Iron-oxidizing Bacteria in Lye Valley

[Information from Owen Green, Oxford Geology Trust, edited by Judy Webb, photos by Tony Gillie from the Lye Valley]

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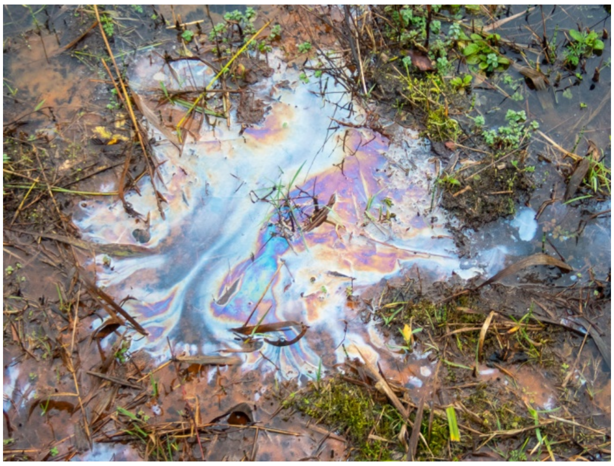
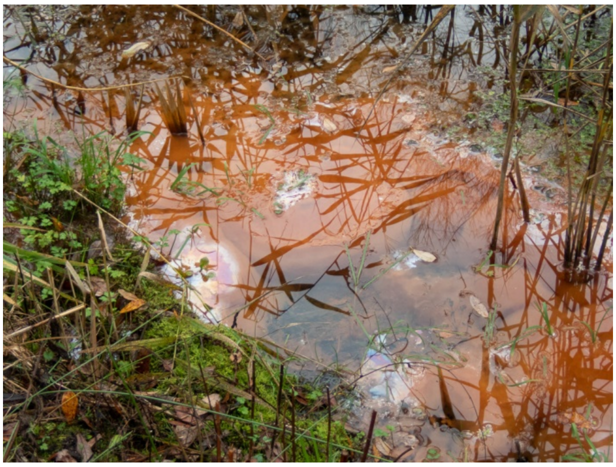

In wetlands such as the Lye Valley fens, a bright orange 'sludge' and a reflective mirror-like sheen on water surfaces are the result of the natural activity of an extremely ancient type of bacteria and not (as is often thought) because of water pollution by oil or petrol. These bacteria are **chemotrophic** (chemical-feeding) which means they derive the energy they need to live and multiply by oxidizing dissolved ferrous iron. They are known to grow and proliferate in waters and soil containing iron concentrations as low as 0.1mg/L. However, at least 0.3 ppm of dissolved oxygen is needed to carry out oxidation. Some springs in the Lye Valley have a lot of dissolved iron in the water if it originates from the Beckley Sands geology, for example under part of the Churchill Hospital. This orange or mirror-like deposit is especially noticeable in Lye Valley in winter, when vegetation dies down and spring flow is high due to increased rainfall.

The bacteria combine iron and manganese with oxygen to form deposits of "rust" and a sticky, slimy, yellow / orange /red-coloured build up. They may also occur as a rainbow-coloured or "oil-like" sheen on the surface of the water. The bacteria cause stains, horrible tastes and odours (often confused with hydrogen sulphide gas and possibly redolent of a swamp, sewage, fuel oil or cucumber) and can create undesirable conditions for the growth of other organisms.

The most common known species of bacteria with microbial metabolisms based on iron oxidation include ***Thiobacillus ferrooxidans*** and ***Leptospirillum ferrooxidans***. These are known as **'extremophiles'**. The study of extremophile organisms, their environments of formation and occurrence in the geological record has received considerable funding in recent years, as astro-biologists and geo-microbiologists recognise their potential in devising analogues for the study of extra-terrestrial life.

Habitat

Iron-oxidizing bacteria colonize the transition zone where de-oxygenated water from an anaerobic environment flows into an aerobic environment. Groundwater containing dissolved organic material may be de-oxygenated by microorganisms feeding on that dissolved organic material.

Where concentrations of organic material exceed the concentration of dissolved oxygen required for complete oxidation, microbial populations that contain iron-reducing bacteria can reduce insoluble ferric oxide in aquifer soils to soluble ferrous hydroxide and use the oxygen released by that reaction to oxidize some of the remaining organic material:

$$4H_2O + 2Fe_2O_3 \rightarrow 4Fe(OH)_2 + O_2$$

(water) + (Iron[III] oxide) → (Iron[II] hydroxide) + (oxygen)

When the de-oxygenated water reaches a source of oxygen, iron-oxidizing bacteria use that oxygen to convert the soluble ferrous iron back into an insoluble reddish precipitate of ferric iron:

$$4Fe(OH)_2 + O_2 \rightarrow 4H_2O + 2Fe_2O_3$$

(Iron[II] hydroxide) + (oxygen) → (water) + (Iron[III] oxide)

Since the latter reaction is the normal equilibrium in our oxygen atmosphere, while the first requires biological coupling with a simultaneous oxidation of carbon, organic material dissolved in water is often the underlying cause of iron-metabolizing bacteria populations. Groundwater may be naturally de-oxygenated by decaying vegetation in swamps, and useful mineral deposits of '**bog iron'** ore have formed where that groundwater has historically emerged to be exposed to atmospheric oxygen. Anthropogenic sources, like landfill leachate, septic drains, or leakage of light petroleum fuels, are other possible sources of organic materials allowing soil microbes to de-oxygenate groundwater.

A similar reversible reaction may form black deposits of manganese dioxide from dissolved manganese, but this is less common because of the relative abundance of iron (5.4 percent) in comparison to manganese (0.1 percent) in average soils. Other conditions associated with iron-oxidizing bacteria result from the anaerobic aqueous environment, rather than the bacteria visibly colonizing that habitat. Corrosion of pipes is another source of soluble iron for the first reaction above and the sulphurous smell of rot or decay results from enzymatic conversion of soil sulphates to volatile hydrogen sulphide as an alternative source of oxygen in anaerobic environments.