UNIVERSITÄT HOHENHEIM

Konversions Technologien

Circular Economy Approach to Construction:

Investigating Hydrochar as a Pore-forming Agent in Fired Clay Bricks

9th June 2026, natalia.toriello@uni-hohenheim.de

Supervisors:
Prof. Dr. Andrea Kruse
Dr. Gero Becker

Agenda

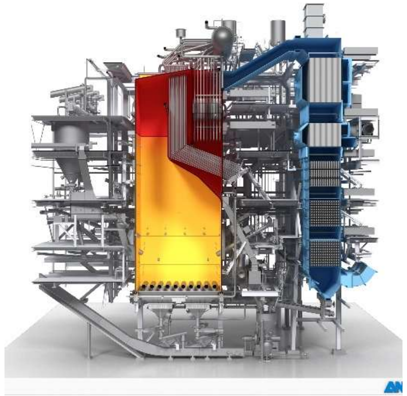
1. Introduction
2. Research questions
3. Methodology
4. Results
5. Conclusions
6. Outlook

1. Introduction

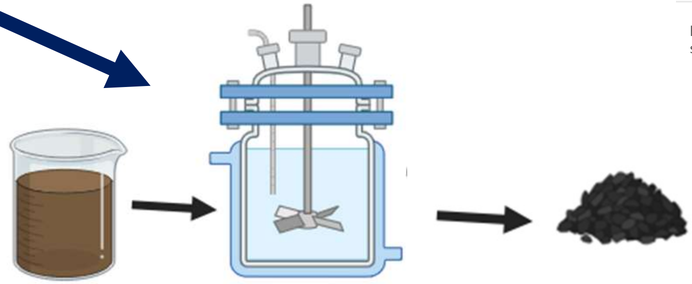
Sewage Sludge Ordinance

Mandatory phosphorus (P) recovery starting 2029 in wastewater treatment plants (WWTP)

https://chemtrust.org/sewage-sludge-mcs/



https://www.andritz.com/products-en/careers-de/environmental-solutions/sewage-sludge-mono-incineration



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Hydrothermal carbonization (HTC) can process feedstock with high moisture content yielding a solid with high P concentration: hydrochar

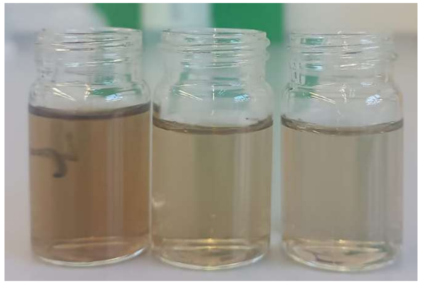
1. Introduction

Implementing phosphorus recovery with circularity

End result

Hydrochar

Recovery



Leachate → rich in P

https://plantsforallseasons.com/how-to-fertilize-trees-shrubs/.

Leached "spent" hydrochar

1. Energy utilization
2. Agriculture
3. Construction?

1. Introduction

Leached hydrochar in fired-clay bricks

Clay Powder

+

Pore -former

Conventional:

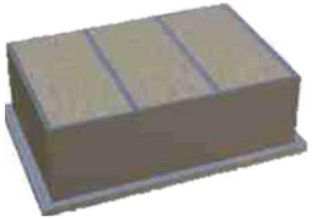
- Coal
- Styrofoam
- Paper Pulp
- Sawdust

+

Water

Mixing and Molding

Wet green brick



Source: Wu, Hu et al 2022 - Recycling of sewage sludge.jpg

Drying

Dry green brick

Source: Adazabra, Viruthagiri 2023 - Effect of variegated biosolids incorporation.jpg

Firing

Fired brick

1.Introduction

State of the Art

Conventional pore-formers in the industry:

- Coal
- Styrofoam
- Paper Pulp
- Sawdust

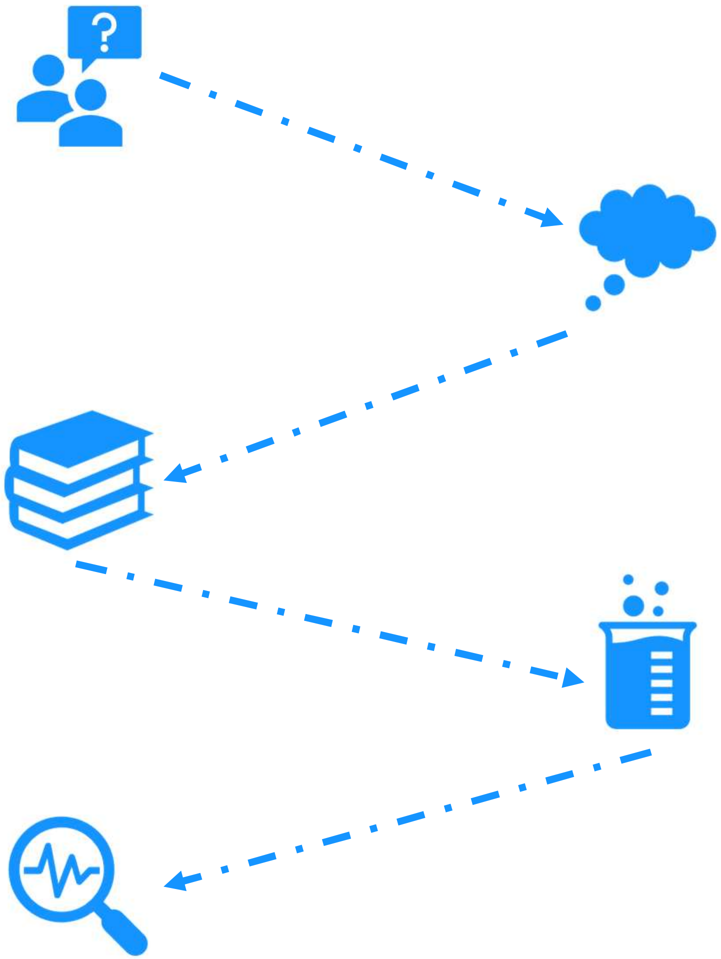
Current research focused on valorizing waste as a replacement for pore-formers:

- Agricultural byproducts: sawdust, rice husk, wheat straw
- Industrial byproducts: ashes, sludge, slag
- Others: polystyrene beads, marble powder, waste glass

There is a notable research gap concerning the use of hydrochar as a potential as a pore-former.

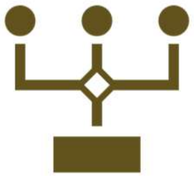
2. Research Questions

Can leached hydrochar be used as a pore-former?



- How does the phosphorus recovery process alter hydrochar's composition and its potential to be recycled?

3. Methodology*



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Screening Process

- Different sludges
- Different temperatures

→

Hydrochar Selection

- Optimal temperature and sludge selected

→

Leaching experiments

- Oxalic acid

→

Analytics

- Thermogravimetric analysis (TGA)
- Proxymate analysis
- Element content

4. Results

Screening Process and Hydrochar Selection

https://www.encyclopedie-environnement.org/en/soil/sewage-sludge-boon-agricultural-land/

Pore-former quality vs phosphorus recovery efficiency

High

Phosphorus concentration	Heavy metal content
Fixed Carbon	Ash content
Volatile matter	

Low

- Optimal balance achieved at 200°C

4. Results

Feedstock characteristics

https://www.encyclopedie-environnement.org/en/soil/sewage-sludge-boon-agricultural-land/

Table 2. Sewage Sludge Proximate analysis (n=2)

	Volatile matter [%]	Fixed Carbon [%]	Ash [%]
Ochsenfurt	48.4	3.6	48.1
Plieningen	56.8	6.1	37.2
Uni Stuttgart	60.0	7.4	32.6

Table 3. Sewage Sludge composition (n=1, dry basis)

	P [mg/g]	Al [mg/g]	Ca [mg/g]	Fe [mg/g]	Cr [mg/g]	Cu [mg/g]	Zn [mg/g]
Ochsenfurt	32	12	43	60	0.04	0.32	0.95
Plieningen	34	36	33	24	0.04	0.45	1.05
Uni Stuttgart	37	44	29	17	0.02	0.40	0.65

4. Results

Hydrochar Production and Material Selection

1 L Parr reactor
4 hours residence time
10% DM

Table 4. Hydrochar from Uni Stuttgart Proximate analysis (n=2)

	Volatile matter [%]	Fixed Carbon [%]	Ash [%]
180°C	48	8.0%	44
200°C	46	7.7%	47
220°C	43	8.6%	48
240°C	42	9.2%	49

- Similar trends noted in all other hydrochars

Table 5. Hydrochar from Uni Stuttgart composition (n=2, dry basis)

	P [mg/g]	Al [mg/g]	Ca [mg/g]	Fe [mg/g]	Cr [mg/g]	Cu [mg/g]	Zn [mg/g]
180°C	58	68	44	26	0.039	0.55	1.34
200°C	61	70	46	28	0.047	0.57	1.40
220°C	61	71	48	29	0.041	0.58	1.41
240°C	64	74	49	90	0.056	0.60	1.46

4. Results

Leaching Experiments

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Experimental conditions:

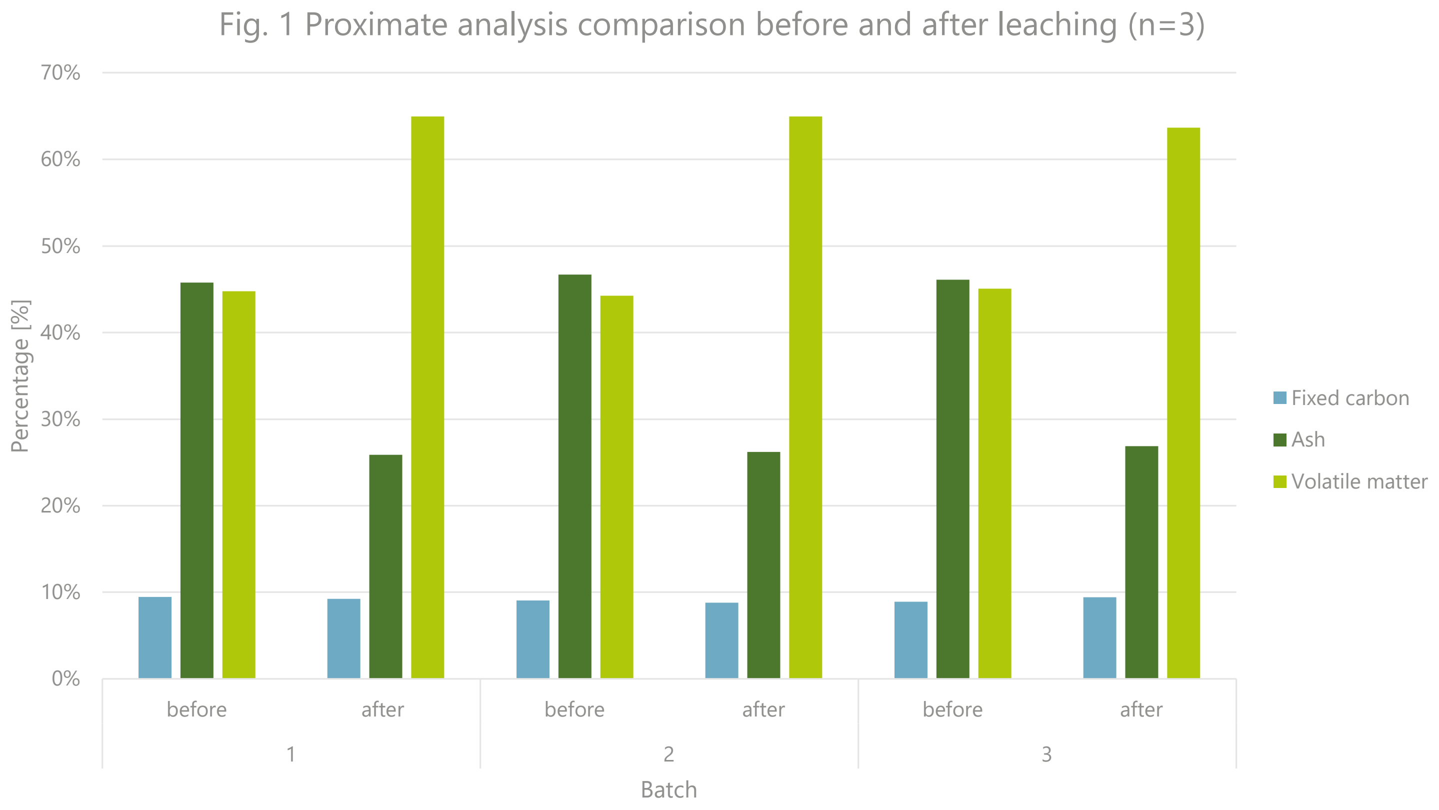
- 15 minutes
- 1:10 solid to liquid ratio
- Oxalic acid 1 M

Table 1. Leaching performance of elements (n=3, dry basis)

Batch	P [%]	Al [%]	Fe [%]	Cr [%]	Ni [%]	Zn [%]
1	79 ± 1.7	72 ± 0.4	54 ± 8.5	13 ± 1.2	10 ± 0.3	13 ± 2.1
2	77 ± 2.5	71 ± 0.6	51 ± 13	8.9 ± 1.9	9.7 ± 1.6	11 ± 4.5
3	74 ± 0.8	67 ± 1.2	57 ± 4.1	14 ± 3.0	7.5 ± 3.7	14 ± 1.2
Average of averages	77 ± 2.6	70 ± 2.4	54 ± 8.3	12 ± 3.0	9.1 ± 2.4	13 ± 2.8

4. Results

Leaching effect on hydrochar's properties

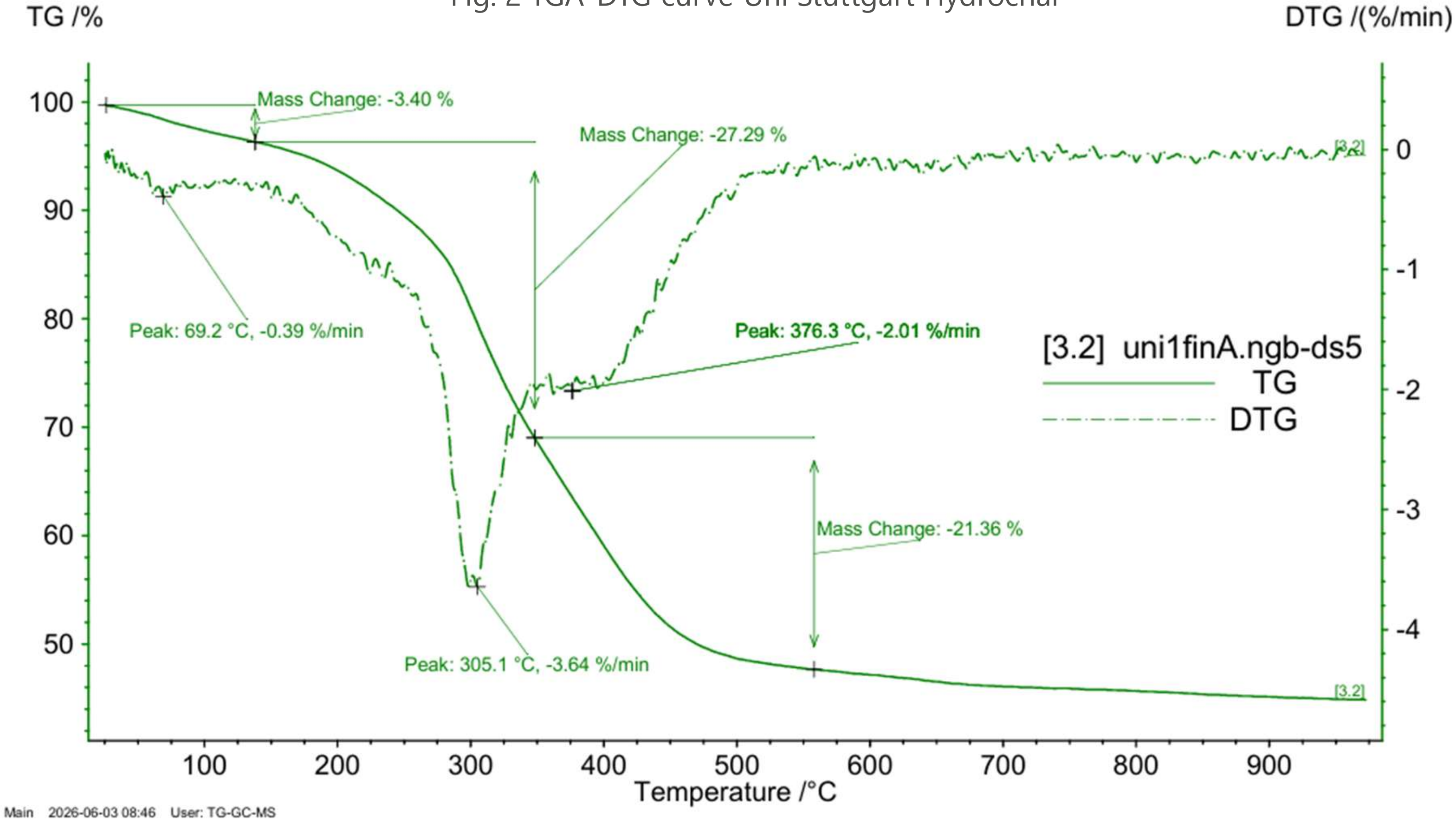


4. Results

Simulating what happens inside the firing brick furnace

- Thermogravimetric analysis (TG): It tracks the weight loss of a sample as temperature increases
- Derivative Thermogravimetric analysis (DTG): tracks the speed of the weight loss.

Fig. 2 TGA-DTG curve Uni Stuttgart Hydrochar



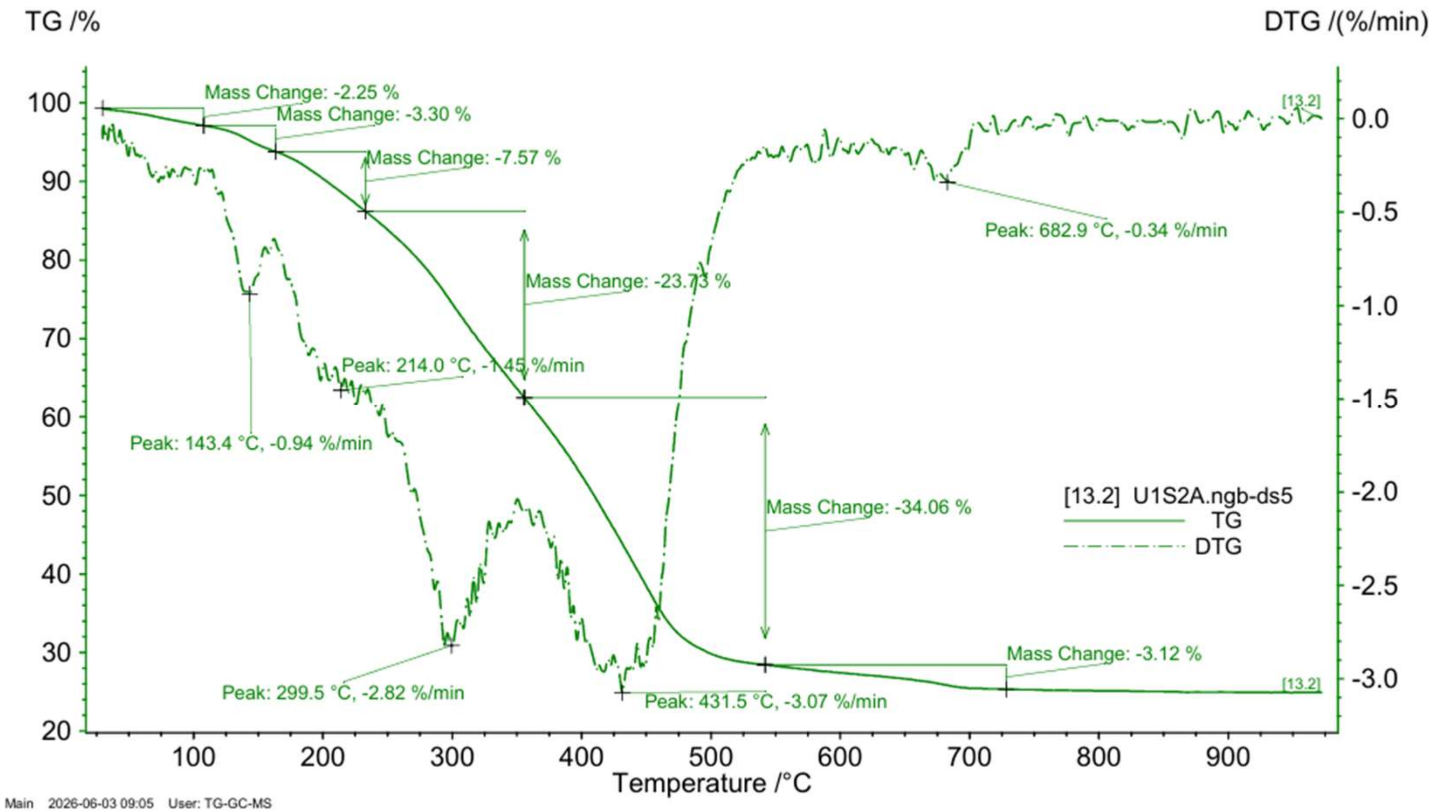
4. Results

Leaching effect on hydrochar's properties

Many mass change steps → desirable for pore development

- ~120-214 °C: Residual oxalic acid
- ~300-430 °C: Biggest mass loss steps → Probale devolatilization/combustion and char burnout
- ~650-700°C: Probable $CaCO_3$ decomposition

Fig. 3 TGA-DTG curve Uni Stuttgart Leached Hydrochar

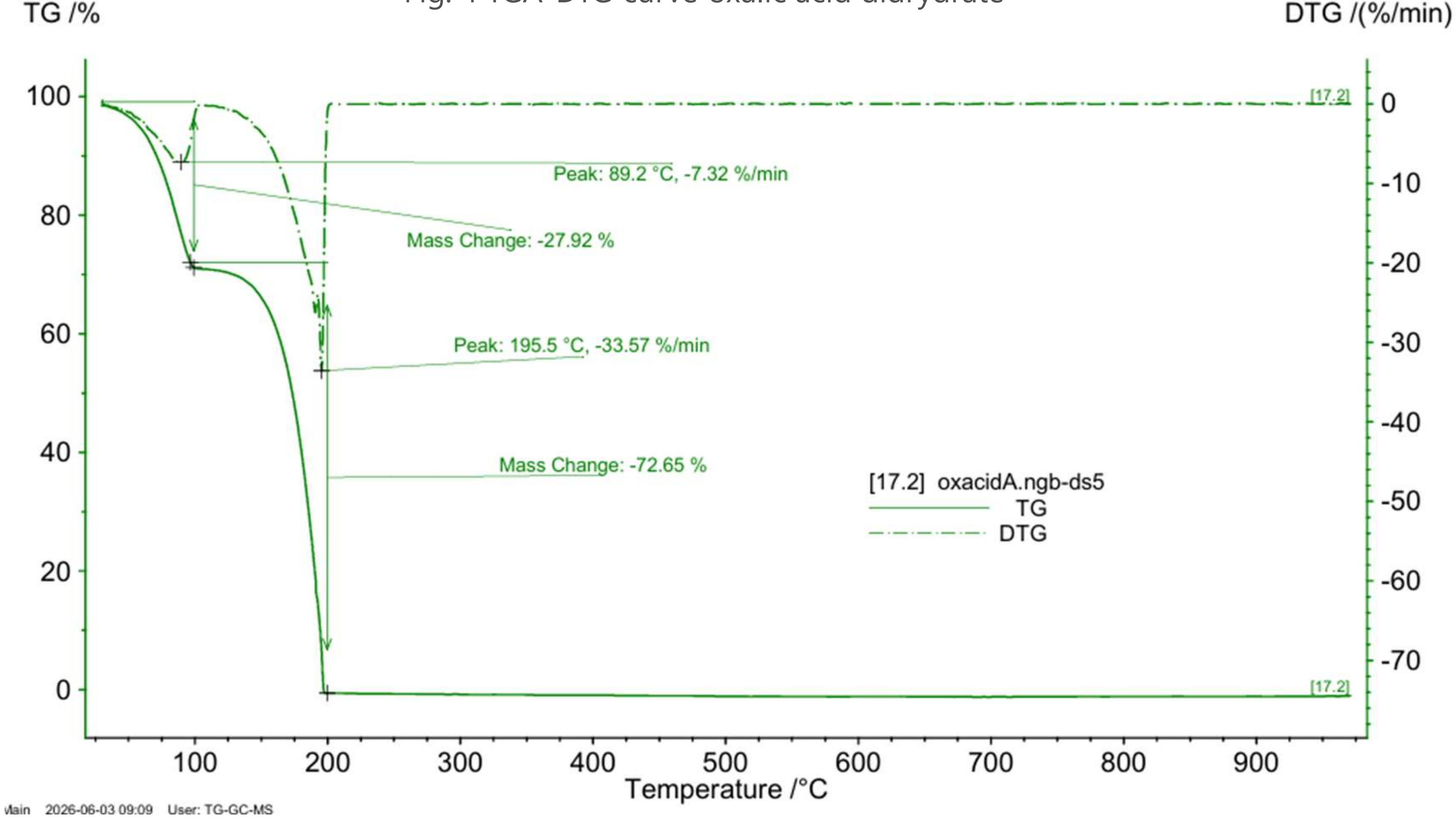


4. Results

Leaching effect on hydrochar's properties

Carrier gas: Synthetic air 20 ml/min
10 K/min heating rate
Temperature range: 25°C-100°C

Fig. 4 TGA-DTG curve oxalic acid didrydrate



5. Conclusions

Acid leaching induces positive changes in hydrochar properties:

- It reduces ash content while rises volatile matter content, while fixed carbon stays the same

- Additional mass loss steps were observed after which are desirable characteristics

- Leached hydrochar has potential as a pore former

5. Outlook

Incorporating leached hydrochar in clay mixture and evaluate its performance

- What properties does the mixture clay-hydrochar has?
- Brick's performance: compressive strength, thermal conductivity, water absorption

Environmental impact of hydrochar use in fired clay bricks

- Hydrochar's high heating value: Potential energy savings during the firing process?
- Contaminants: Heavy metal leaching assessment and speciation

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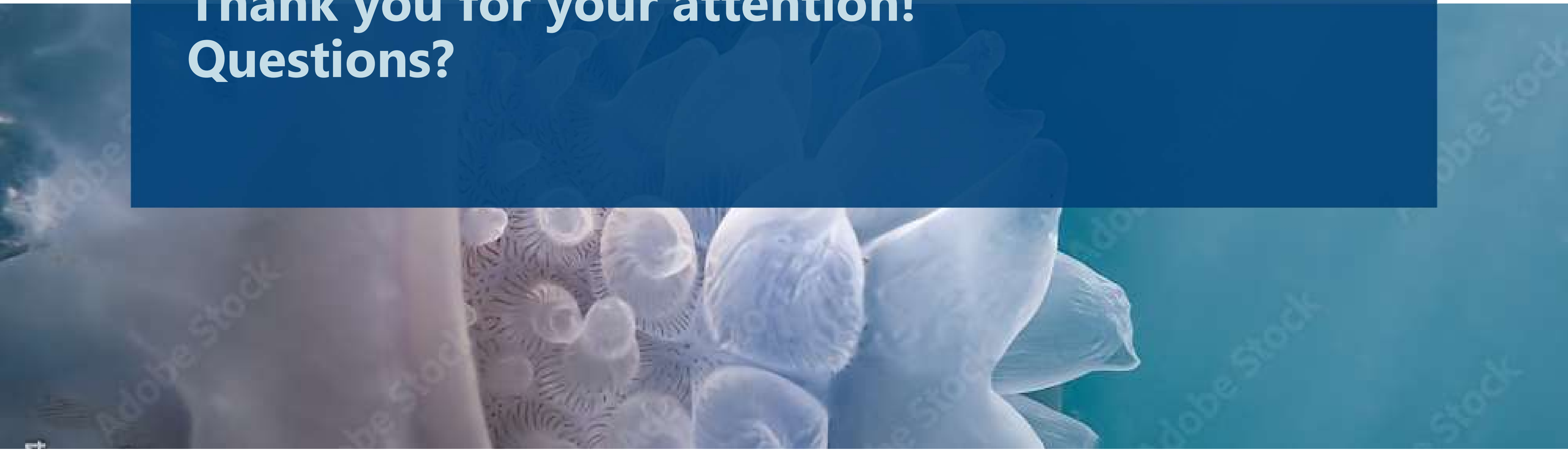
Thank you for your attention! Questions?



RESI2PORES

Goal → Treatment of sewage sludge via HTC with integrated phosphorus recovery to produce biogenic pore-formers for the brick industry

Sponsored by Bundesministerium für Forschung, Technologie und Raumfahrt

ZIZ Ziegel-Innovations-Zentrum GmbH
Landsberger Str. 392
81241 München

Renergie Systeme GmbH & Co.KG
Hoher Markstein 26
97631 Bad Königshofen

Universität Hohenheim
Schloss Hohenheim 1
70599 Stuttgart

Ziegelwerk Bellenberg Wiest GmbH & Co. KG
Tiefenbacher Str. 1
89287 Bellenberg

Our Research Group

Dept. of Conversion Technologies of Biobased Resources:
Phone: +49 (0)711 459 24701
Email: bioraffinerie@uni-hohenheim.de
https://konversionstechnologie.uni-hohenheim.de/en

Director
Prof. Dr. Andrea Kruse
Phone: +49 (0)711 459 24700
Email: andrea_kruse@uni-hohenheim.de

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