSH and ACGIH have published more up-to-date recommendations.[16,17]

OSHA has published models for medical surveillance of workers exposed to a variety of chemical hazards. Because the Duluth Complex rock includes silicates and other minerals, characterization of the potential adverse chemical and mineral exposures for workers using Duluth Complex-derived rock is important. OSHA provides medical surveillance models for nearly 20 compounds; however, no single overarching medical surveillance recommendation exists for sulfide mining. Given the long latency for the appearance of mining-related health effects, establishment of medical surveillance programs should be considered in the planning of the mine project.

Planning for Unanticipated Events

Proposals for sulfide mining operations must describe how water quality will be preserved, but may not take into account the extent of extreme weather events. In Minnesota, we are experiencing more significant rain events.[18] In June 2012, for example, the northeastern part of the state received 10 inches of rain in 24 hours. Significant rainfall such as this may result in unintended escape of mining wastewater and accompanying toxins.

A 2015 study of tailings storage facility failures centering on those categorized as "serious" or "very serious" determined that such failures have increased over the last 20 years.[19] For example, in 2014, a British Columbia copper and gold mine tailings pond breach spilled over 6 billion gallons of waste and polluted water into the surrounding lakes and watershed. Such events underscore the need to plan for a catastrophic event involving sulfide mines.

Current regulations also require mining companies to provide plans for the closure of an operation; this involves continued water treatment using filters or reverse osmosis systems. Post-closure water treatment can be necessary for centuries. Equipment malfunctions, natural disasters, extended power outages or inadequate funding can create an unintended interruption in water treatment. It is essential to pre-plan in order to prevent such interruptions from contaminating ground and surface water and the human water supply.

Current Regulation and What is Needed

In 1969, the federal government enacted the National Environmental Policy Act, which directs all federal agencies to take into account the health impacts of all federal actions "significantly affecting the quality of the human environment."[20] The Minnesota Environmental Policy Act of 1973 directs "all department and agencies of the state government to … undertake, contract for or fund such research as is needed in order to determine and clarify effects by known or suspected pollutants which may be detrimental to human health."[21]

With these laws in mind, physicians might assume existing regulations will protect human health. The current mandated evaluations of mining proposals do address air and water quality impacts and toxin discharges. Yet the laws do not require a comprehensive, long-range examination of potential effects on health. For example, environmental reviews may scientifically model the amount of mercury that may be released into surface and ground water, but they do not answer questions about the potential effects on human health of that mercury as it accumulates in food sources.

The short- and long-term effects on human health should be considered in present and future sulfide mining proposals. Both the EPA's Health Risk Assessment (HRA) and Health Impact Assessment (HIA) can be used for this kind of evaluation. The HRA estimates the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environments now and in the future.[22] The HIA focuses on "health consequences of decisions upstream from health"[23] and can be defined as "a systematic process that uses an array of data sources and analytic methods and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program or project on the health of a population and the distribution of those effects within the population." The HIA provides recommendations on monitoring and managing those effects.[24] Incorporating an HRA and an HIA into the environmental review for a proposed sulfide mining project could enable a more informed, integrated and meaningful discussion of human health concerns.

Conclusion

Sulfide ore mining presents a significant departure from the traditional iron ore mining done in Minnesota. Because of our state's water-rich environment and the chemical composition of sulfide ore, proposed sulfide mining raises concern about potential deleterious effects on human health. Physicians must continue to educate themselves about the evolving interplay of mining operations and the health of the communities in which they practice. MM

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EMPLOYMENT OPPORTUNITIES