

Management of sulfide soils under drained conditions

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Key recommendations

- ✓ Apply coarse-grained limestone at doses exceeding the soil's acidification potential.
- ✓ Fine-grained limestone can be used at lower application rates due to its higher reactivity.
- ✓ Ensure limestone is evenly distributed throughout the soil mass.
- × Avoid layered application of limestone, as this does not provide sufficient protection against acidification.

Expected outcomes

- Near-neutral pH
- Reduced acid generation
- Lower metal mobility
- Reduced environmental risk

Why are these measures needed?

When sulfide soils are excavated and exposed to oxygen

- Sulfide minerals oxidise
- Sulfuric acid is formed
- Soil and drainage water become acidic
- Metals become mobilized and may leach into surrounding waters

Potential consequences

- Deterioration of water quality
- Negative ecological impacts in receiving waters
- Increased environmental management costs



Evaluating mitigation measures

The experiments in the project assessed whether limestone and peat amendments could reduce

- Acid generation
- Sulfate release
- Metal leaching

→ The test conditions were representative of sulfide soils stored above groundwater level.



Laboratory experiment
2.5 years



Field experiment
4 years

Evaluating mitigation measures

Treatments

- Coarse-grained limestone (agricultural limestone)
- Fine-grained limestone (C2, Nordkalk)
- Limestone + peat
- Layered limestone
- Untreated control

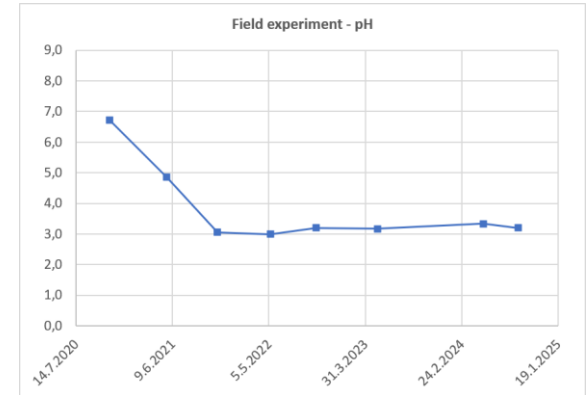
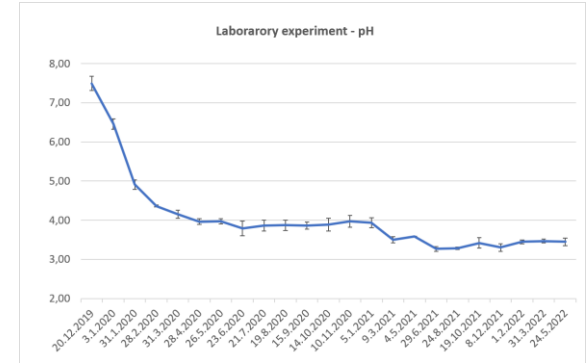
Monitoring included

- pH and redox potential
- Acidity
- Sulfate
- Dissolved metals
- Soil microbial community composition (DNA analyses)



What happened without treatment?

- pH dropped below 4 within the first year
- Acidity increased substantially
- Sulfate concentrations increased
- High dissolved aluminum concentrations developed
- Nearly half of the original sulfur content was lost



Performance of different treatments

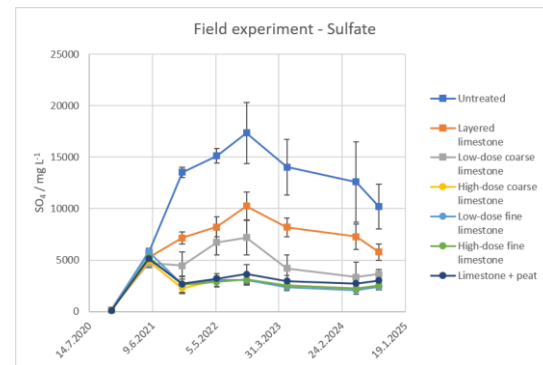
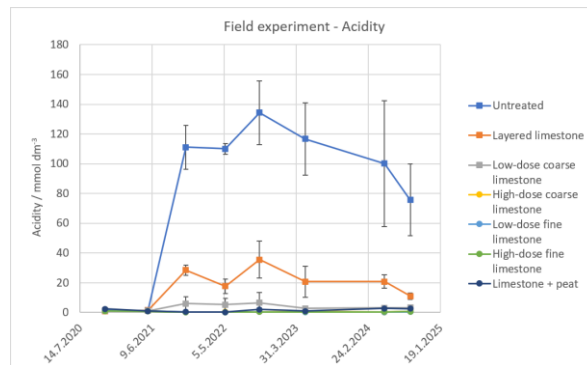
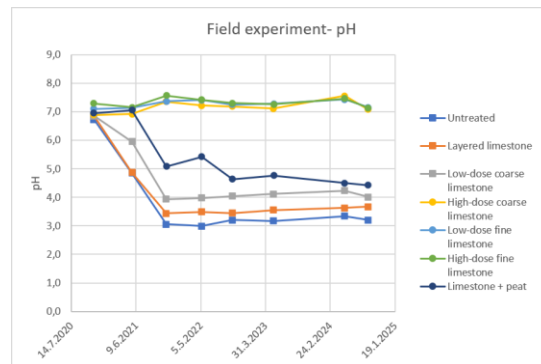
Treatment	Performance
Low-dose coarse-grained limestone	Reduced impacts but did not prevent acidification
High-dose coarse-grained limestone	Maintained near-neutral pH
Fine-grained limestone (both low- and high-dose)	Maintained near-neutral pH
Limestone + peat	Variable performance
Layered limestone application	Ineffective

→ Neutralisation efficiency depended on both limestone particle size and dosage.

Environmental benefits of effective neutralisation

When pH remained near neutral we observed

- Strong reduction in acidification
- Lower sulfur losses
- Reduced metal mobility
- Reduced leaching of
 - Aluminum
 - Nickel
 - Cadmium
 - Zinc
 - Copper



What did the microbiology show?

Treatment performance	Microbial community composition
Untreated, oxidised sulfide soil	• Dominated by acidophilic microorganisms • Typical of acid sulfate soils
Successfully neutralised sulfide soil	• Dominated by diverse neutrophilic bacteria • Community differed clearly from untreated controls

- Evidence that neutralisation fundamentally alters soil processes, not only water chemistry
- Neutralisation did not completely stop sulfur transformations as
 - Some neutrophilic sulfur-oxidising bacteria remained active
 - Sulfate could still occur in drainage water

Why did fine-grained limestone work better?

Fine-grained limestone has higher reactivity

- Provides a larger reactive surface area
- Neutralises acidity more efficiently
- Protects iron sulfides from further oxidation
- Promotes stable near-neutral conditions



Implications for authorities and consultants

When sulfide soils are excavated and stored above groundwater level

- Neutralisation measures are required
- Limestone should be thoroughly mixed with the soil
- Particle size and dosage are critical for success
- Layered application is not accepted as a stand-alone mitigation measure
- Monitoring should include e.g. pH, acidity and dissolved metals.