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Acid Rock Drainage in Southwest Nova Scotia

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Acid Rock Drainage (ARD) is a phenomenon that occurs when naturally occurring sulphide minerals in rocks are exposed to air and water, resulting in sulphide mineral oxidation. During sulphide mineral oxidation, pyrite (and other sulphide-bearing minerals) react with oxygen and water to produce iron-oxides, sulphide minerals and sulphuric acid, which discharge into groundwater and streams, rivers or lakes. These affected waterbodies typically have higher acidity (pH levels between 2 and 4), making them corrosive and unable to support many forms of aquatic life. Acidic waterbodies can negatively impact potable and industrial water supplies, and can cause excessive corrosion in metal and concrete infrastructure (Fox, 1999; White and Goodwin, 2011). Furthermore, through a process called metal leaching, the acidic waters may break down other metal-bearing minerals in the rock, causing the release of dissolved metals (e.g. iron, aluminum, manganese, copper, zinc, cadmium, lead and other heavy metals), which will have adverse effects on human health. ARD can render municipal or domestic water supplies unusable and unpalatable, or aesthetically unpleasant. The oxidation of sulphide-bearing rocks tends to produce elevated iron concentrations, leaving an orange discoloration on rocks (Fig. 1), in stream beds (Fig. 2), and when in drinking water, discoloring laundry and porcelain fixtures.

***Figure 1**. Small, bronze-coloured, cubic pyrite crystals are embedded in this slate. The rusty-coloured iron stains indicate sulphide oxidation and ARD.*

***Figure 2**. Sulphide mineral oxidation of the surrounding pyritic-slate bedrock discharges iron-oxides into this stream, discoloring it red.*

***Figure 3**. Slate bedrock outcrop located on Route 101 has iron staining, which indicates sulphide mineral oxidation, and is potentially an ARD site.*

ARD occurs naturally at slow rates. Once ARD begins, it will continue to generate acid until all the exposed sulphides have oxidized, which may take centuries.

If disturbance is unavoidable, then potentially acid-producing bedrock must be managed (neutralized and/or excavated and disposed of) in accordance with the Sulphide Bearing Material Disposal Regulations (Section 66 of the *Nova Scotia Environment Act;* Province of Nova Scotia, 1995). Pieces of weathered sulphide-bearing bedrock may be incorporated into the overlying surficial till and soils. The Sulphide Bearing Material Disposal Regulations defines these as 'sulphide-bearing materials'. Exposing these materials can also initiate acid rock drainage.

What Factors Influence ARD?

The potential for bedrock to develop ARD depends on a number of factors:

- **Mineralogy:** Bedrock must contain sulphide minerals that can oxidize in order for ARD to develop. The chemical composition and structure of the sulphide minerals influences the amount and rate of potential acid that can be produced. In general, bedrock with higher concentrations of sulphide minerals has a greater potential of developing ARD.
- **Neutralization:** The production of sulphuric acid can be neutralized if sufficient carbonate-bearing minerals and rocks (e.g. calcite and limestone) are present. Also, till and soils in the surrounding environment that are high in carbonate material may have an acid buffering capacity that may reduce the overall acidity of the runoff.
- **Exposure:** When sulphide-bearing bedrock is physically disturbed or the overlying till (which acts as a buffer) is removed, ARD can be produced. The length of exposure is critical in the development of ARD. If bedrock is exposed then quickly (within days to weeks) covered by impermeable till or other similar material, ARD may be halted.
- **Bacteria:** A variety of bacteria, when present, accelerate the rate of ARD by assisting with the decomposition of sulphides into sulphuric acid.

Not all sulphide-bearing rocks are acid-producing. Site-specific geochemical analyses are necessary to determine if a rock sample will produce ARD. Standardized tests calculate the ratio of acid-producing minerals to acid-consuming minerals to determine the amount of acid that the bedrock could potentially produce if exposed.

What Activities Disturb Bedrock?

Exposing or breaking up sulphide-bearing bedrock can produce ARD by increasing the surface area available for oxidation to occur. Disturbing the bedrock can result from activities that uncover rock surfaces or by physically altering the bedrock. Many human activities can initiate the development of ARD.

- Blasting for roadcuts, foundations and quarries exposes new bedrock surface to air and water. This is a common source of ARD in southern Nova Scotia.
- Drilling wells can directly expose acid-producing sulphide-bearing bedrock which can initiate ARD that can leach heavy metals directly into drinking water.

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- Removing overlying surficial till material and soils, during activities such as landscaping and digging trenches or ditches for municipal services and pipelines, exposes bedrock that could potentially begin reacting with air and water to produce acid.
- Lowering the local water table, by locating too many wells in close proximity for example, can expose sulphide-bearing bedrock and initiate ARD.
- Natural factors such as flooding or slumping of tills can also expose sulphide-bearing bedrock.

What Are the Effects of ARD?

The negative impacts of ARD are not confined to the oxidizing site because acidic runoff flows downstream, potentially contaminating aquifers, watercourses and drinking water supplies. ARD can adversely impact the environment, infrastructure and human health.

Impacts on the Environment
Runoff from ARD sites has lower pH and higher concentration of heavy metals and degrades water quality and habitats downstream. Aquatic flora and fauna are sensitive to changes in pH and die if they cannot handle higher acidity levels. Fish kills are often triggered after a rainstorm event, especially following a prolonged period drought, when runoff dissolves a build-up of oxidized material from an ARD site, including sulphuric acid and iron oxides, and rapidly increase the acidity levels in the receiving watercourses downstream. In addition, soluble metals in water clog fish gills, causing them to die of asphyxiation. As watercourses recover and return to normal pH levels, metals come out of solution, precipitate and deposit on the stream bed as a solid orange or red-coloured veneer. The metals remain in the sediments for years making it difficult for plants and animals to inhabit the stream. Sometimes, the metals in the environment adversely impact aquatic habitats more so than the acidity itself (White and Goodwin, 2011).

Impacts on Infrastructure
Acidic runoff is corrosive to concrete and metal infrastructure. Civil infrastructure can be corroded and degraded by the acidity of ARD causing maintenance and replacement costs to increase. Vulnerable infrastructure includes concrete foundations and bridges, metal culverts and pipes, and buried wiring.

Human Health Impacts
ARD reduces the water quality downstream and is associated with immediate and chronic human health effects. The corrosiveness of runoff water originating from an ARD site varies and direct contact with the acidic runoff can cause skin and eye irritation. Drinking water supplies from wells drilled into acid-producing bedrock, lined with sulphide-bearing bedrock, or downstream from an ARD site can have an increased acidity and increased concentrations of heavy metals. In Nova Scotia, heavy metals found in drinking water as a result of ARD and metal leaching may include arsenic, copper, lead, iron and manganese. Although some of these elements are essential in human metabolism in minute amounts, such as copper, iron and zinc, excessive levels can cause heavy metal poisoning, while others are carcinogenic or toxic. Arsenic is common in Nova Scotia and is classified as a human carcinogen, linked to causing lung, bladder, liver and skin cancers (Health Canada, 2010). Copper, iron, and manganese in drinking water have impacts that are considered aesthetic, including undesirable taste and discoloration (red-black) which can stain laundry and plumbing fixtures.

The typical pH range of drinking water is between 6.5 and 8.5. Health Canada (2010) states that there is no direct relationship between pH and human health. Water supplies with lower pH levels may contribute to the corrosion of water supply mains and metal pipes, however, releasing metals such as lead, zinc or copper into drinking water. Also, pH can influence the effectiveness of water treatment, such as chlorine disinfection (Health Canada, 2010).

Mapping ARD in Southwest Nova Scotia

Recent bedrock mapping in southwestern Nova Scotia (White and Goodwin, 2011; White, 2012) has shown that some bedrock formations with abundant pyrite, pyrrhotite and other sulphide minerals have the potential to generate ARD. A series of maps (Open File Maps ME 2013-002 to 2013-027) showing the bedrock acid rock drainage potential of southwestern Nova Scotia (Fig. 4) classifies ARD potential as high, moderate or low. This map is a tool that can be used during the planning stages of development and construction to broadly determine if sulphide-bearing bedrock is present in order to mitigate negative environmental and human health effects caused by ARD, as well as to reduce costly remediation efforts.

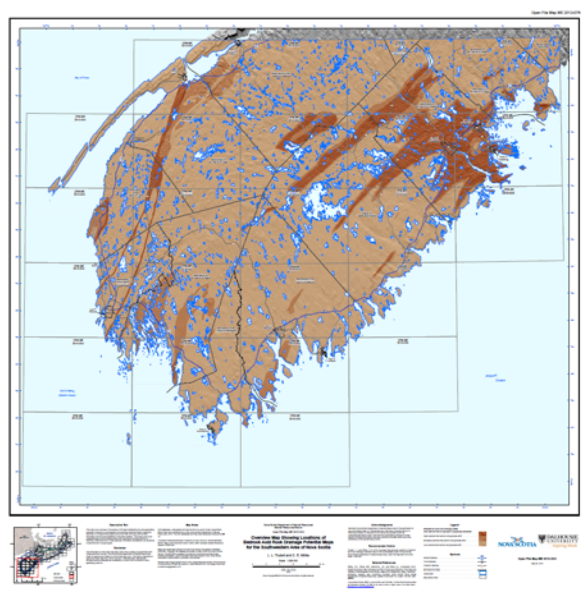

***Figure 4**. Overview map showing locations of the bedrock acid rock drainage potential maps for the southwestern area of Nova Scotia (Open File Map ME 2013-002; scale 1:250 000). Open File Maps ME 2013-003 to 2013-027, at a scale of 1:50 000, show more detailed views of the acid rock drainage potential of bedrock in southwestern Nova Scotia.*

Conclusion

Exposing and physically disturbing sulphide-bearing rocks can initiate acid rock drainage and can negatively impact the environment, human health and civil infrastructure. Several factors influence the severity of acidic runoff from bedrock. In simple terms, the best way to prevent ARD from developing is to know where sulphide-bearing bedrock is located and avoid disturbing it.

References

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