8th EURASIA WASTE MANAGEMENT SYMPOSIUM

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# Valorization of Sewage Sludge Gasification Biochar for the Adsorptive Removal of Acid Blue 25 from Aqueous Solutions

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AdSorB

HrZZ
Croatian Science Foundation

# Sewage sludge: the costly by-product of clean water

**≈50%**

of operating costs at a typical medium-sized WWTP go to sludge handling and disposal



## Incineration

the familiar option, with emissions to air

## Pyrolysis

thermal decomposition without oxygen

## Gasification

lower emissions, energy-rich syngas and a solid residue: biochar

# Gasification: waste in, energy and biochar out

**Dried sludge**

over 90% solids, Karlovac WWTP

↓

**LOOPER reactor**

850–900 °C, no combustion;
superheater above 1000 °C

↓

**Syngas**

hydrogen-rich

**Biochar**

porous,
about half carbon




LOOPER pilot system, INDELOOP d.o.o., https://indeloop.hr/

# Project AdSorB: one by-product, two lives

Advanced Wastewater Treatment by Repurposing Sewage Sludge Derived Biochar

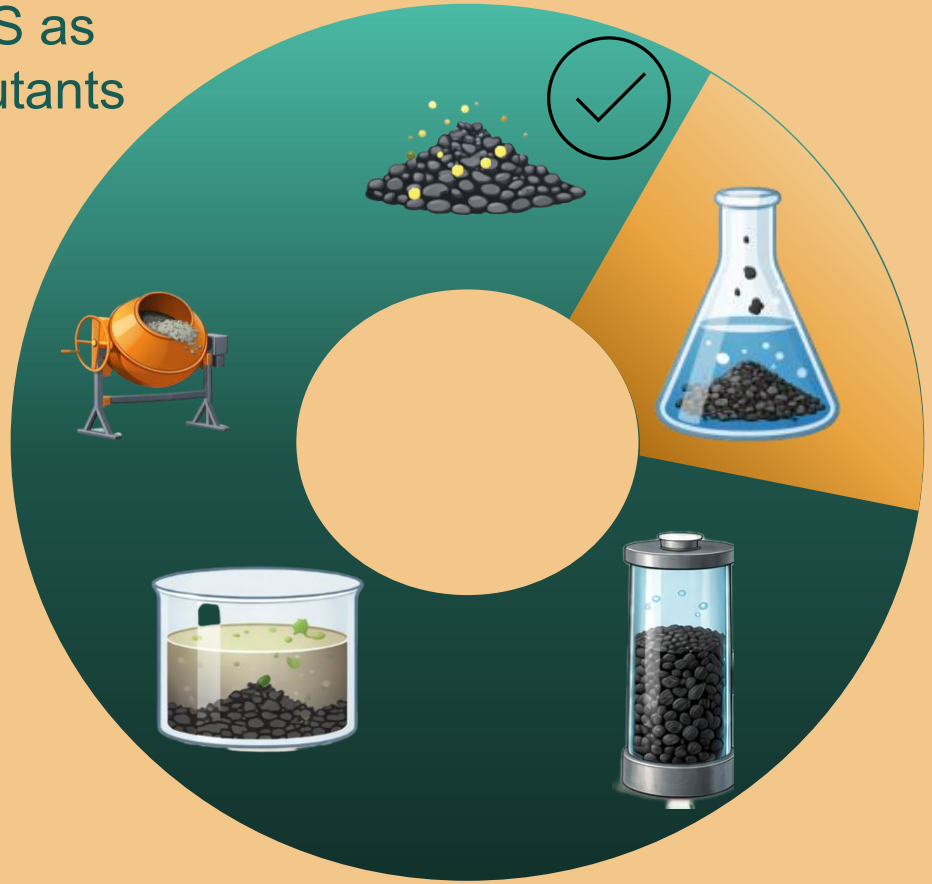


## 1 Biochar production and characterization

Derivation of biochar through the gasification of sewage sludge collected from local wastewater treatment plants, followed by its characterization.

# Project AdSorB: one waste, two lives

The project explores the use of biochar produced from SS as a low-cost and efficient adsorbent for various (micro)pollutants from wastewater



## 2 Batch adsorption: synthetic, then real wastewater

Investigation of the efficiency of removing various pollutants (nutrients, heavy metals, pharmaceuticals, pesticides) from synthetic and real wastewater in batch tests using the obtained biochar as an adsorbent, with optimization of process parameters.

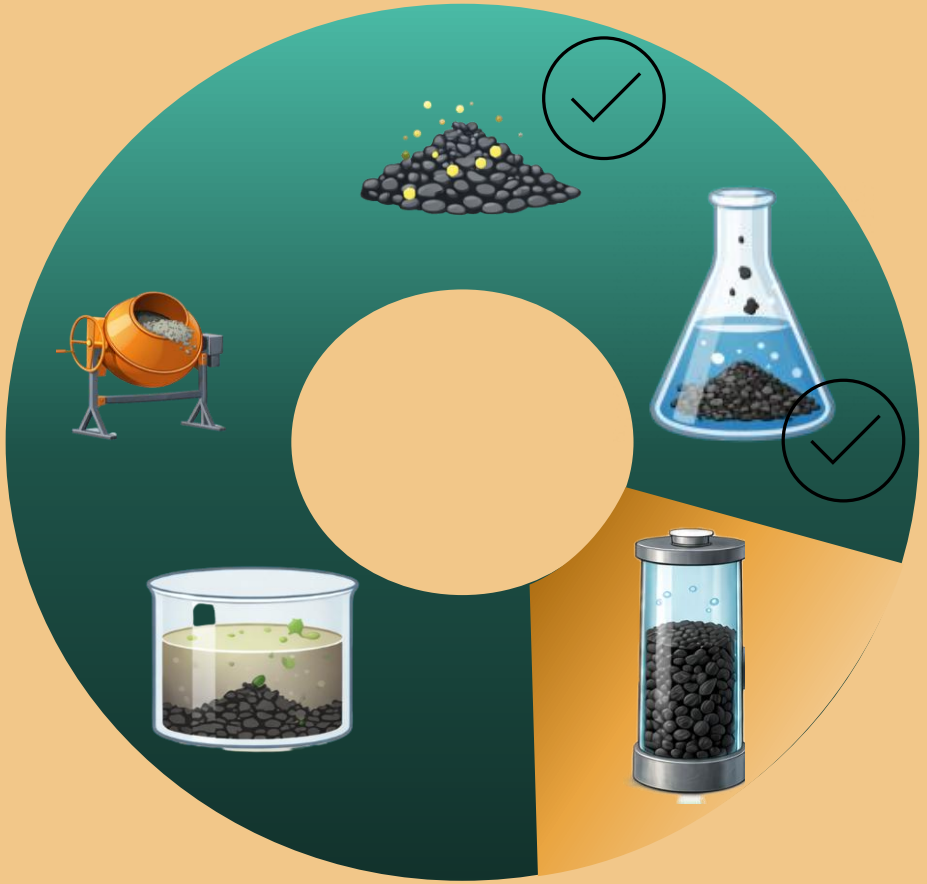
# Project AdSorB: one waste, two lives

Five stages, one life cycle.

3

## Continuous-flow column filter and modelling

Development of a flow-through column filter filled with biochar and evaluation of its efficiency in removing various pollutants from synthetic and real wastewater, with process parameter optimization and process modeling.



# Project AdSorB: one waste, two lives

Pollutants captured and immobilized.



4 **Environmental safety: leaching, secondary pollution**

Evaluation of the potential secondary wastewater pollution arising from pollutant leaching from biochar during its use as an adsorbent.

# Project AdSorB: one waste, two lives

First life: adsorbent. Second life: construction material. The waste of one process becomes the raw material of the next.

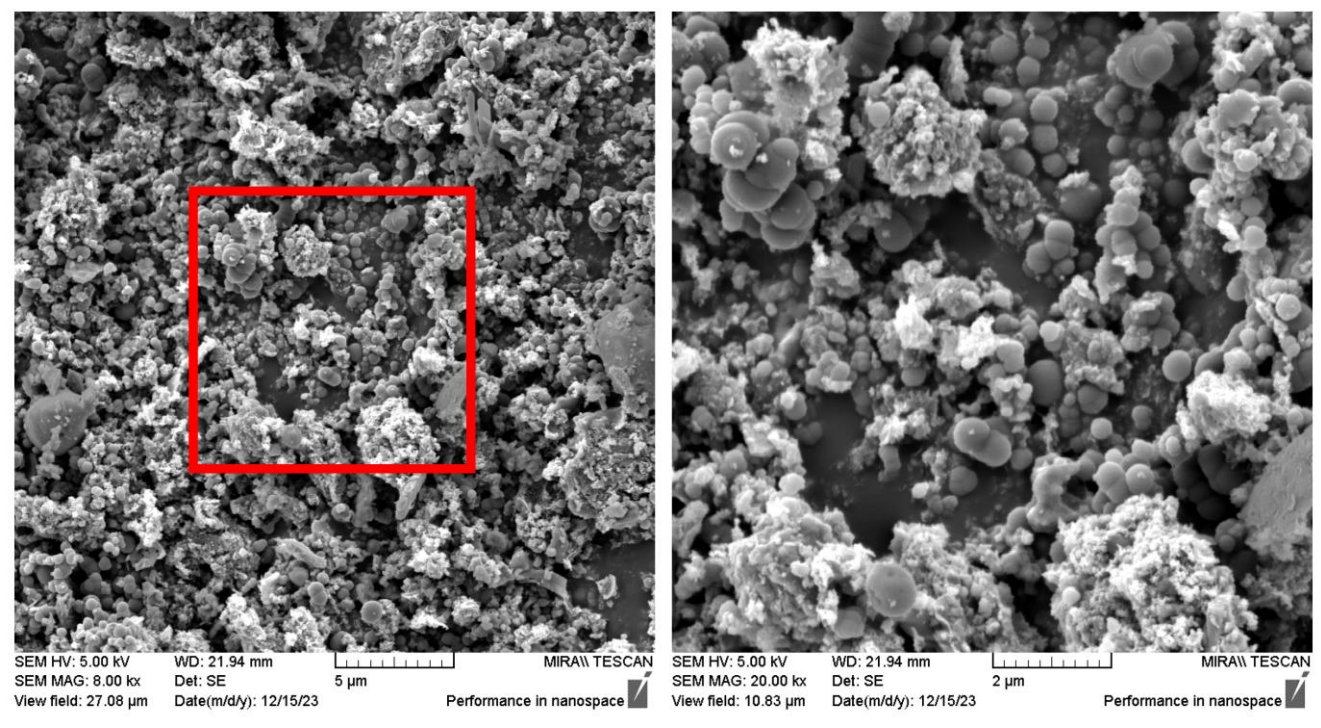
## 5 Spent biochar in cement composites

Investigation of the technical and environmental properties of cement composites incorporating biochar, previously used for pollutant adsorption from wastewater, as a partial replacement for raw materials.



# From sludge to biochar

- Karlovac WWTP sludge, dried to over 90% solids
- Used unmodified: no activation, no functionalization
- Porous, heterogeneous particles (SEM)
- Metals largely retained in minerals (EN 12457-2)




**10.5**
$pH_{pzc}$
positive surface

**10.6%**
$Fe_2O_3$

**15.6%**
$Al_2O_3$

**14.7%**
CaO

# One biochar, many pollutants

| 97.8% | >99% | 37–58% | 54% | 100% |
|---|---|---|---|---|
| **Phosphate** | **Cd, Cr, Cu** | **Pharmaceuticals** | **Acetamiprid** | **Dye AB25** |
| ammonium 26.5% | Pb 95% | NSAIDs | pesticide, variable | this talk |



Pristine, unmodified biochar.
Batch tests with synthetic wastewater.



# Acid Blue 25 – anionic model dye

**15-run Box–Behnken design**
**200 mL batches, 45 rpm**




**10, 20, 30** mg/L initial AB25

**0.5, 1.5, 2.5** g/L biochar dose

**2, 5, 8** hours of contact

Unmodified biochar.
Controlled aqueous solutions.
Concentration measured by UV–Vis.

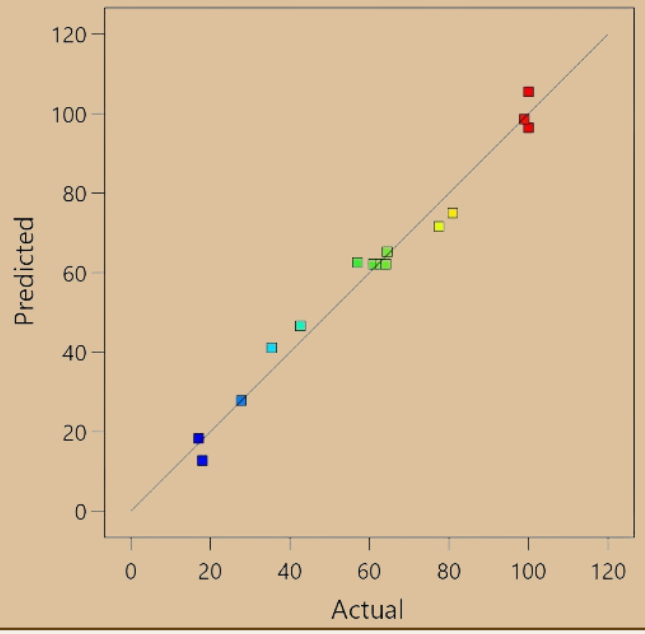
# Dye removal: what controls it

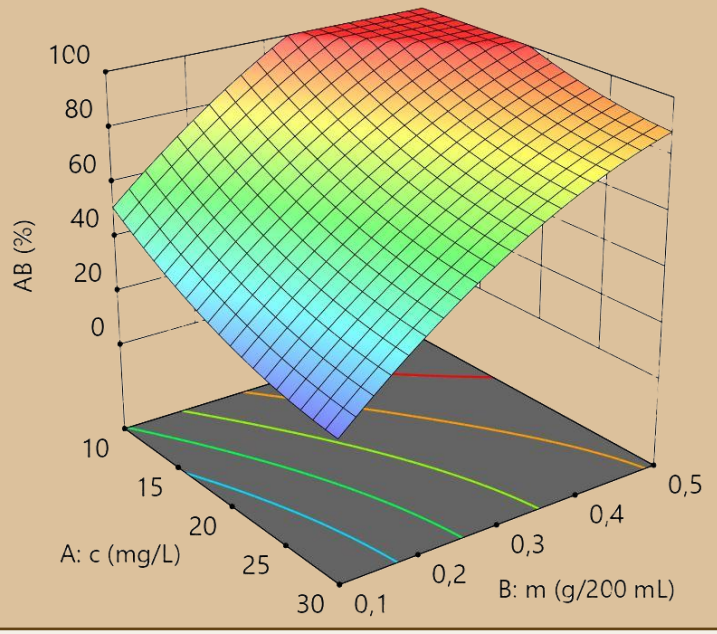
**17–100%**
AB25 removal across 15 runs

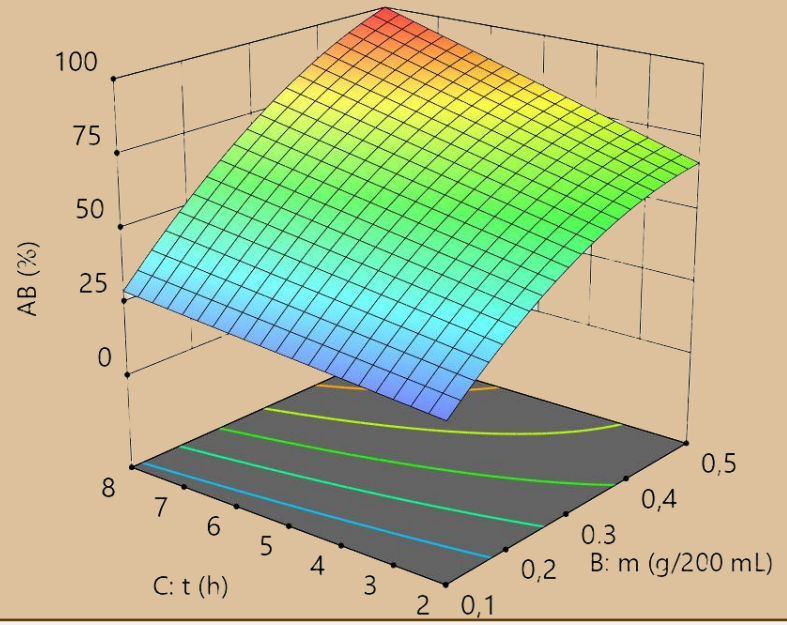
**100%**
10 mg/L AB25; with 0.5 g biochar after 5 h

**12.22 mg/g**
max capacity within the design (4.00 - 12.22 mg/g)

**Biochar dosage** is the strongest factor, then **initial concentration**, then **contact time**. The model explains 97.9% of the variability.

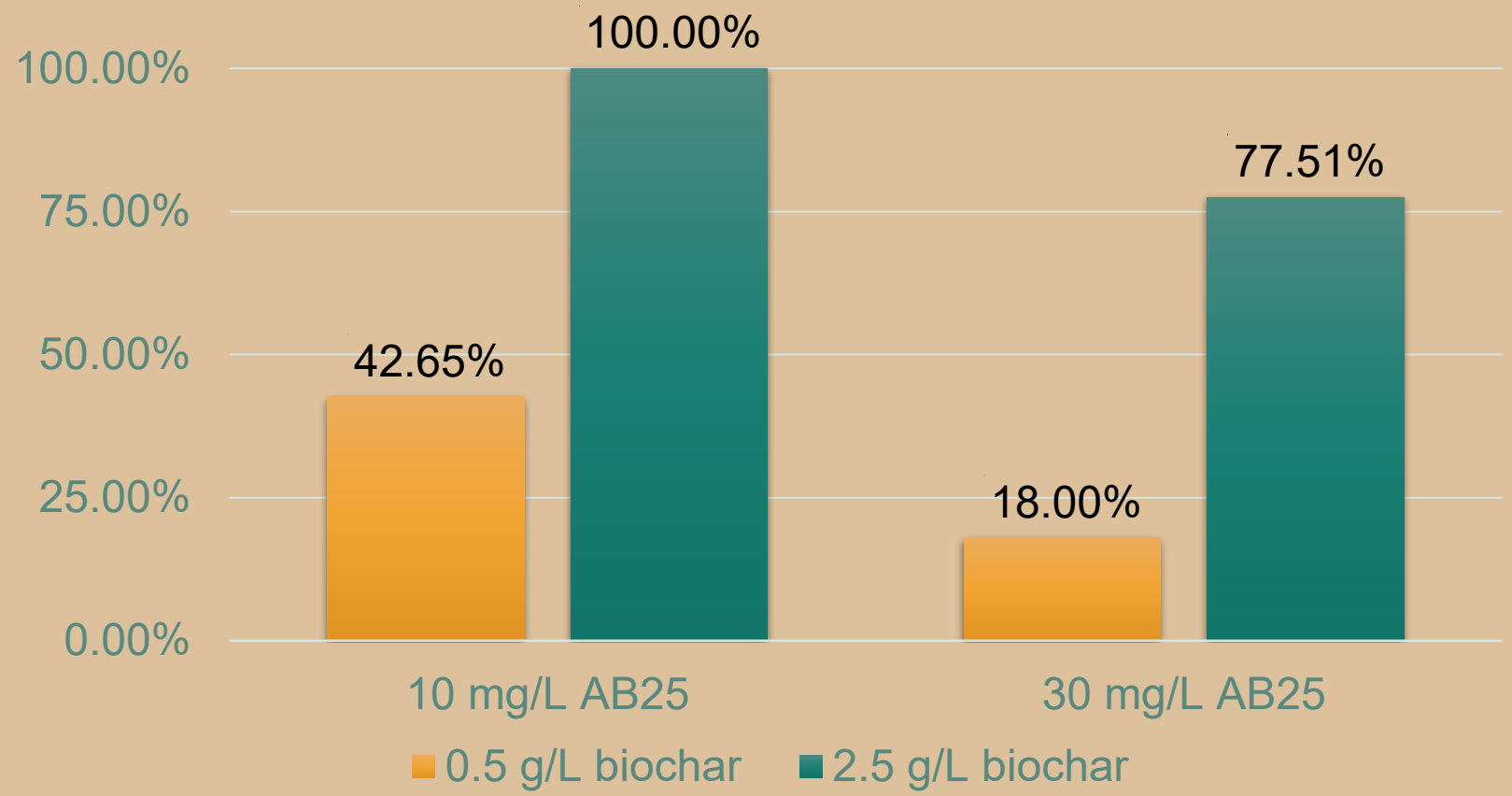


# More biochar increased dye removal

## 4x higher removal for 5× more biochar




Runs 1, 8, 11 and 12.

Same contact time for all four runs.

**5 h**

# How fast, and how much

Equilibrium after about 2 h, pseudo-second-order fit ($R^2$ 0.998), Freundlich-type uptake on a heterogeneous surface.




| Contact time | AB25 removed |
|---|---|
| 15 min | 51.5% |
| 30 min | 67.0% |
| 60 min | 89.9% |
| 120 min | 100% |

**41.8 mg/g**

highest capacity in isotherm tests (up to 150 mg/L)

# Closing the loop

## Shown

- ✓ Unmodified biochar removes AB25 effectively.
- ✓ Lower capacity, but zero activation chemicals, energy or washing.
- ✓ Biochar can be dosed generously for pre-treatment or polishing.
- ✓ Equilibrium in about 2 h, up to 41.8 mg/g

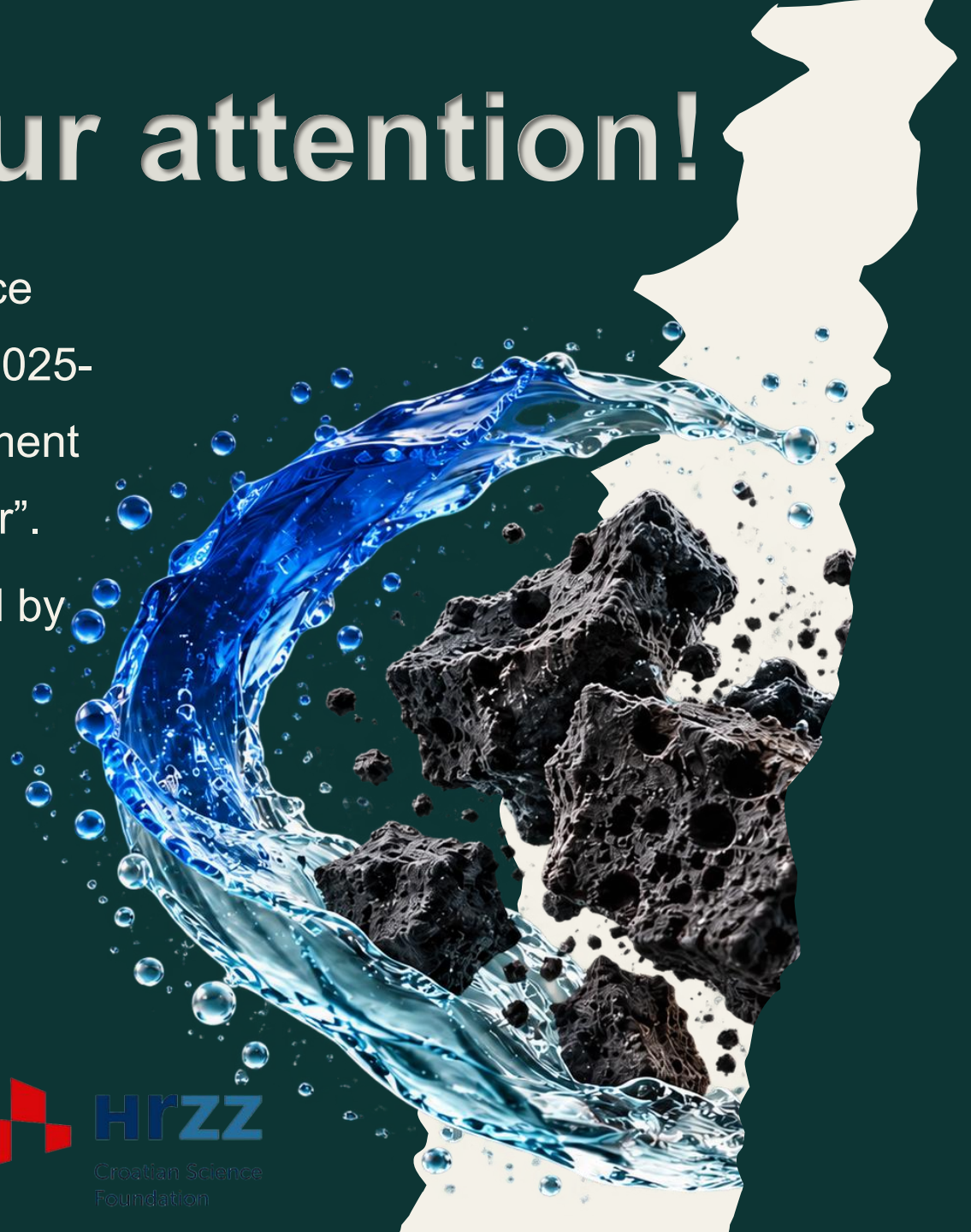
## Still open

- ○ Real dye-containing wastewater
- ○ Regeneration and reuse
- ○ Leaching after adsorption
- ○ Spent biochar in cement-based materials

# Thank you for your attention!

This work was supported by the Croatian Science Foundation under the project number [HRZZ-UIP-2025-02-9907]: AdSorb – “Advanced Wastewater Treatment by Repurposing Sewage Sludge Derived Biochar”.

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