Nanostructured vermiculite - A new material for recycling ammonium from different types of polluted matters

The vermiculite research group at

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Market potential by

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Aim of this talk

- Present vermiculite and the new nanostructured product, **GT-1**, for use in ecologically sound and efficient removal of ammonium from polluted areas and its re-use as secondary product **GT-2** - soil improver for nitrogen depleted areas

- ***Vermiculite is a vaste product in carbonatite mines***

- Present the nanotechnology behind the invention

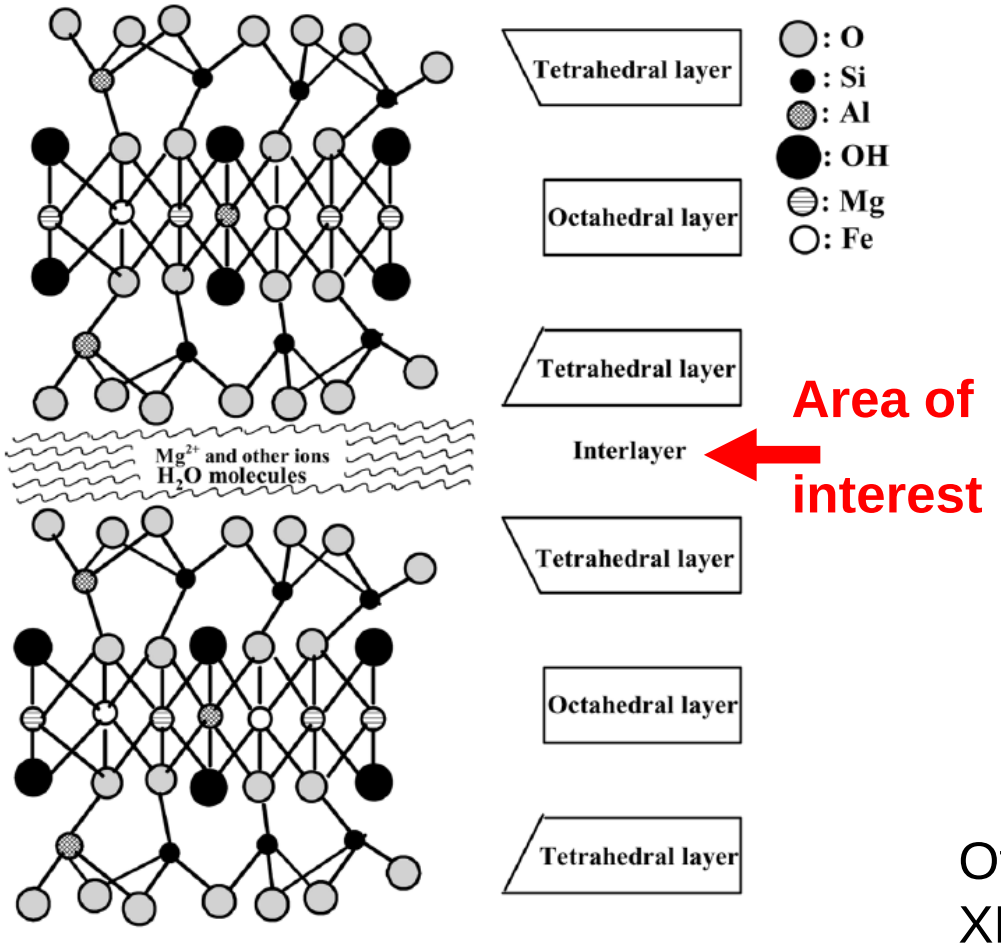
GeoTrap-1, **GT-1**

GeoTrap-2, **GT-2**

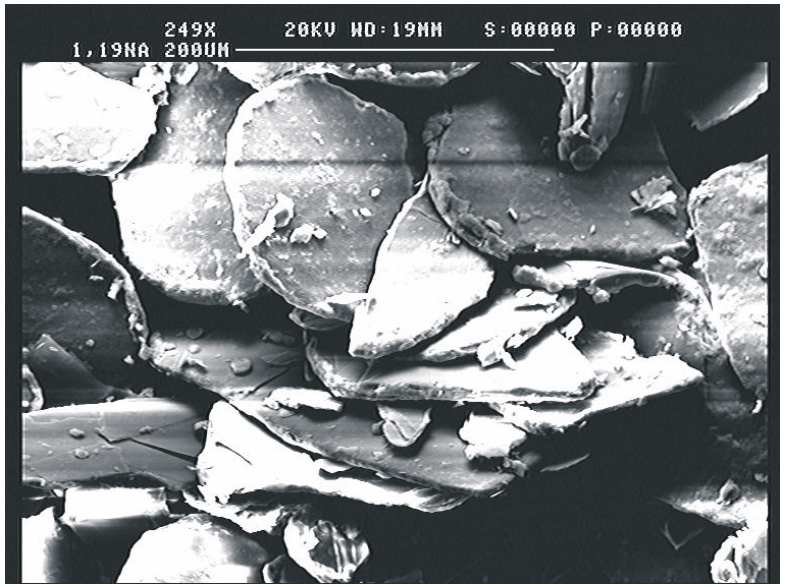
Raw-material for nanomodification

We use Kovdor vermiculite, Russia
(Reserves - 22.9 mln tons)

$$(Mg,Fe,Al)_3(Al,Si)_4O_{10}(OH)_2 \cdot 4H_2O$$



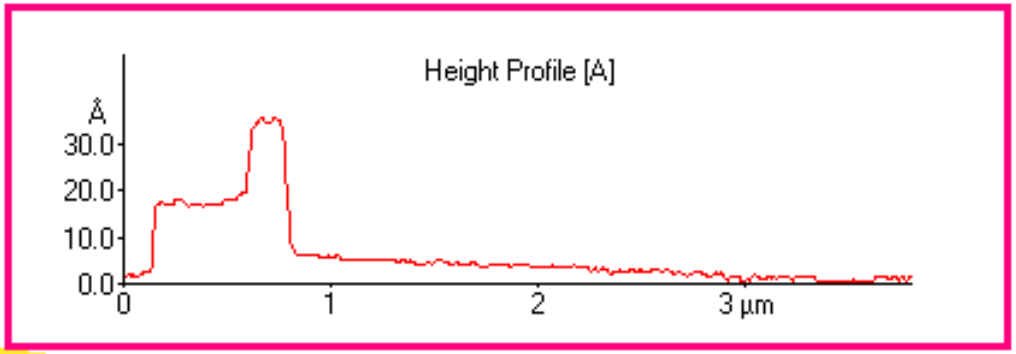
Area of interest



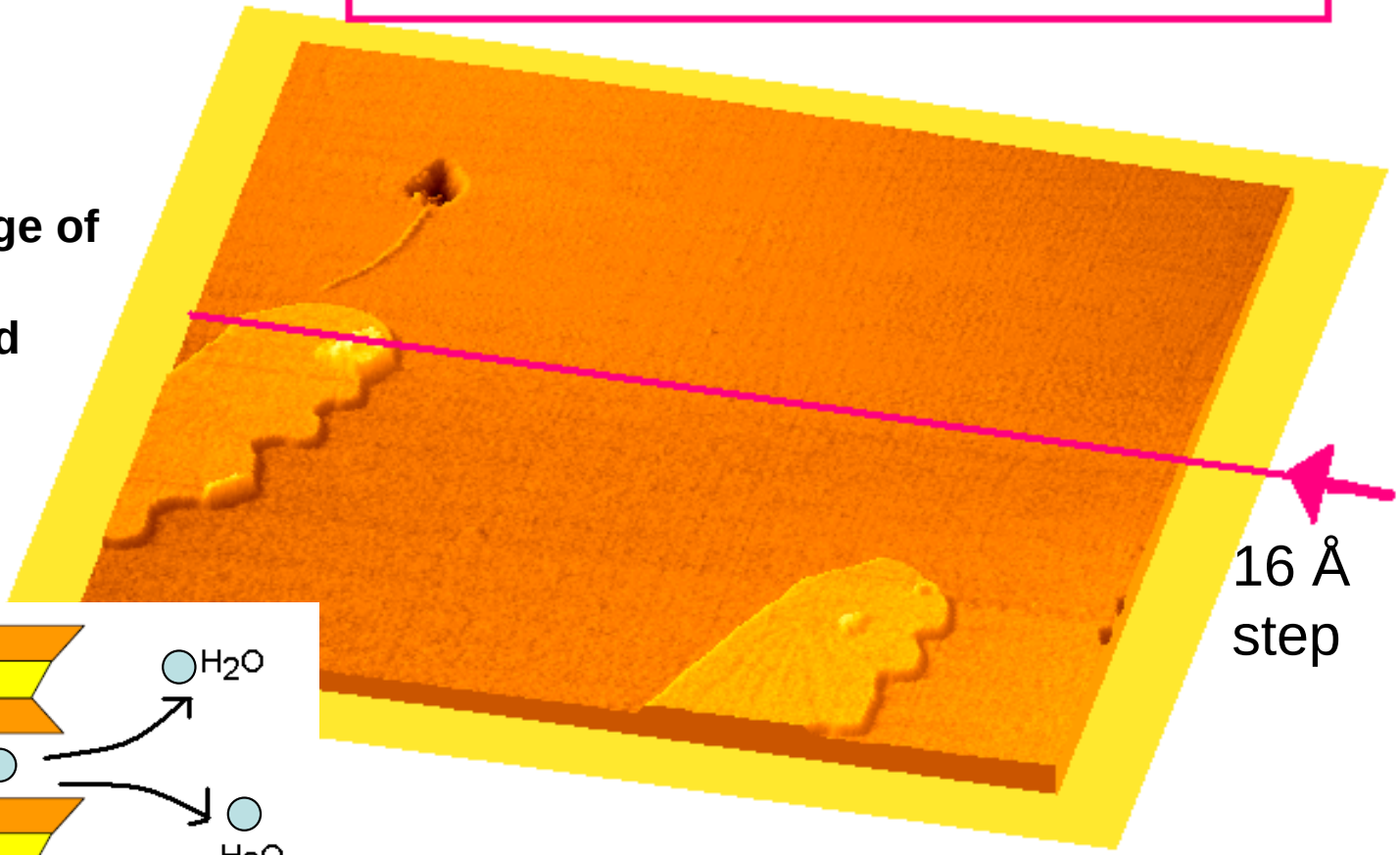
SEM image of vermiculite flakes

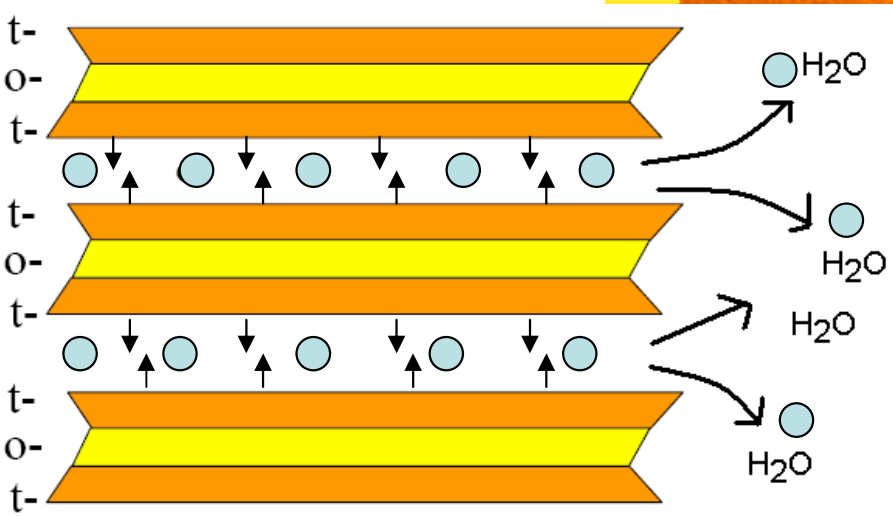
Other methods of characterization used:
XRD, AFM, TG, XPS and PIGE (MGC-20)

From vermiculite to GT-1 by nanomodification



Topographic AFM image of freshly cleaved vermiculite surface and a line profile from the image.



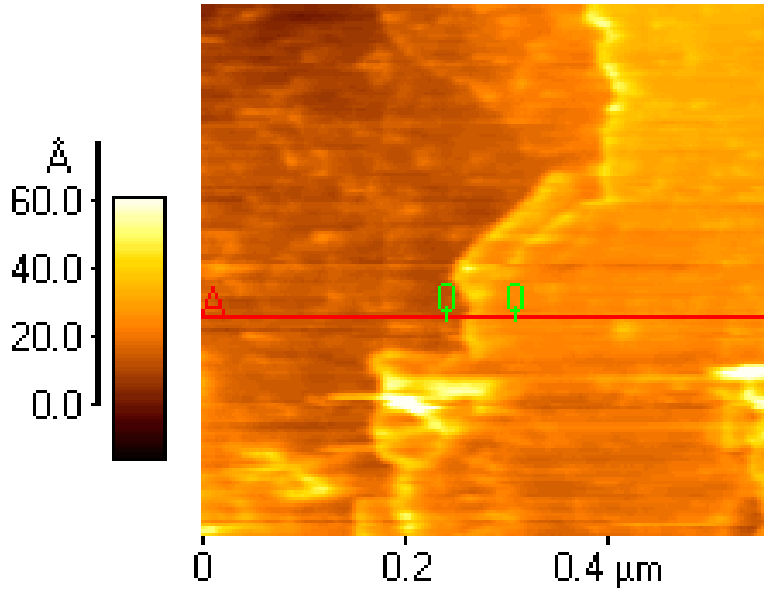


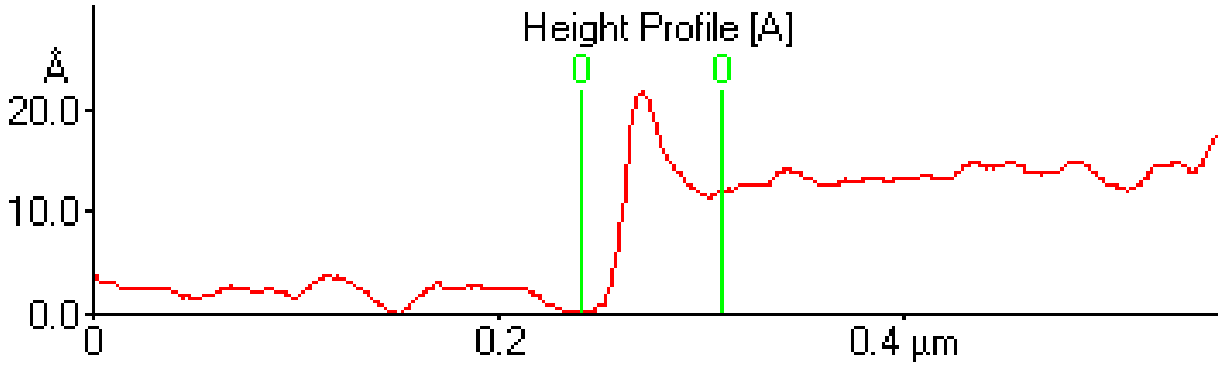
Water and some ions leave structure as a results of controlled heating – material gets adjusted by patent heating regimes (Patent FI 20050700)

GT-1

Lattice structure of GT-1 as the result of nanomodification of vermiculite

Topographic AFM image of freshly cleaved GT-1 surface and a line profile from the image





Line	Height
[A]	0: 11.7 Å

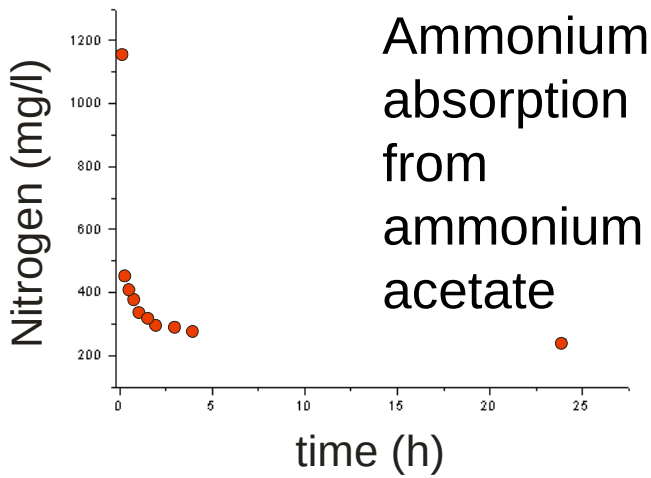
GS-1 material step height is diminished from 16 to 11.7 Ångström (Å)

Functional characteristics of GT-1

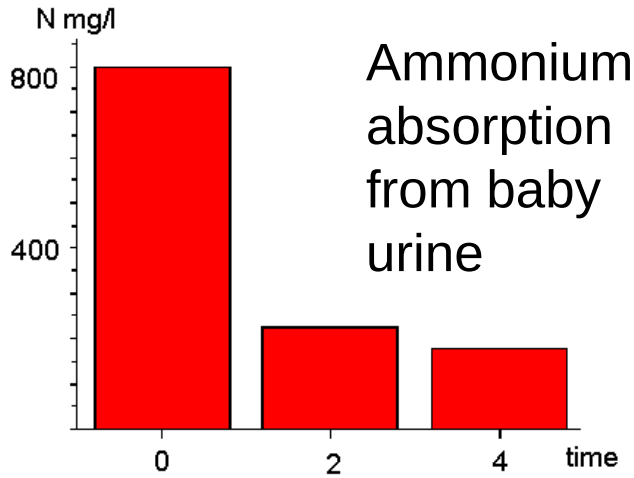
- Nanostructured geomaterial, filter and immobilizer of ammonium ion from different pollutions (water, soil, gas etc)
- Particle size – 3-5 mm
- Parameter C_{d002} = 0.99–10.5 nm
- Absorption capacity – 2.5-3.9 wt.% *(up to 4.7 wt%)*
- Speed of ion exchange – 20–60 min.
- Exothermic reaction
- Recommended pH <8

How does the invention work?
From **GT-1** to **GT-2**

- **Selective ammonium absorption tested in:**
- human urine
- waste water from biogas plants
- ammonium solutions
- solutions with competiting cations (K, Na, Ni, Cr)
- combustion experiments (fox excrements)
- industrial chimneys



Ammonium absorption from ammonium acetate



Ammonium absorption from baby urine

The ammonium molecule is locked into the crystal lattice, and stays there!

Market opportunities

- **GT-1** has a business potential in:

- dry toilet market
- agriculture
- waste water treatment
- landfill
- composting processes
- slaughterhouses

Other areas with elevated NH_4^+

Dry toilet market

NH_4^+ = 800 - 1600 mg/l

- Business starts in the Nordic countries
  (in Finland 500 000 summer cottages, dry toilets for festivals etc)
- Extensive market in the developing countries (270.000.000 people lack toilets in India)
- Red cross, WHO for sanitary education

Agriculture

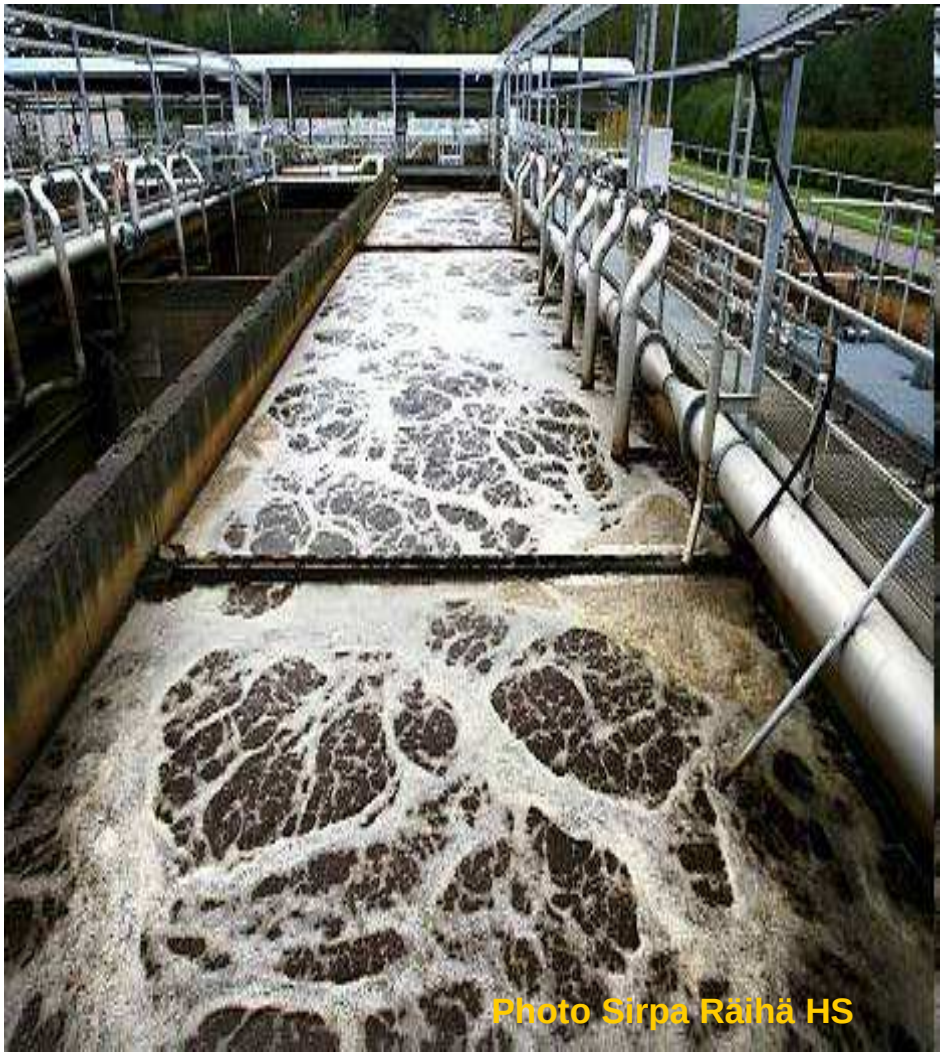
NH_4^+ = 80 – 2700 mg/l

- Reduce the smell in farms (alternative solutions are not user-friendly and/or cost-efficient
- Recover ammonia
- Protect water fronts from contaminated streams
- Ammonium doped material can be reused as soil conditioner

Waste water treatment

NH_4^+ = 150–1700 mg/l

- EU-directive – reduce ammonia by 70%
  (for 80% of European population)
- Process development
- Most cost efficient in smaller water treatment plants



Landfill

NH_4^+ = 100 – 300 mg/l

- Cold water streams with low ammonium contents
- 1100 landfill sites only in Finland

Composting

NH_4^+ = 500 – 5000 mg/l

- **GT-1** in composting processes increases the nitrogen content in the final compost

Slaughterhouse waste destruction

NH_4^+ = 300 - 800 mg/l

- High nitrogen content in slaughterhouse waste
- Urban (European) problem
- Increasing problem with wellfare

GT-2

When GT-1 has settled its mission as a selective ammonium absorbent, it starts a new life as **GT-2**, an improver for N-depleted soils.

left: 5 month old pine seedlings growing in a substrate containing GT-2 (ammonium doped GT-1)

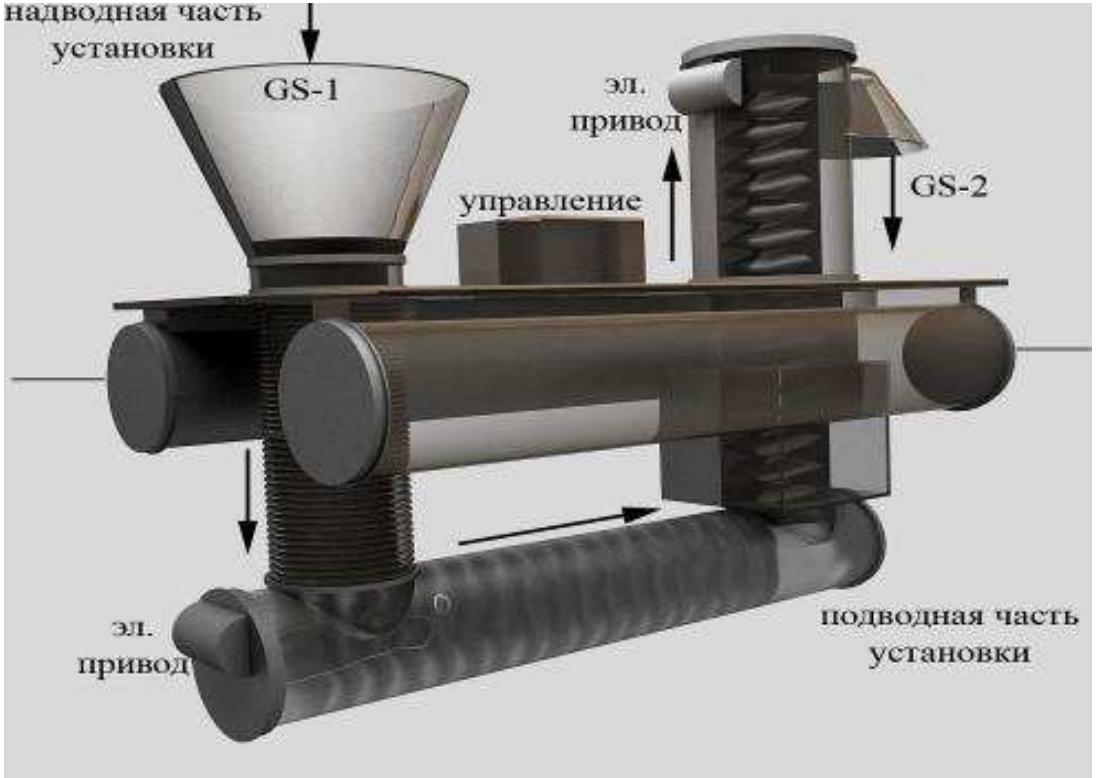
right: 5 month old pine seedlings growing in a reference substrate

Greenhouse experiments with GeoTrap-2 as soil improver. Seedlings growing in GT-2 (ammonium doped GT-1) are 10 times stronger than the reference seedlings!

Functional characteristics of GeoTrap-2

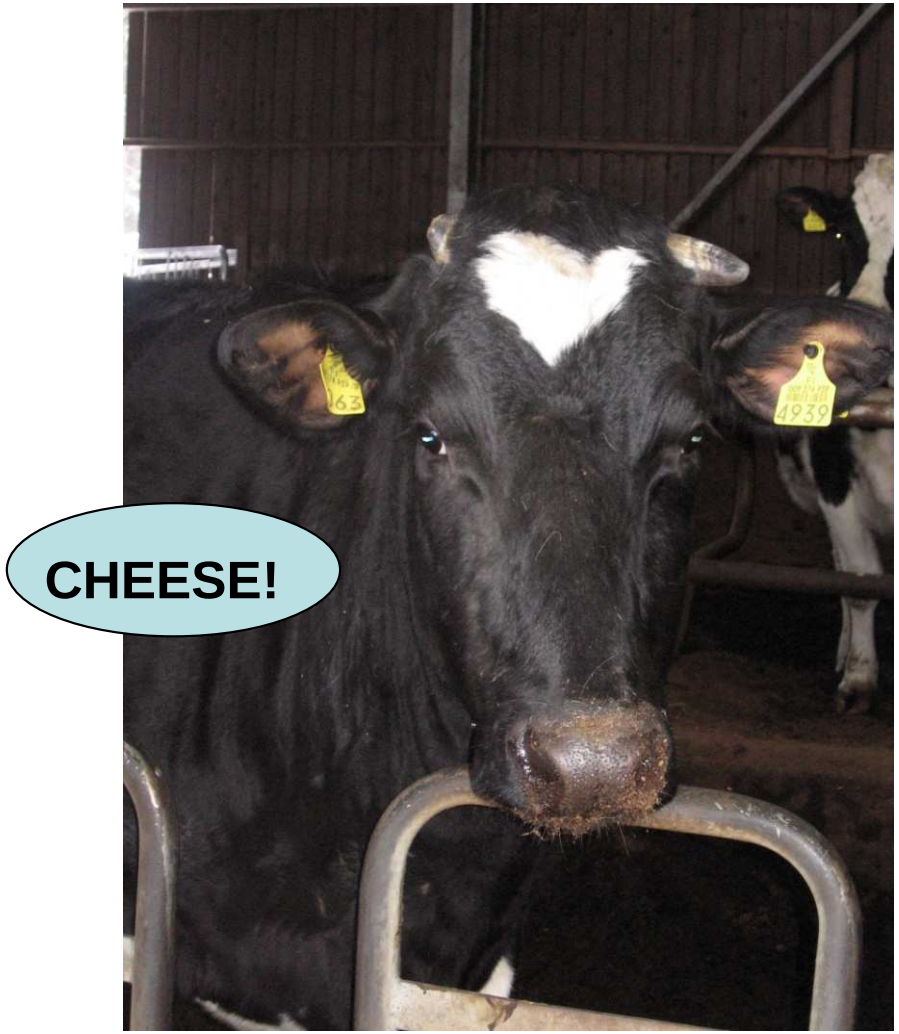
- **Ammonium-doped modified geomaterial**, fertilizer for a long period of use and soil conditioner
- Parameter C_{d002} = 1.124–1.248 nm
- N – 2.5-3.9 wt. %; K– 2-3 wt. %; Mg – not less than 7 wt. %; H_2O – not less than 14 wt. %
- **Complex fertilizer – 2-3 seasons of use**
- Soil conditioner – several years of use
- **Ecologically friendly – not over-fertilizing the soil**
- Useful components being extracted by “silicate bacteria” gradually to the plant root zones, in various cases can be used as natural fertilizer for organic food
- **Water-insoluble – does not require special storage conditions**

Engineering solutions for GeoTrap-1 to GeoTrap-2 - process



Technical solution for purification of still waters (lakes, sediment basins)

AGRICULTURE



Tests with manure sludge

Starting material: Manure sludge
Dry matter of the sludge = 13,1 %

	Manure sludge (g/kg)	Dry matter (g/kg)
Total nitrogen	**4,84**	**36,95**
Nitrogen in solution	**1,24**	**9,47**

GT-1 was mixed direct into the manure sludge:
sludge + **GT-1** (200 g + 20 g)
Time of experiment 48 h.

10% GT-1 in the manure sludge reduces 70% of its nitrogen.

The nitrogen content in GT-2 is 3.5 wt %

Reducing environmental loading from a feedlot

TEST: Reducing nitrogen from feedlot water

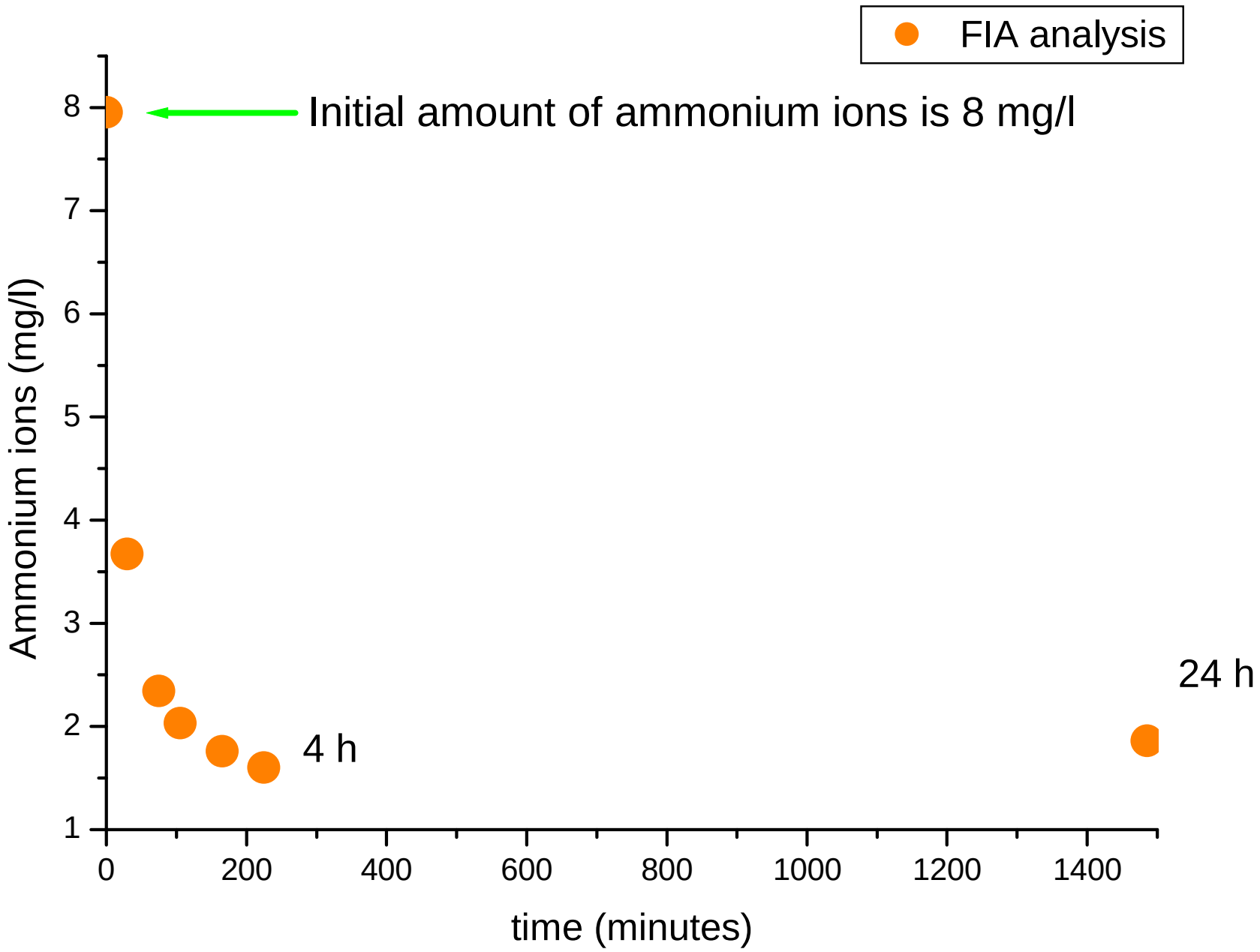
Water was collected from a feedlot.

400 ml of water from feedlot was mixed with 40 g of GeoTrap

Samples (30 ml of water and 2 g of GeoTrap-1) were taken for analysis.

Analysis were performed by FIA method at NOVIA Vaasa.

RESULTS FROM THE FEEDLOT TEST



Ongoing research

The innovation works, we are now testing the technology in different case studies

- Biogas plants (ongoing pilot research)
- Water treatment plants (from case to case)
- Filters for chimneys (ongoing project, good results)
- Eko farming (ongoing projects)
- Recycling of **GS-2** back to **GS-1**(ongoing project)
- A company has been started, NanoGeo Finland**,** that will start to manufacture Geotrap

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