Acid sulfate soils

Polders with acid sulfate soils in Guinea Bissau along a sea-arm amidst mangroves. Source: R.J.Oosterbaan

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Acid sulfate soil scald

Acid sulfate soils are formed when sulphide-bearing minerals come in contact with air and oxidise. This reaction produces sulfuric acid which can lower soil pHvalues below 4 as the soil's buffering capacity is exceeded. When the soil pH is lowered, metals previously bound to soil particles are mobilised and can be taken up by plants. They are also washed out of the soil profile, especially after heavy rains. Sulfuric acid and metals can thus be leached out of the soil profile into groundwater and nearby waterways. As mostorganisms do not cope well in acid environments, this can have devastating effects on aquatic organisms as well as on vegetation.

Likewise, many of the heavy metals leached out through acidification are potentially toxic to both plants and animals, including humans. One example of the adverse effects of acid sulfate soils can be illustrated by an event in the Tweed River in Australia in 1987, when all gilled organisms were killed along a 23 kilometre section of the river after a heavy rain released toxic amounts of aluminium from an acid sulfate soil, leaving the affected section virtually sterile for 18 months.

Occurrence

Acid sulfate soils produce such vast quantities of acid, that any effort to neutralise the pH requires enormous amounts of lime. It has been calculated that in order to neutralise one hectare of soils in a fishfarm in Nigeria, 4.1 tonnes of lime would be required. In economic terms, Australia provides an example of AUS $90,000 per hectare, not including labour costs. Scandinavian countries have successfully limed receiving stream water, but this effort requires liming at every leaching event and the heavy downpour common in tropical countries is rare in the Nordic countries.

Acid sulfate soils may not comprise a large part of the world's problem soils, but they are often present in coastal areas with high density populations, where their adverse effects on the environment can affect many people. Their concurrent location in well-populated areas is a result of ideal environmental conditions for acid sulfate soil formation that often coincide with ideal living conditions for humans; along coastlines in tropical or subtropical countries. As sulfide-bearing minerals and sediments are formed when the sulfate abundant in seawater reacts with organic material to form sulfide, mangroves for example, provide an excellent environment for pyrite formation, one of the main minerals associated with acid sulfate soil formation. As a result, acid sulfate soils as well as potential acid sulfate soils (those that have not yet reacted with oxygen and become acidified) are mainly found in coastal areas, but they are also found inland along former coastlines. Their oxidation and subsequent acidification can be due to natural causes exposing soil to air, such as the Scandinavian isostatic land rise or declining sea levels, as in Thailand. In most cases however, it is the human interference with these soils that cause their oxidation. Large areas of wetlandhave been and still are drained for agricultural, aquacultural or urban development. Similarly, excessive pumping of groundwater or dumping of mine waste on the surface result in oxygen coming in contact with previously anaerobic soils, initiating the process of acidification.

Human health impacts

A direct effect on human health and wellbeing from soil acidity is the pollution of drinking water sourceswith acid and potentially toxic elements, and to a lesser degree of edible plants. It should be noted that acid sulfate soils do not necessarily hold higher metal concentrations than other soils, but it is the increased mobility of metals from acidification that causes problems. For example, acidity has been highlighted as a risk factor for decreased drinking water quality with regard to fluoride, arsenic, selenium and manganese mobility from soil. In the Mekong delta, concentrations of arsenic and manganese were found to exceed World Health Organisation guidelines in drinking water wells as a result of acidification. The acidity may also mobilise metals found in plumbing systems, such as lead and copper, resulting in elevated concentrations in drinking water. In Finland, metal discharge from acid sulfate soils into waterways has resulted in increased concentrations of especially aluminum, cadmium, cobalt, manganese, nickel and zinc, and has been estimated to exceed the total industrial discharge of these elements. Also in Finland, discharge of metals from acid sulfate soils have been found to result in elevated concentrations in oat grain and in milk from cows feeding on affected grass grown on acid sulfate soils. The effects of acid sulfate soil drainage can thus affect humans through elevated exposures to potentially toxic metals in both food and water.

Aquaculture

Acid and toxic elements mobilised through acid sulphate soil processes cause adverse effects on organisms living in the receiving water bodies, both on an individual and communal level (see Simpson and Pedini, 1985 for a thorough review). Those organisms least mobile, such as oysters and many shellfish are often severely affected as they cannot escape the acid water. However, during heavy rains when large amounts of acid are released from the soil, fish are also affected. The acid in the water can damage the skin and triggers mucus production to protect the gills, which are also damaged by precipitated iron. As gill damage reduces the ability of fish to regulate oxygen and salt intake and skin damage increases susceptibility to fungal or bacterial infections, these reactions can cause fish disease and even death. Acidity together with increased aluminium concentrations in the water can disturb early life in fish as the hatching of eggs delayed and the survival of fish larvae reduced. Both severe acute effects on fish populations and species diversity have been observed following heavy rains, as described above, or as a result of large drainage projects in acid sulfate soil regions. Lower turtle fertility and higher dugong mortality have been reported as a result of toxic algal blooms, suggested to be triggered by acid sulphate soil drainage. Some species of mosquito larvae, however, have been found to thrive in acid-affected pools. Unfortunately, these mosquito species are responsible for carrying the Ross River virus, which causes arthritis-like symptoms and rash in humans, sometimes persisting for months. The virus is endemic to Australia and Papua New Guinea and it is unknown whether acid sulfate soils also affect breeding patterns of species responsible for other vector-borne diseases. Effects on the smaller aquatic organisms, such as bacteria, micro- and meiofauna may not be as obvious as fish kills but are nonetheless significant. Benthic algae are rendered inedible for meiofauna as they are encrusted by iron hydroxides. Shrimps, crustaceans and oysters suffer from soft shells as carbonate used for their exoskeleton is depleted in the acid buffering process. In addition, low levels of primary production as a result of increased acidity and toxicity in aquatic environments result in extreme water clarity, reducing shelter from predators.

Effects on aquatic organisms affect the livelihoods of those depending on fish and aquaculture for their income or food source. With the reduction of the world's fish stocks, aquaculture organisms represent a large and growing proportion of protein intake for many of the world's poor. According to FAO, fish provides at least half of the total animal protein intake in a number of countries where aquaculture is developed on acid sulfate soils. Unfortunately, aquaculture development on acid sulfate soils is seldom successful, and it requires careful preparation and good management, and of course an awareness of the presence of acid sulfate soils. In many cases, the failure of expected high yields has resulted not only in a loss of food source, but also in unemployment and failure to repay loans taken to finance the development.

Agriculture

Similar results as for aquaculture have been experienced where acid sulfate soils are drained for agricultural production, including rice which is a staple food in many poor countries. Low rice yields from acid sulfate soils have been reported in Indonesia, Thailand, Guinea-Bissau, Sri Lanka, Sierra Leone, Vietnam and Guyana. The drained wetlands often seem fertile and produce good yields in the first couple of years, but then quickly deteriorate as acidity increases. In Vietnam, acid sulfate soils in the Mekong delta which have been drained for agriculture since the 1970's, are now recognised as major impediments to crop production. Acid sulfate soils not only affect plant growth through its acidity. Although especially the root system is sensitive to low pH, poor plant growth is more often attributed to aluminum, iron and manganese toxicity. In addition, the microbial process which makes nitrogen available for plant uptake is adversely affected by soil acidity while some fungal diseases are known to develop only in acid soils. Soil acidity also inhibits plant growth as the availability of several essential micro- and macro nutrients decreases, including phosphorous,calcium, magnesium and potassium.

The processes transforming potential acid sulfate soils to actual acid sulfate soils deteriorate the soil's structure resulting in compaction, further limiting plant growth. Moreover, soil moisture escapes from the soil profile more easily as the mulching effect of vegetation is absent, which may cause salt crusts to form during dry periods. The adverse effects on vegetation from acid sulfate sol formation can sometimes inhibit plant growth to such a degree that vegetation is chronically excluded, and so called soil scalds are formed. In addition to the consequences of poor or absent plant growth in both environmental and economical terms, bare soil areas increase the risk for soil erosion which in turn affects water quality in nearby water bodies. In addition, areas available for grazing are diminished.

Livelihood and economy

Indirect effects of acid sulfate soils on human well-being are mainly economical, including affected income opportunities for farmers and fishermen. Estimates of the loss of production in New South Wales, Australia due to acid sulfate soils have been calculated at between AUS $2.2 and 23 million per year. Losses include not only fish, but also lobsters and oysters. In Queensland, losses to the sugarcane industry have been estimated at AUS $189 million for only a small part of the land area covered by acid sulfate soil. Queensland is also home to the Great Barrier Reef and concerns have been raised about adverse effects on reef life as a result of acid sulfate soil discharge, which in addition to the environmental damage may in turn affect livelihoods of those working in the tourism industry. In addition to effects on the natural environment, our built environment is affected by acid sulfate soils. The acid produced can corrode constructions made of concrete or steel, which includes pipes, bridges, house foundations, road pavements as well as railway and road tunnels. The decreased bearing capacity and instability of the soils as they undergo oxidation also affect our built environment. Significant costs related to these processes have been recognised in Australia and Canada, where premature replacement of pipes, pavements and bridges burdens the economy of local governments, and home-owners worry about falling house prices.

The greatest concern with regard to human health and well-being, however, is the effects it has on subsistence farming communities. As many acid sulfate soils are located in poor countries, the environmental damage often affects those who are least able to cope with reduced yields and do not have the opportunity to move to more fertile land/less acidic water or switch to more acid-tolerant crops. Although disturbance of acid sulfate soils is generally advised against, successful aquacultural and agricultural production is possible. However, it requires careful planning, monitoring and an understanding of the system, requirements that may not be met as the demand for more agricultural and aquacultural land rises. In addition, the presence of acid sulfate soil is sometimes not discovered until the processes already have been initiated.

References and further reading

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