

Unravelling Acid Sulfate Soils: Challenges and Strategies for Sustainable Management

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Abstract:

Acid sulfate soils (ASS) are a complex soil type characterized by the presence of iron sulfides, predominantly pyrite (FeS_2). These soils are typically found in coastal and estuarine environments, wetlands, and floodplains. The inherent properties of ASS can lead to the development of acidic conditions upon disturbance, resulting in the mobilization of toxic metals such as aluminum and iron. This mobilization poses significant threats to aquatic ecosystems, contributes to infrastructure corrosion, and diminishes agricultural productivity. Effective management strategies for acid sulfate soils are crucial to mitigate their negative impacts. Key approaches include avoiding soil disturbance to prevent oxidation, implementing water management techniques to maintain stable conditions, and applying lime to neutralize acidity. Additionally, establishing vegetative covers can help reduce soil erosion and further protect these vulnerable environments. Understanding the dynamics of acid sulfate soils is essential for developing sustainable land use practices and preserving ecosystem health. Continued research is necessary to refine management techniques and assess the long-term effects of various interventions on soil chemistry and ecology. This review aims to synthesize current knowledge on the formation, impact, and management of acid sulfate soils, providing a comprehensive resource for researchers, policymakers, and land managers engaged in coastal and wetland conservation efforts.

Keywords: Acid Sulfate Soils, Environment, Reclamation Strategies, Agricultural Sustainability.

1. Introduction

Acid sulphate soils are one of the problematic characters of soil. These are problematic due to their potentiality of releasing acidity in case of exposure to air, which leads to widespread soil degradation. These types of soils are commonly found in coastal and estuarine regions. These soils causes significant challenges for agricultural productivity and environmental health.

Acid Sulphate Soil (ASS), introduced by Chenery et al, (1954) are characterized by drained soils with absorbed sulphate and low pH (<4.0) when in water.

In India ASS are primarily found in coastal saline soil zones which covers 0.26 million hectares. West Bengal's Sundarbans, Andaman and Nicobar island and Kerala's coastal areas contains most of the acid sulphate soil of India.

Formation process of ASS

Acid sulphate soils forms in coastal and estuarine areas which contains oxygen-deficient condition.

Seawater or sulphate rich ground water provides sulfate ions (SO_4^{2-}) and iron, released from weathering of rocks or sedimentation, produces Iron-sulphides which is also termed as pyrite (FeS_2).

Oxidation process

Due to some natural processes and human works pyrite gets exposed to air. After getting exposed to air pyrite goes through oxidation, forming sulfuric acid (H_2SO_4), which make the soil pH low and releases some metals like iron and aluminium.

Pyrite oxidation reaction: $4\text{FeS}_2 + 15\text{O}_2 + 8\text{H}_2\text{O} \rightarrow 4\text{Fe}^{3+} + 8\text{SO}_4^{2-} + 16\text{H}^+$

Impacts of ASS in agriculture

Soil acidification: sulfuric acid which is produced due to oxidation of pyrite, lowers soil pH.

low soil pH reduces soil fertility and kills beneficial microbes

Release of Toxic Metals: ASS releases toxic metals like aluminium, iron and arsenic which directly put impacts on plants, mostly affects root growth and nutrient uptake.

Nutrient deficiency and imbalance: essential nutrients becomes less available in acidic soil, which affects in plants growth and yield.

Poor soil structure and drainage: Acid sulphate soil often form hard and compacted layers, reducing water infiltration and root penetration.

Contaminated Water Supply: Acid Runoff from ASS pollutes irrigation water and affects plant growth.

Economic Loss: Due to negative impact of ASS in crops and soil, it ultimately impacts as Economical loss.

Management of Acid sulphate soil

Controlled use of groundwater: Maintained use of groundwater reduces exposure of pyrite to oxygen.

Use of Lime: Use of lime (Calcium Carbonate) can neutralize the acidic condition

Chemical Treatments: Iron chelating agents and specific buffering agents can be used to treat affected soils, stabilizing iron and preventing its solubility. These treatments are typically more expensive and often reserved for smaller, highly affected areas. Bandopadhyay (1989) and Mongia and Bandopadhyay (1993) have also reported beneficial effects of liming, leaching and MnO₂ application singly and in combination in improving acid sulphate soils.

Use of Organic Amendments: Organic materials, like compost and manure, can buffer the acidification effects of ASS. These amendments add organic matter, increasing microbial activity that can help restore soil health and reduce acidity.

Conclusion

Acid sulfate soils pose serious environmental and agricultural

challenges due to their potential to generate extreme acidity and release toxic metals upon exposure. Their management requires a combination of preventive and remedial strategies, including controlled water use, liming, organic amendments, and chemical treatments. Sustainable handling of these soils is essential to protect ecosystems, ensure agricultural productivity, and minimize economic losses. Continued research and adaptive land management are key to mitigating the long-term impacts of acid sulfate soils.

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