

MANGROVE MUDS

The smelly, black, muddy soil that forms in mangrove swamps is home to bacteria that love to live in anoxic conditions (where there is no oxygen). You can see the bacteria (billions of them) as purple or white milky scum on top of the mud and in stagnant pools (figure 2). There are many different types of bacteria living in these soils and they all work together to form part of the "Sulfur Cycle".

Mud with bite



Figure 1. This picture shows a soil core taken from a relatively "pristine" mangrove woodland near Gillman. The black soil contains pyrite giving it the potential to form sulfuric acid if it dries out. These black soils are termed **Potential Acid Sulfate Soils (PASS)**.

Sulfur (S) is an element that is essential to life and is abundant in seawater as calcium sulfate (CaSO_4). Sulfate-reducing bacteria that live in these anoxic sediments can use the oxygen from sulfate (SO_4) and leave behind hydrogen sulfide gas (H_2S) in the water. This gas gives swamps their "rotten egg" smell. Sulfide (SO_3) ions left in the water can react with iron (Fe) from the sediment to form an iron-sulfide mineral called pyrite (FeS), also known as "fools gold".

The pyrite accumulates in the black "sulfidic" sediments (figures 1). Another type of bacteria that lives on rotting seaweed, seagrass and dead mangrove leaves actually forms sulfuric acid (H_2SO_4) as a by-product. Sulfidic sediments can also produce sulfuric acid if they are dried out and exposed to oxygen.



Figure 2. Bacteria that live in these anaerobic environments cause this white slick. Their abundance here indicates that there are too many nutrients available in the soil and water. These mangrove pneumatophores are struggling to survive in this highly reducing environment.

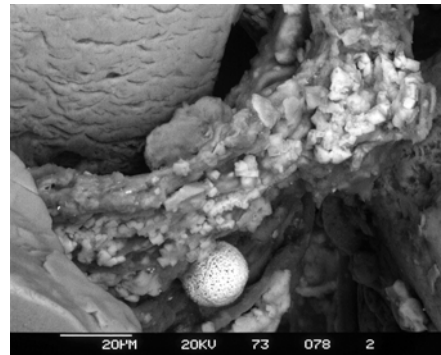


Figure 3. This photomicrograph of some sulfidic sediment was taken with an electron microscope and shows a small ball made of pyrite crystals called a "framboid".

Actual Acid Sulfate Soil (ASS)

When pyrite is exposed to the air it oxidizes to form iron oxide (rust) and sulfate. The sulfate then dissolves in water to form sulfuric acid. "Sulfide-oxidizing" bacteria can accelerate this process and love to live in acidic environments. These reactions happen whenever mangrove soils are drained or disturbed.

Draining mangrove swamps for farming or building marinas can cause the soil to turn acidic (with a pH as low as 2.0). This kills any plants that are growing there, and the animals that depend on them (figure 4). We call these dried out acidic soils actual Acid Sulfate Soils (ASS). The acid can leak into creeks and inlets, killing fish and aquatic plants.



Figure 4. About 60 years ago this levee bank was built to stop the tide coming in to a mangrove swamp so the land could be "reclaimed" for farming or buildings. The mangrove trees all died and the sulfidic sediments dried out. This allowed the pyrite in the sediments to oxidize and form sulfuric acid and rust. The sulfuric acid has killed many of the plants and animals living in this rust coloured water. The acid can also dissolve concrete structures such as pipes and buildings.

Because wet mangrove soils have the potential to become acidic if they dry out, soil scientists call them "Potential Acid Sulfate Soils" or "PASS" for short. The levee bank which forms part of the mangrove walk at St Kilda was built to stop the tide from covering the land on the western (landward) side of the wall so it could be used for farming. The embankment was a bit leaky though and was eventually breached by the sea in a few places. The land was then re-flooded when salt evaporation ponds were built on it in the 1930s, so the "PASS" didn't get much of a chance to dry out and form actual "ASS".

Pull My Finger

If you pick up some of the mangrove mud, you will notice it is very black. This is the highly decomposed organic matter in the soil and the sulfide minerals (pyrite). Now squeeze the soil between your fingers and then smell your hand. It smells a bit like rotten eggs. This is hydrogen sulfide gas (H_2S), produced as the pyrite starts to oxidize when it is exposed to the air. Soil scientists call soil that contains sulfide minerals (pyrite), "sulfidic material". Now wash your hands in the seawater as sulfuric acid will be forming on them.



Figure 5. Taking samples of mangrove mud at St Kilda.

Why are mangroves dying?

At a number of sites around the St Kilda Mangrove walk you may see pipes sticking out of the mud. The thick white pipes are for measuring the height of the water table and for taking soil water table samples. The thin black pipes with wires sticking out of them are for measuring the oxygen activity (redox potential) of the soil. This is related to the amount of oxygen in the soil and gives us an idea of what chemical reactions are taking place at different depths in the soil.

The CSIRO, Environment Australia, Salisbury and Port Adelaide Enfield City Councils, The Barossa and Torrens Catchment Management Board, and the St Kilda Mangrove Interpretive Centre are working together to understand the chemical processes that are going on in the mud and in order to stop the mangroves from dying.

When there is too much organic matter in the sediments, the soils become too reducing (anaerobic) for even the mangroves to survive. The mangroves pneumatophores (aerial roots) start to die back, retreat from the more stagnant pools (figure 6). The mangroves then become very unstable and can easily fall over in high winds.



Figure 6. Mangrove pneumatophores retreat from the stagnant pool filled with rotting seagrass and sea-cabbage. Sea-cabbage (green seaweed) can suffocate mature mangrove trees by covering their pneumatophores or strangle seedlings preventing rejuvenation of the mangrove woodland.

The reason the mangroves are dying seems to be caused by an increase in the amount of organic material entering the mangrove woodlands. Most of the organic matter (detritus) in the sediments is seagrass and sea-cabbage (ulva). The seagrass beds that occur along the intertidal and subtidal mud flats along Adelaide's coastline have been dying off for years. This has been attributed to many factors such as polluted stormwater, sewage sludge outfalls and even just the increase in freshwater from diverted stormwater drains.

The higher nutrient content of the metropolitan seawater has also led to the increase of algal blooms such as sea-cabbage, which can suffocate pneumatophores and mangrove seedlings (figure 5). When all this organic matter is washed into the mangrove woodlands on the high tide, it gets trapped by the trunks and pneumatophores and starts to rot in little pools around the base of the mangrove trees. The rotting organic matter supplies the sulfide reducing bacteria with nitrogen causing them to proliferate and form the extremely reducing soil condition that is killing the mangroves (figure 7).



Figure 7. Mangrove dieback is caused by eutrophication (over-enrichment with nutrients) of the sediments that forms extremely reducing soil conditions, damaging the mangroves pneumatophores (aerial roots).

In a healthy environment, mangroves have a radial root system that spreads over a large area and there are crabs everywhere that burrow into the soil letting oxygen in. There are young mangrove seedlings sprouting and you can actually stand on the mud without sinking at all. These are the areas where young fish come to feed at high tide. Without healthy mangrove forests, there would be no fish for Rex Hunt to kiss.

The St Kilda mangroves face a bleak future if nothing is done to stop the eutrophication (over enrichment) of St Kilda bay. While these chemicals are necessary for plant growth, an excess of them can unbalance and ultimately destroy an ecosystem.



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