TOPIC: WATER QUALITY AND MINING

SUB-TOPIC:
PART B: AN OVERVIEW OF ACID MINE DRAINAGE AND ITS CONSEQUENCES

Supporting Transcript

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This transcript accompanies associated presentation slides and video content developed for the TIDE project in 2021, with acknowledgements and disclaimer as noted in associated files.

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In this mini-lecture I'll be giving an overview of acid mine drainage and its environmental consequences.

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I'll be explaining how copper deposits form geologically and then how and why the extraction of such ore can have severe consequences on the environment.

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Acid mine drainage, or acid rock drainage, can occur naturally where there are sulphide minerals present in the underlying rocks which are exposed to water and air. By increasing the exposure of such acid-forming minerals to water and air through mining, we increase the likelihood of acid formation, which can have serious impacts to waterways and biodiversity. Acid mine drainage is a good example of point source pollution which potentially can be considered either anthropogenic or geogenic depending on its source and controls.

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And the objectives are to explain the geological processes which concentrate iron and copper in the Earth's crust, to explain the fundamental processes which generate acid-mine drainage, from the sulphide minerals these deposits are associated with, and also to explain the environmental consequences of acid-forming systems

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So let's first talk about the formation of copper.

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So this is a compilation of all the major mines in the world that are active currently and what they're used for. Some have estimated that there are around one million abandoned mines in addition to this. If we look at the copper mines marked as orange dots on this map we can see that these are often found at the edge of continents, and this is not a coincidence but rather related to the geological formation of copper.

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One of the main ways copper deposits form is through magma intrusions from subduction zones. You can see the correlation between the orange dots and the world subduction zones roughly marked out here.

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So lets take a look at how these environments form copper. At subduction zones, tectonic plates are driven down into the Earth's mantle and this causes them to heat up and melt. Melt can rise through the Earth's crust to form a magma chamber away from this subduction zone which may sit idle for long periods of time. Minerals begin to cool down and crystallize, and since solids take up a larger amount of space than liquids, pressure builds up in this magma chamber. Eventually, the pressure becomes so high that the overlying rock fractures and hydrothermal fluids escape. Given the right conditions, copper can precipitate from the hydrothermal fluids in a way which enriches it above the background concertation.

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So let's talk about how these mineral deposits can have environmental consequences.

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Copper minerals such as pyrite and chalcopyrite are very unstable when we expose them to oxygen and water. There are a number of chemical reactions that occur as a result of this but we can simplify this to say sulfuric acid is produced along with ferrous hydroxide. So now we have an acid being produced by this reaction and explains why we say 'acid-mine drainage' in the first place, and we'll talk about the consequences of lowering the pH in a second.

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So acid mine drainage can occur from a number of settings and this can be from an active and closed mines in the form of open mine pits or it can occur from mine tailings and spoil heaps, and typically we can see pH around 2 to 3 and even as low as -3.6 in one reported location in the literature. You might be thinking how we get a negative pH, well we'll be performing a simple pH calculation to achieve this in the learning exercise. Acid mine drainage can typically form a red/orange precipitate, and that's from the formation of what is called ochre, which is just insoluble ferric oxide being produced.

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So here we can look at some of the chemical characteristics of mine drainage, here from an example in Tasmania and I've put chemical compositions of the mine alongside WHO guidelines values for each of these parameters. And as you can see for pH, sulphate, arsenic, copper lead and zinc, every single one of these exceeds the WHO guidelines significantly. To take arsenic for example this has exceeded the guideline by many orders of magnitude and is about 1000 times the WHO guidelines value.

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Here we've got an example of acid-forming rocks at a copper mine and you can see the rocks are typically orange from iron and copper hydroxides. This particular example is from Cyprus.

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The Monywa Mine is the largest mine in Myanmar and it is made up of four-sulphide deposits which are rich in copper, Kyisintaung being one of them. Locals have reportedly found that they can no longer grow crops in areas close to where the mining takes place. What exacerbates the problem is further artisanal mining. It is reported that locals may be forced to make money from artisanal mining as their farmland is now so severely degraded from the industrial mining.

Locals use the waste rock to extract more copper from the mining area and there is often little clean up of the toxic ponds that develop after this small-scale form of mining occurs, which require small, basins around 10 square metres to be created for copper extraction
Now there are mitigation steps to reduce the drainage, which do hep to some extent. The large industrial scale mines use technologically advanced methods and equipment, including complex chemical processes. Though no matter the technology, the extraction of copper is commonly a notoriously messy process. Sulfuric acid is used to dissolve the rock for copper extraction collected using a trough system and this is recycled so that it is not lost into the environment. However, this does not stop any runoff from any of the acid-forming rock that is left behind. And what's more, these supposedly impermeable trough systems are prone to leaking, which can have disastrous consequences for the environment.

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So what's the consequence of a lowered pH? Well, firstly a low pH can mean crops can no longer grow due to the acidity. We cannot grow crops in soils of pH 2 as many biological functions do not work at this pH.

Perhaps less obviously, metals are much more mobile at lower pHs and this may mean they become more available for organisms to take up. The main influencer of metal leachability is pH. This graph shows a leaching study of heavy metal release from waste rock. We can see that the positively charged, or cations are much more susceptible to leaching at lower pHs in this study. Of course, this will depend highly on what minerals are present and what the overall chemistry of the system is. So you may conclude this is fantastic for anions in acid mine environments, but we need to consider that almost all metals exist as cations, especially the ones we are worried about. We also need to have a think about speciation of the metals at different pHs.

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And we need to think about how pH may affect speciation of different metals and the toxicity of them, for example As(III) is more mobile and more difficult to deal with than As(V) - a change in pH could result in a change from one to the other.

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This is not what this lecture is about, although its worth covering some of the effects of increasing the mobility of certain heavy metals. These can interfere with numerous cellular processes in animals and humans, such as nutrient uptake, cell division, enzyme functions and ultimately anything related to DNA being converted into proteins. These cellular effects can have fatal consequences to organisms of any size and this may have enormous adverse effects to the food chain.

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In summary, acid mine drainage is often a severe and complex problem in Myanmar and globally. The low pH can increase metal mobility and speciation, which can have adverse effects on organisms, which makes mitigation of AMD an important step for active and closed mines.

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For the learning exercise, there are a few things to do here. Firstly, I'd like you to become familiar with the equation for calculating pH from hydrogen ion concentration, and this concentration is denoted by the brackets around the H+. So see if you can work out the hydrogen ion concentration of these two reported values of acid drainage cases, by substituting the pH into the equation. Hopefully you'll be able to see that negative pH is possible at small hydrogen concentrations, if you didn't know this already. Next, I'd like you to discuss how acid mine drainage can degrade the environment and how it may have social economic results as a result, of which there could be many. Lastly, I'd like you to do your own research on acid mine drainage, to try and see if you can find examples of acid mine drainage occurring in Southeast Asia, and then more specifically in Myanmar. Perhaps you were familiar with the example of Monwya, or somewhere more local to you. Find out what impact this is having locally and if there are any controls in place to mitigate the drainage.

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Please see the references used for the slides. Those that are marked 'OA' are freely accessible for anyone to view.

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And some further resources which are open access, with a useful link on the formation of porphyry deposits as well as some links to acid mine drainage resources

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Please note the disclaimer and conditions of use, and thanks for listening.