



Nature-Inspired Clays: Smart Rheology for Reactive Systems

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Lotus Effect



Velcro



Aeronautics



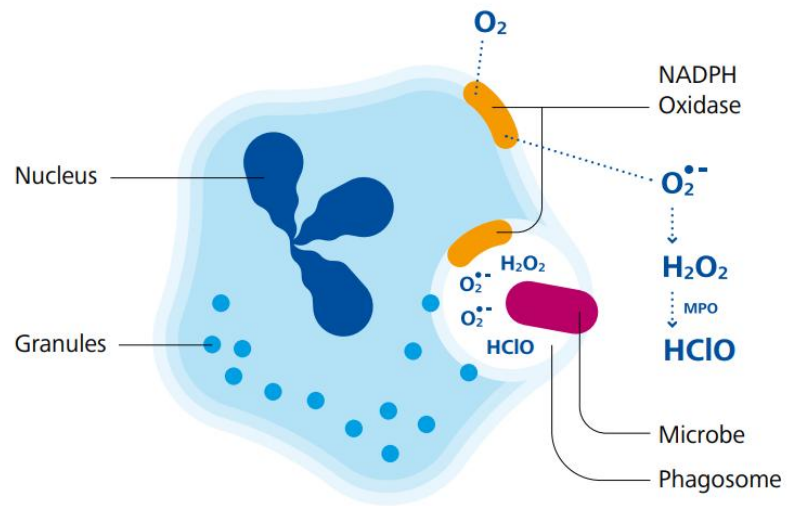
Biomimicry

Learning from evolutionary
optimized structures and
processes in nature

HClO and H₂O₂

Natural weapon against pathogens in our bodies

HClO/H₂O₂ is build in the white blood cells of mammals as part of the immune answer



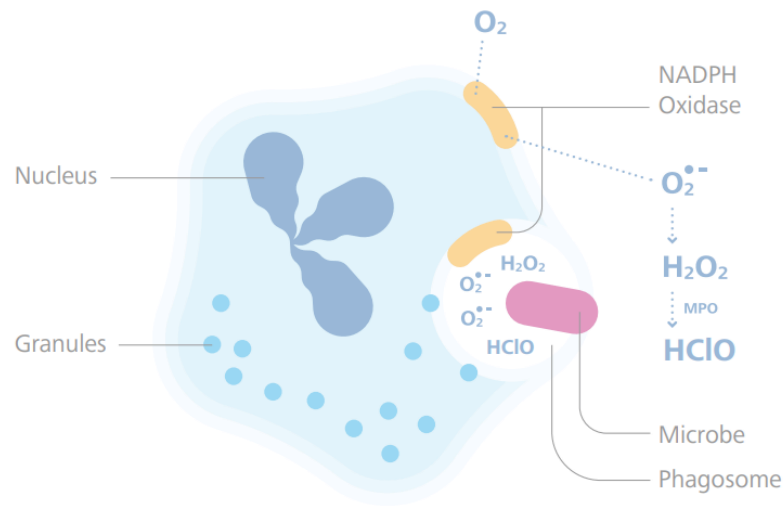
Schematic demonstration of oxidant production of a neutrophil^[1]

MPO: myeloperoxidase

HClO and H₂O₂

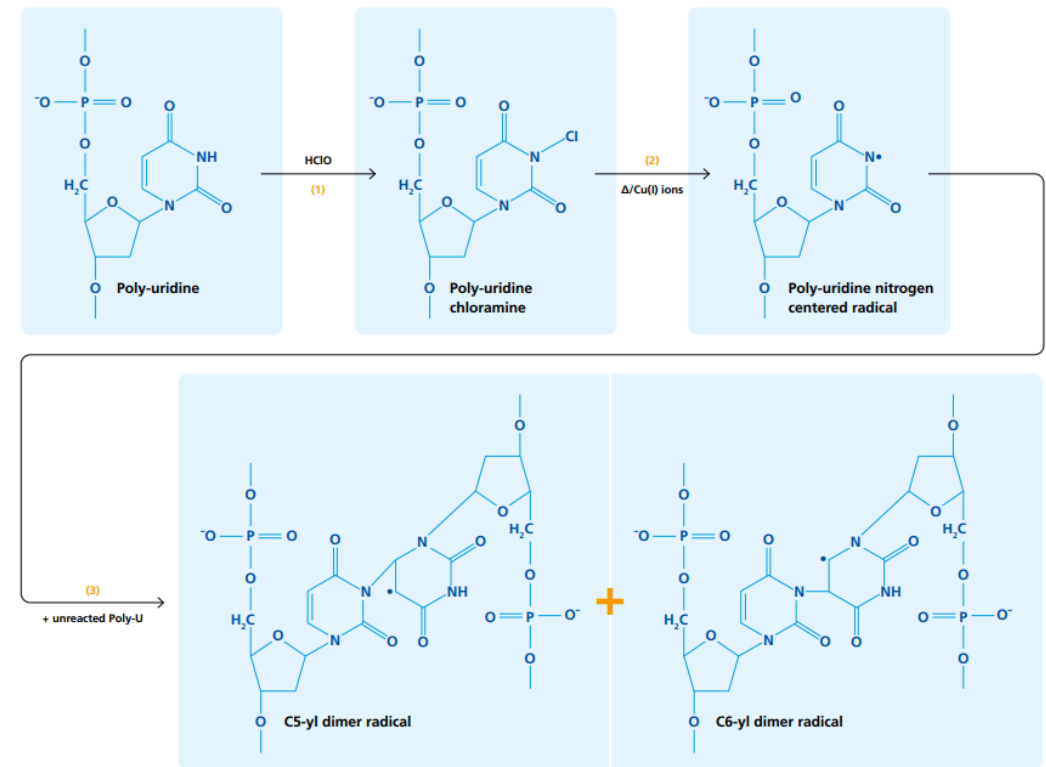
Natural weapon against pathogens in our bodies

HClO is build in the white blood cells of mammals as part of the immune answer



Schematic demonstration of oxidant production of a neutrophil^[1]
MPO: myeloperoxidase

Strong oxidizer penetrate rapidly bacteria cell walls and destroys proteins and DNA of microorganisms:



Mechanism of oxidative reaction of HClO with virus DNA^[2]

HClO and H₂O₂ as alternatives to alcohol based cleaning and disinfection products



Effectiveness

- › Strong oxidizing properties
- › Cleans, disinfects, deodorizes
- › Anti-bacterial, anti-fungal, anti-mold, anti-mildew



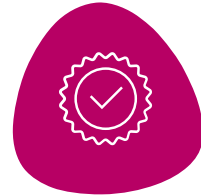
Cost efficient

- › High Versatility : “all-purpose” solution
- › Relatively low costs



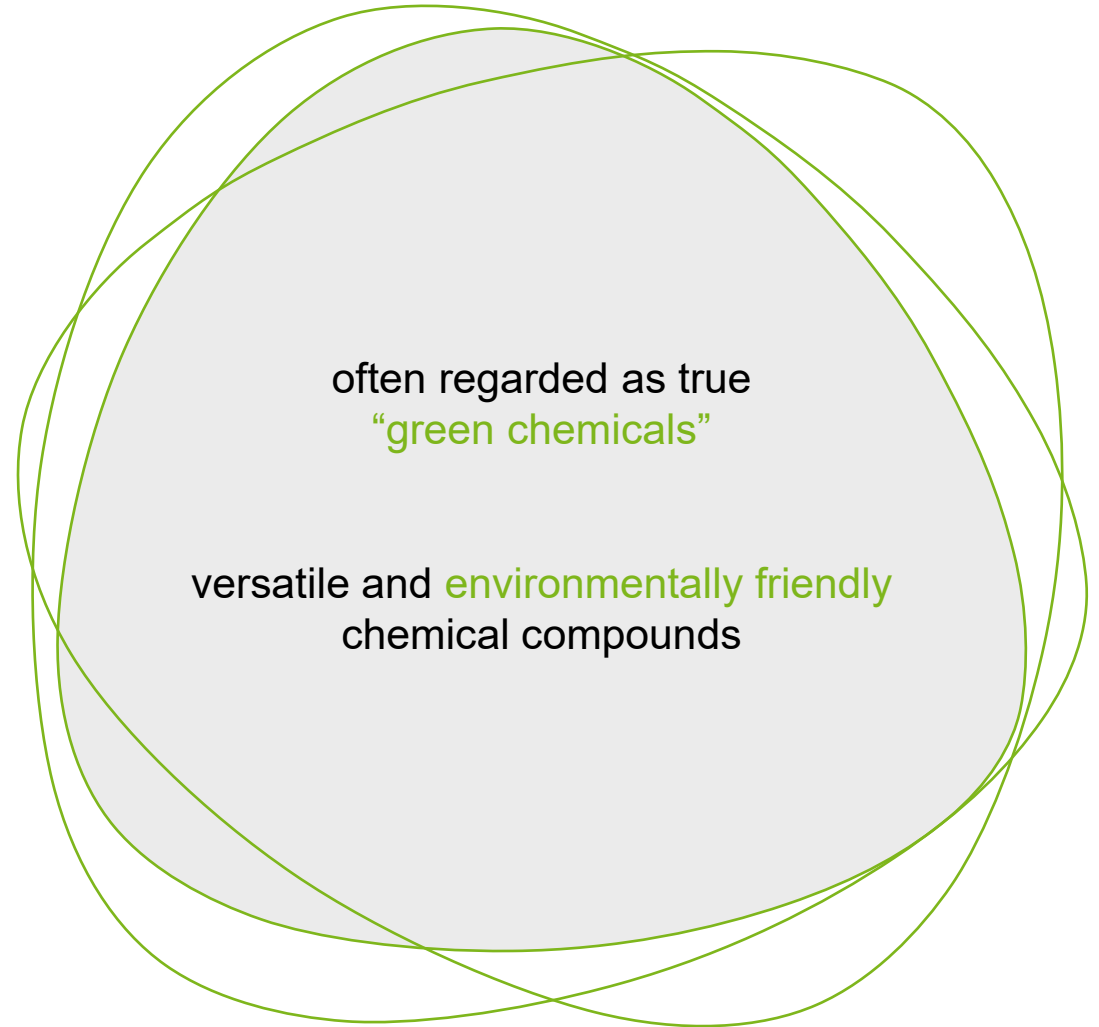
Eco-friendly

- › “Green chemicals”
- › Degrade in harmless substances



Safety

- › Gentle to the skin and to the equipment



Benefits of hydrogels



HClO/H₂O₂ solutions

water-thin: **drain away** rapidly from surfaces

HClO/H₂O₂ hydrogels

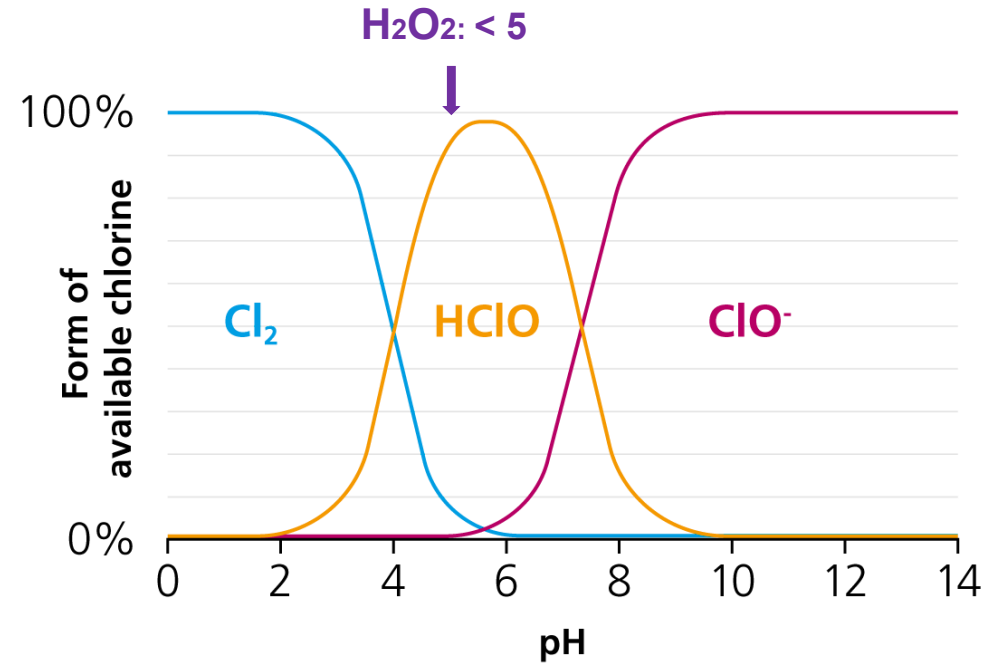
remain in contact with surfaces for extended periods of time to allow improved sterilization and protection

improved **storage stability**

HClO/ClO⁻ and H₂O₂

Challenging systems for thickening

- Must be stabilized at certain pH to maintain chemical stability
- activity is **degraded by organic chemicals**:
organic polymer thickeners and organic buffering acids cannot be used
- activity is **degraded by transition metal ions**:
natural clay thickeners and hydrated silica cannot be used



Hydroclays – Introduction

Natural clay-based additives

Raw material source



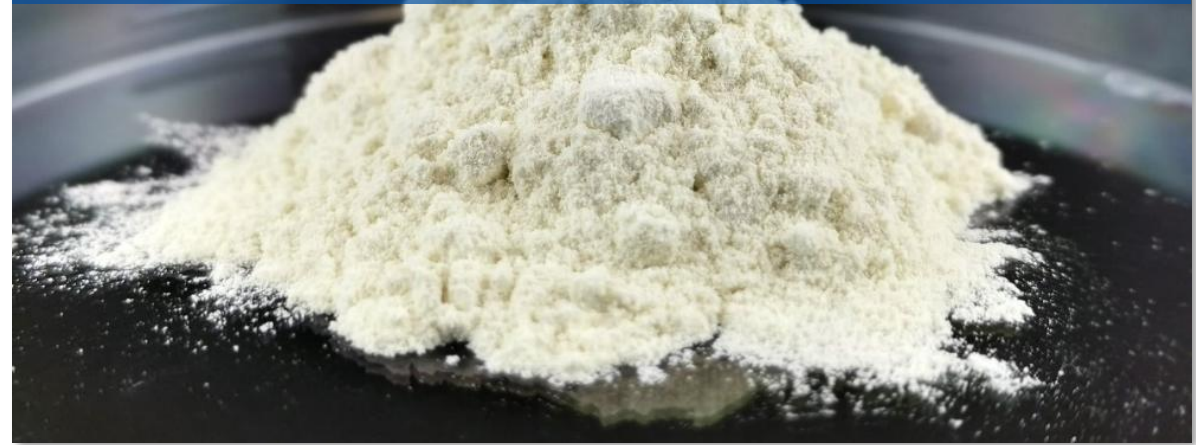
Open pit mining*



Crude clay



Cleaned, dried, and milled



**Image of BYK's Baulking quarry (Oxfordshire, UK) before and after restitution*

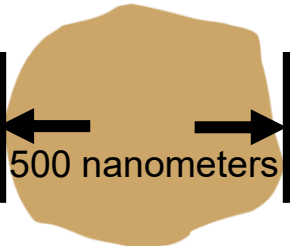
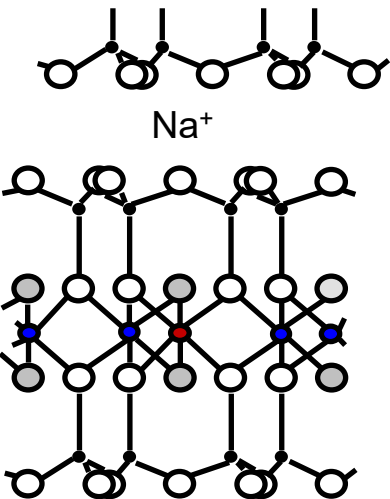
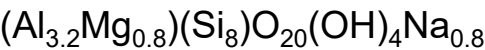
Improving nature

Different types of swellable layered silicate clays

Layered silicates - smectites

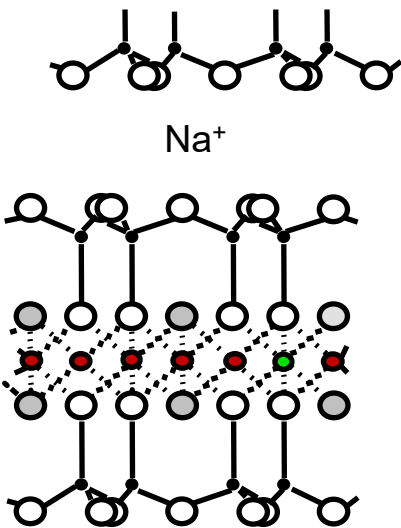
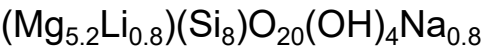
Natural clay

Montmorillonite

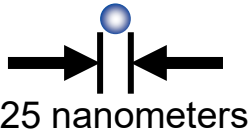


Synthetic clay

Hectorite

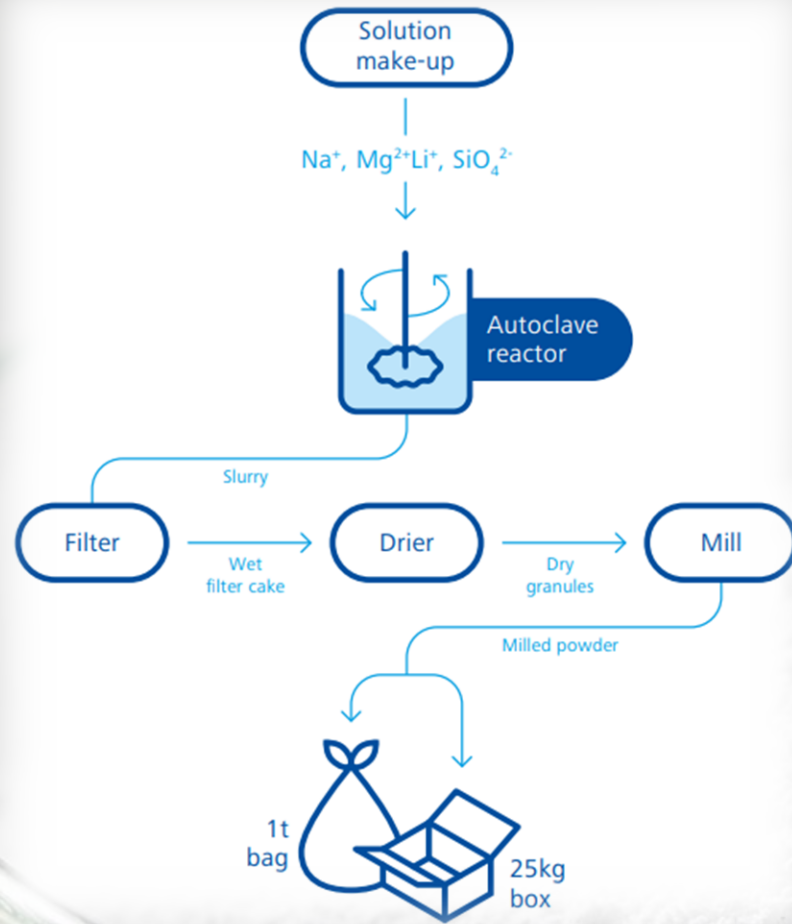


New synthetic clay developments



Synthetic smectorite clays

Production process



Schematic representation of production process

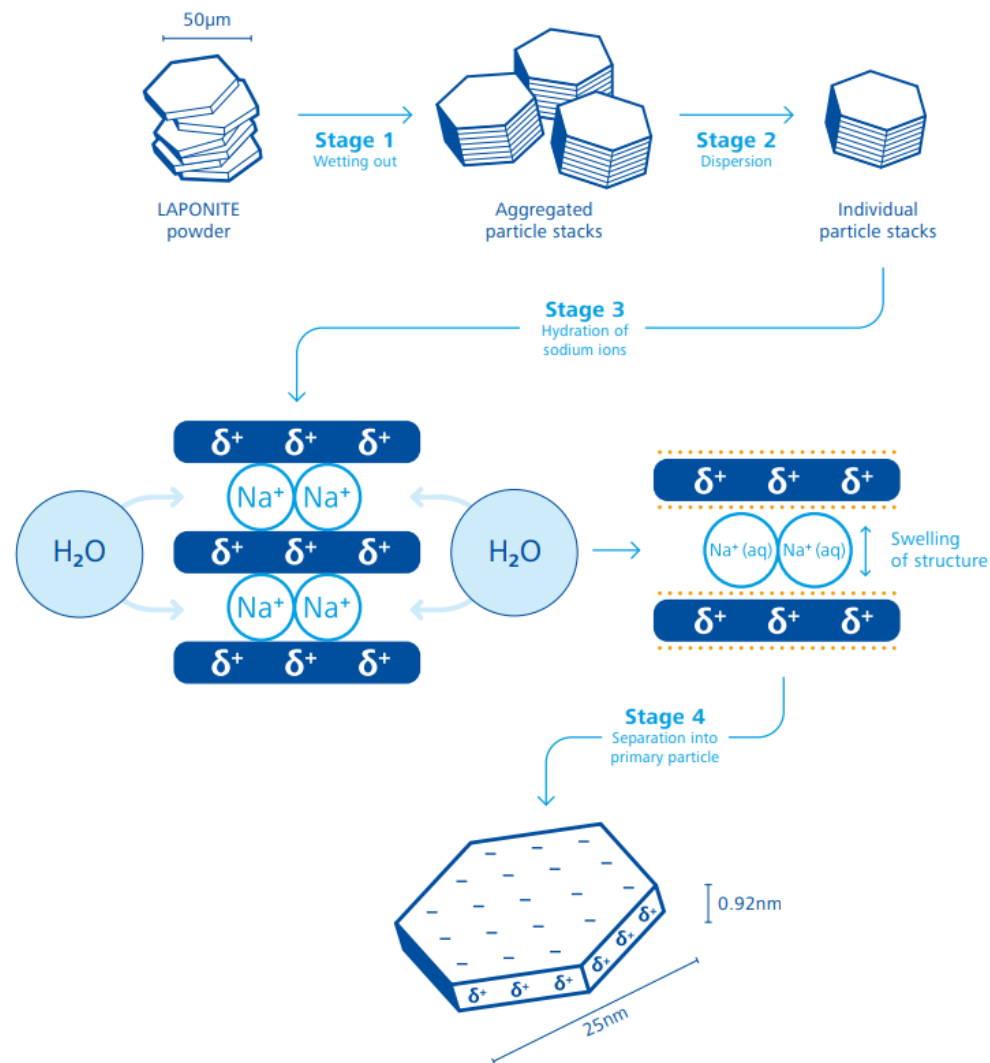
Synthetic smectite clays

Key benefits

- Synthetic clay products are based on synthetic hectorite hydroclay with a **consistent controlled chemical composition**
- They are characterized by **very high purity and reproducible performance**
- Highly shear thinning gels are formed that leave a **clean, dry feel**
- **100 % natural origin index** rheology modifiers
- **Unaffected by temperature variations**

Rheology based on swellable layered silicates

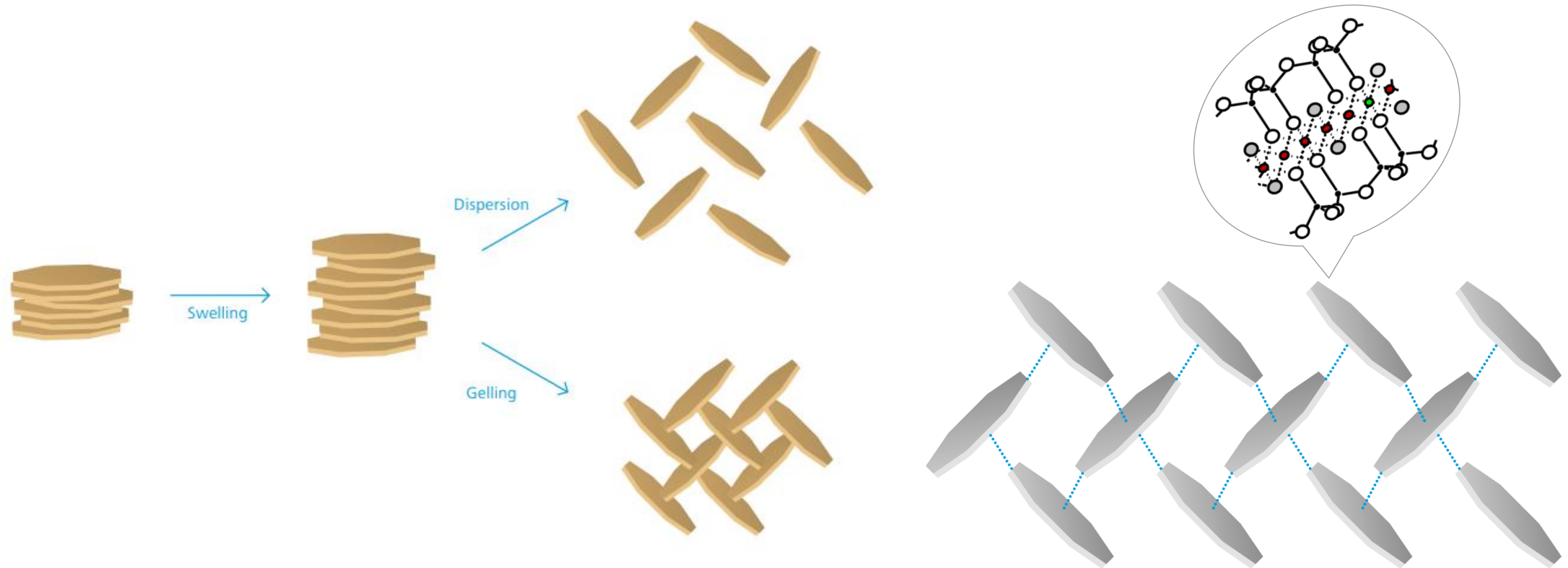
Hectorite platelets dispersion in water



Addition of hectorite clay into water

Rheology based on swellable layered silicates

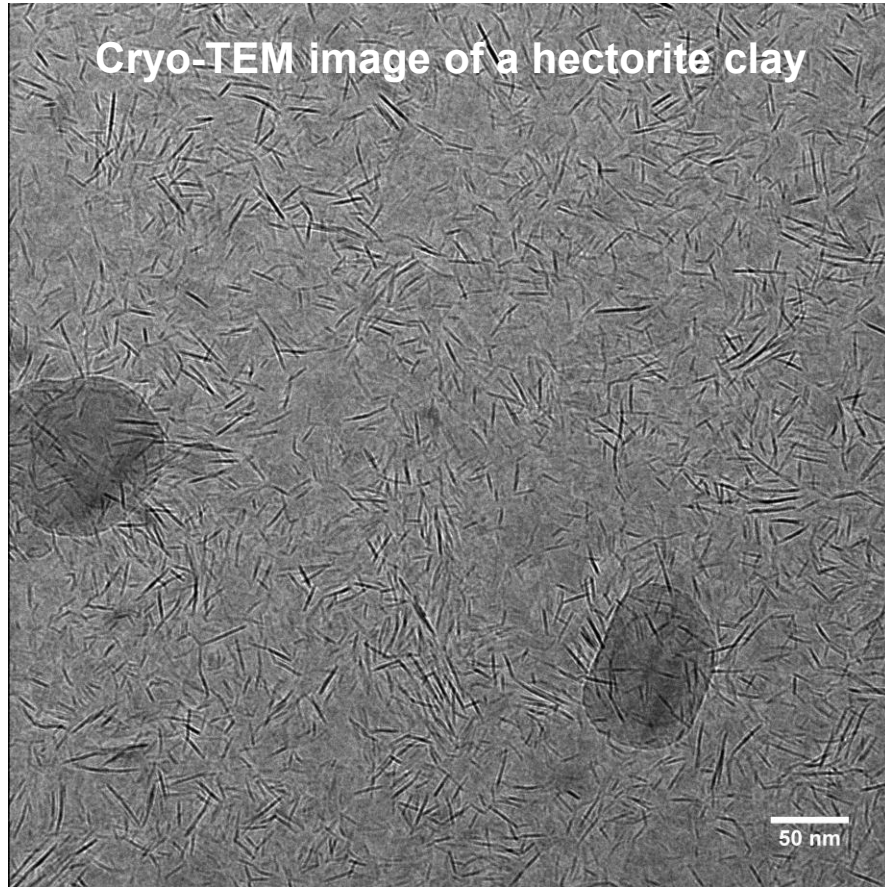
Hectorite platelets building “house-of-cards” gel structure



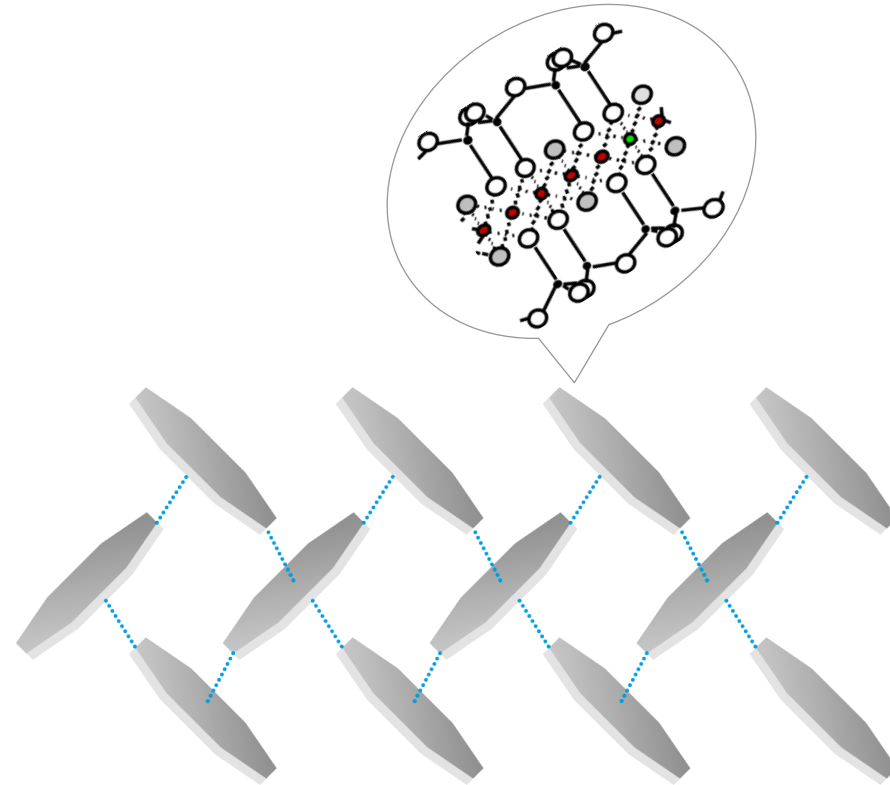
Network formation for rheological effect: “house-of-cards” structure

Cryo-Transition electron microscopy (TEM)

“house-of-cards” structure of hectorite clay

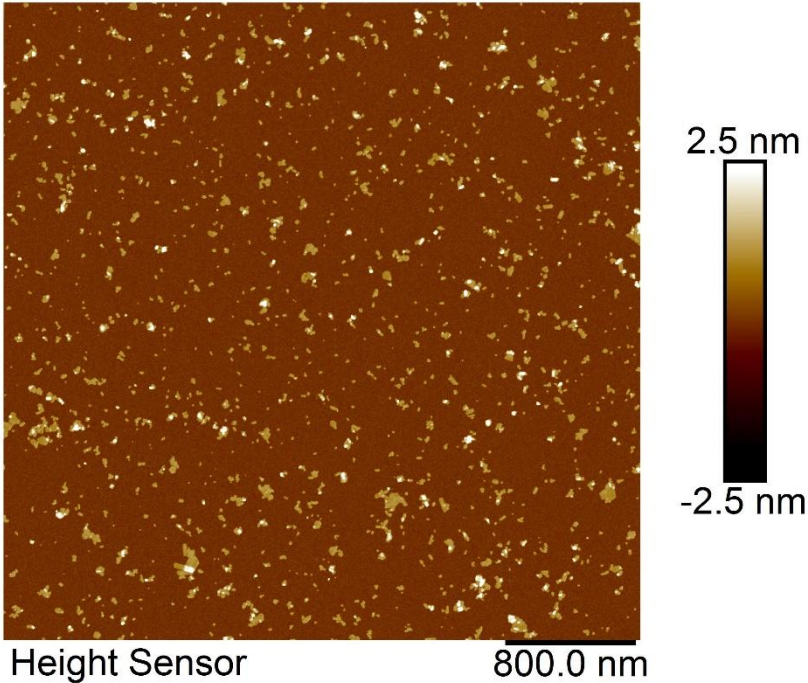


Cryo-TEM (transmission electron microscopy) image of a dispersed hectorite^[4]



AFM image of synthetic fluorohectorite

Exfoliaton in dispersion



AFM (atomic force microscopy) picture of hectorite clay in dispersion, with Bruker Icon-PT instrument^[3]

Height range					
Ø height, nm	Median height (d50), nm	Min. height, nm		Max. height, nm	
1,11	1,05	0,87		2,17	

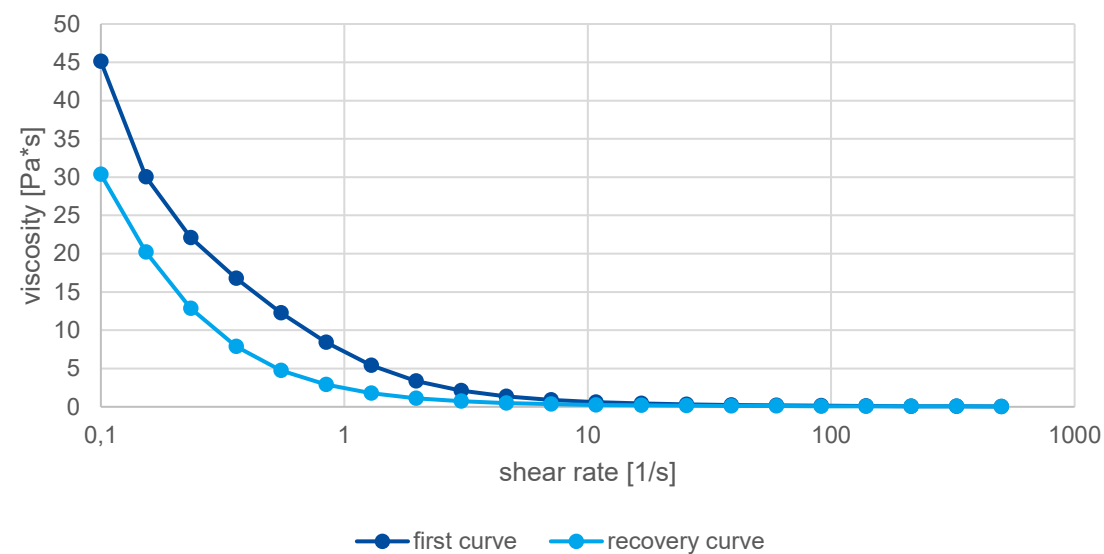
Degree of exfoliation					
	% (1-2) platelets stack	% double stack	% (2-3) platelets stack	% triple stack	% > 3 platelets stack
	0.75-1.75 nm	1.75-2.25 nm	2.25-2.75 nm	2.75-3.25 nm	>3.25 nm
	61.2	10.0	13.6	2.8	0.0
cumulative	73.6	83.6	97.2	100.0	100
	Fully exfoliated	Double-stacked		Triple-stacked	

- Good exfoliation:** Majority (73.4 %) is fully exfoliated. Very poorly exfoliated platelets (more than three platelets in stack, or >3.25 nm height) are not detected.

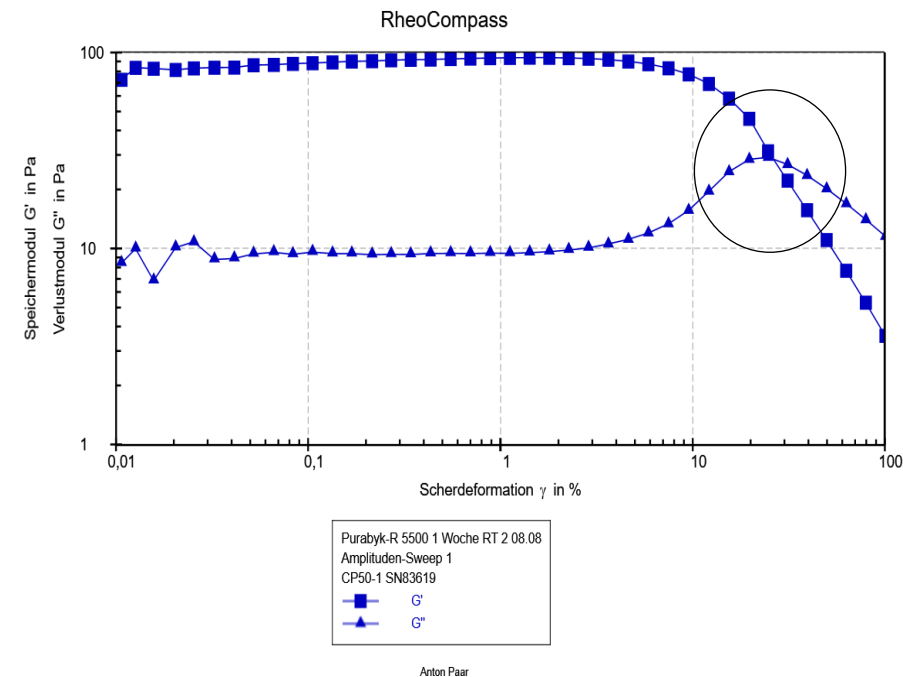
Rheology based on swellable layered silicates

Thixotropy and yield stress

Viscosity curve of the HClO hydrogel



Yield stress of the HClO hydrogel



Benefits of hydrogels



HCIO/H₂O₂ solution

water-thin: **drain away** rapidly from surfaces

HCIO/H₂O₂ hydrogels

remain in contact with surfaces for extended periods of time to allow improved sterilization and protection

improved **storage stability**

PURABYK-R 5501 in Peroxide-based systems

Tailoring the desired viscosity



... from medium viscosity increase



... to strong gel

PURABYK-R 5500 in Hypochlorous acid systems

Tailoring the desired viscosity

- Hypochlorous acid gel with PURABYK-R 5500 after 4 weeks:

Room temperature



40 °C



Synthetic clay-based additives

usage in a sprayable cleaner

- unique rheology enables easy sprayability and rapid viscosity recovery → **spray-with-cling**
- Results in prolonged contact and improved cleaning



No negative impact on the biocidal efficacy of HClO solutions

- Quantitative suspension tests shows **no restriction** on the bactericidal and virucidal activity:



	HClO-based solution without rheological modification	HClO-based solution with 3.5 % hectorite clay
HClO content	1000 ppm	1000 ppm
Test methods in accordance to	EN 13727 and EN 14476	EN 13727 and EN 14476
Pass criteria for	Bactericidal activity*	Bactericidal activity*
Pass criteria for	Virucidal activity*	Virucidal activity*



* Tested exemplarily on selected standard bacteria and virus types. Tested via quantitative suspension tests at an external DAkks accredited laboratory. Depending on the application and the concrete process phase 2 step 2 tests might be necessary.

Features & benefits

High gel strength
and extremely shear
thinning formulations

Soft, non-sticky
texture and dry
feel

Compatible with and
stabilizes gels in the
required pH range

Direct addition to
oxidant solution
possible

No restriction on the
biocidal activity

Acknowledgements & References

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- Technical support: **Neil Grant** (BYK Additives Widnes)



[1] Myeloperoxidase: a key regulator of neutrophil oxidant production, A.J. Kettle, C.C. Winterbourn, Redox Report (1997) 3(1), 3-15

[2] Biology Stack Exchange. How does hypochlorous acid inactivate viruses? Available at: https://www.echemi.com/community/how-does-hypochlorous-acid-inactivate-viruses_mjart2205202619_500.html. Accessed 14.09.2022.

[3] AFM measurements have been performed with a Bruker Icon-PT instrument, ScanAsyst-Air probe under Peak Force Tapping© mode

[4] Cryo-TEM measurements: sample was imaged on a JEOL 2200FS TEM with a Gatan K2 direct electron detector at the University of Warwick.

Thank you for your
attention.

If you have any further questions, feel free to reach out:

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