ADVANCED WASTEWATER TREATMENT USING SEWAGE SLUDGE–DERIVED BIOCHAR AS A CIRCULAR ADSORBENT MATERIAL

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Introduction

- Sewage sludge treatment and disposal have become one of the most important and most expensive issues within WWT cycle

- Thermal transformation treatment (gasification, pyrolysis and hydrothermal carbonization) can convert sewage sludge from a problematic waste material into a valuable raw material

- Gasification - the process of converting biomass to gas fuel using gasification agents (temperature generally higher than 800°C), without combustion

Source: https://indeloop.hr

Project AdSorb

- Advanced Wastewater Treatment by Repurposing Sewage Sludge Derived Biochar

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

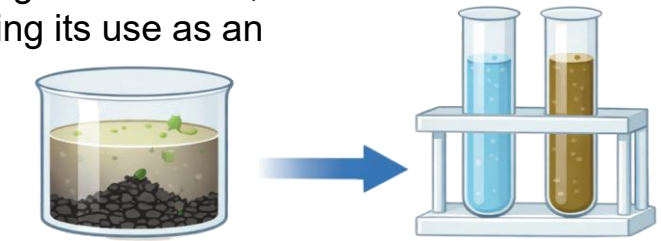
Research objectives

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

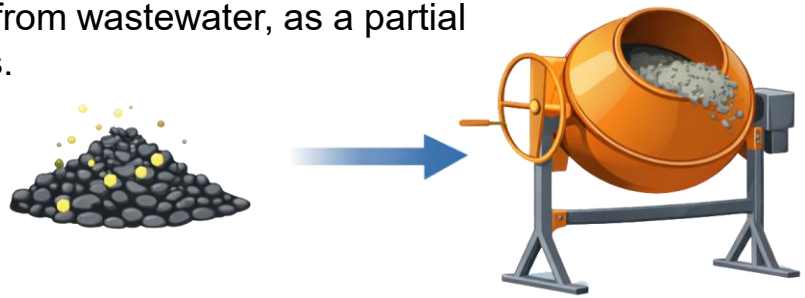
2. Investigation of the efficiency of removing various pollutants (nutrients, heavy metals, pharmaceuticals, pesticides) from synthetic and real wastewater in batch tests using the obtained biochar as an adsorbent, with optimization of process parameters.

3. 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.

4. Evaluation of the potential for secondary wastewater pollution arising from pollutant leaching from biochar, produced via sludge gasification, during its use as an adsorbent.

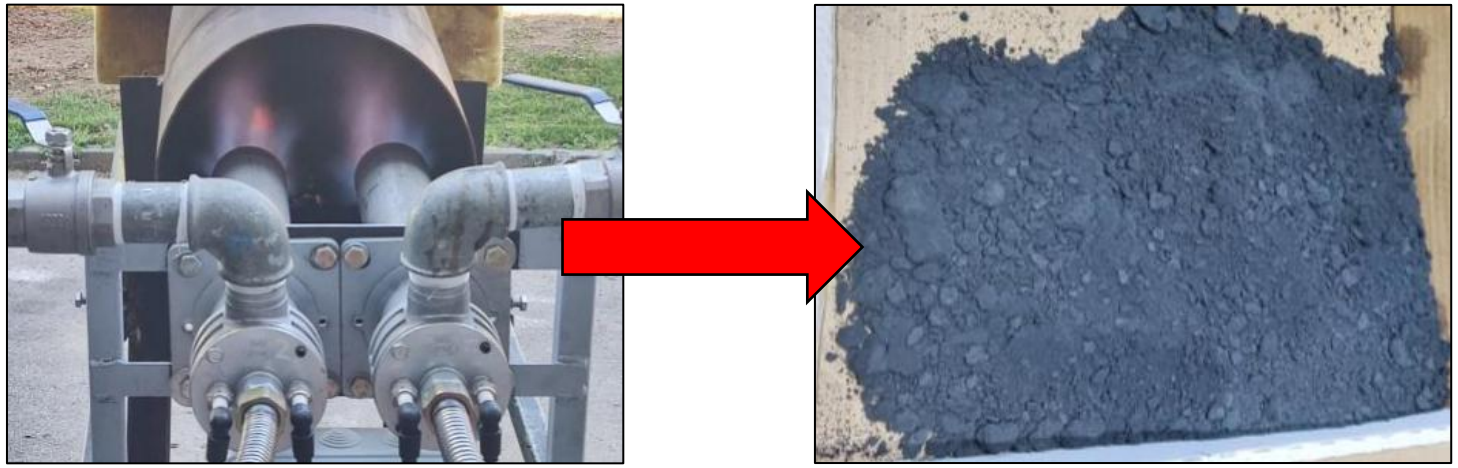


5. Investigation of the technical and environmental properties of cement composites incorporating biochar, previously used for pollutant adsorption from wastewater, as a partial replacement for raw materials.



Materials and Methods

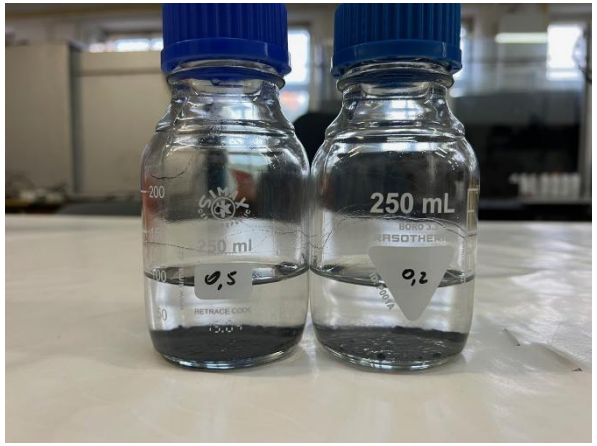
- Biochar was produced by sewage sludge gasification using the LOPPER system



- Preliminary characterization of the biochar was performed: chemical composition, heavy metal content, leaching behavior, and surface morphology and microstructure using scanning electron microscopy (SEM)

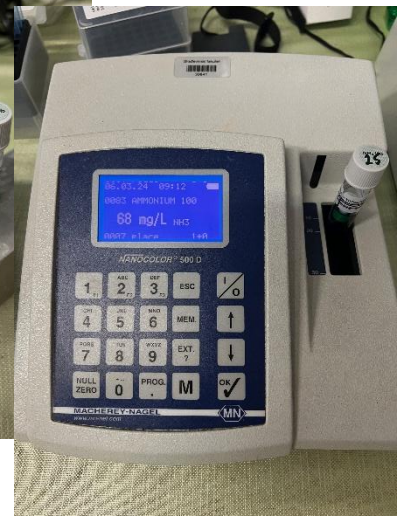
Materials and Methods

- Batch adsorption experiments were conducted by dissolving appropriate amounts of the selected pollutants in distilled water and varying:
  - the initial pollutant concentration,
  - biochar dosage,
  - solution pH, and
  - contact time



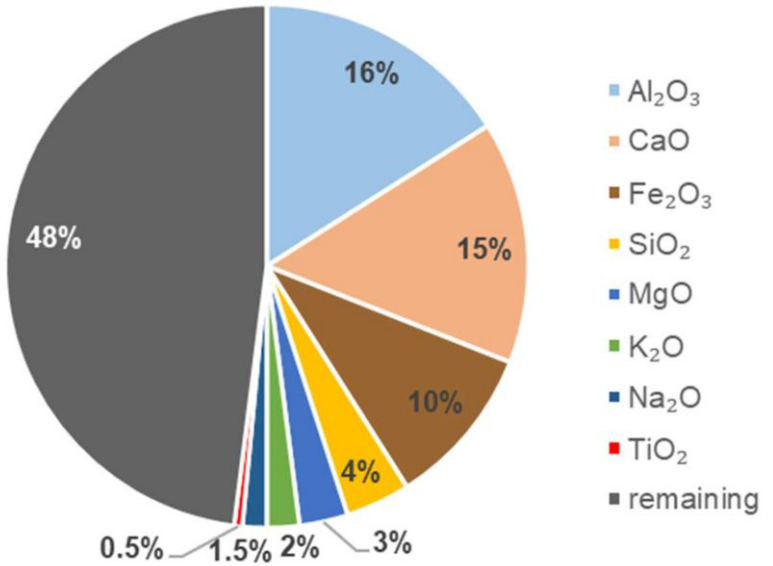
Materials and Methods

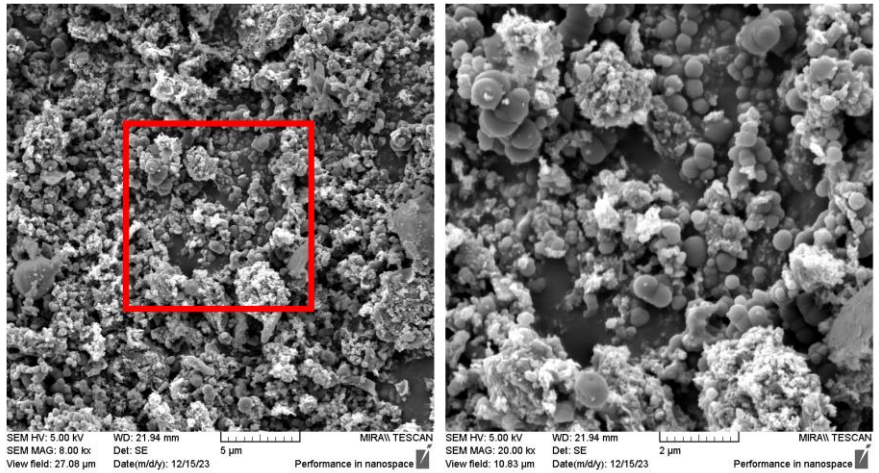
- Depending on the type of pollutant investigated, the initial and final concentrations in the solution were determined using the appropriate analytical method:
  - inductively coupled plasma optical emission spectrometry (ICP-OES),
  - high-performance liquid chromatography (HPLC),
  - UV–Vis spectrophotometry, or
  - the corresponding cuvette test followed by spectrophotometric determination



Results – biochar characteristics

- Nearly half (50%) of the sample remained undissolved, which was attributed to carbon (char)
- SEM revealed a rough, highly porous surface with numerous cavities and channels, providing a large surface area and abundant active adsorption sites
- Low levels of hazardous metals, with leachate concentrations notably low or below detection limits, indicate that heavy metals are stably bound in SS-derived biochar, significantly reducing the risk of environmental contamination

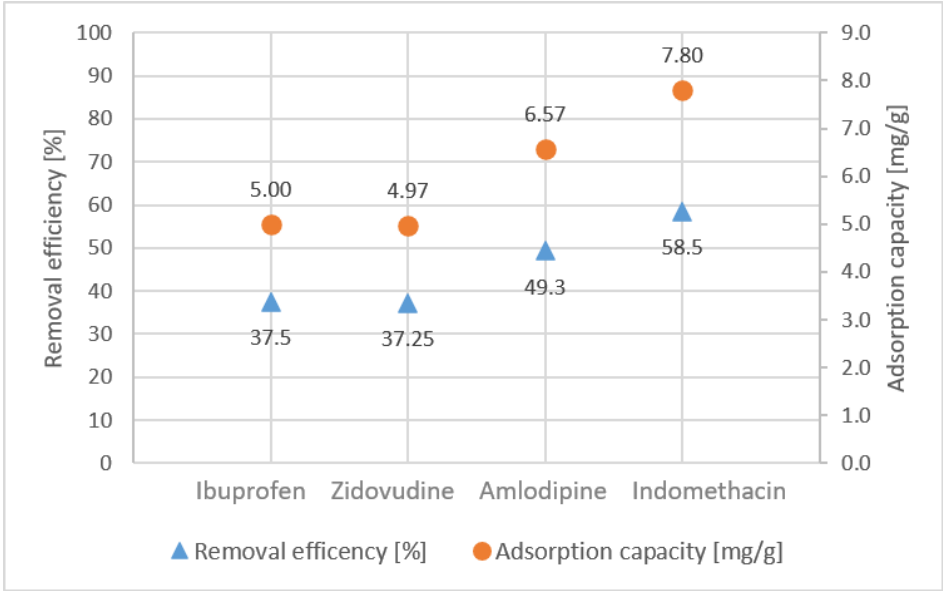


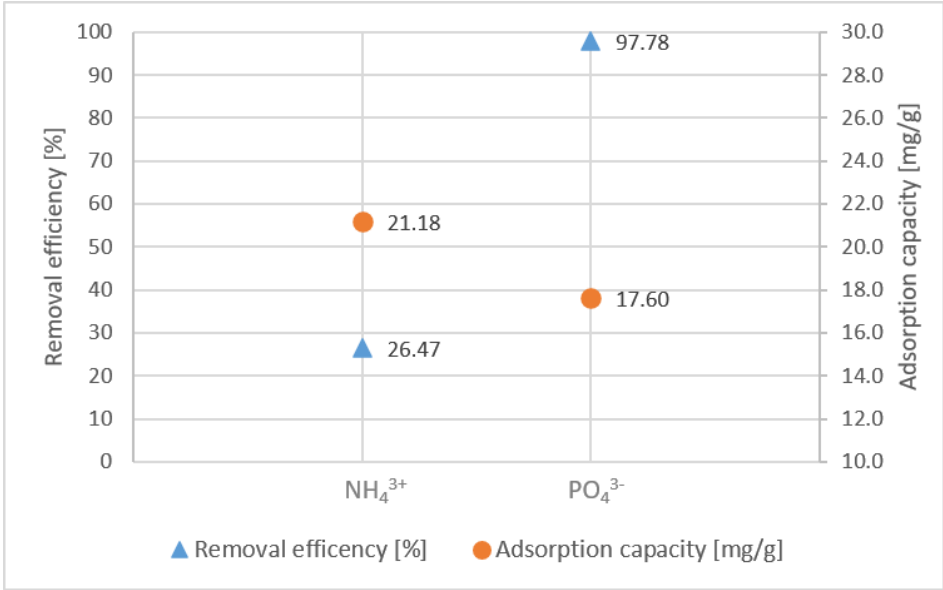


Results – batch adsorption experiments

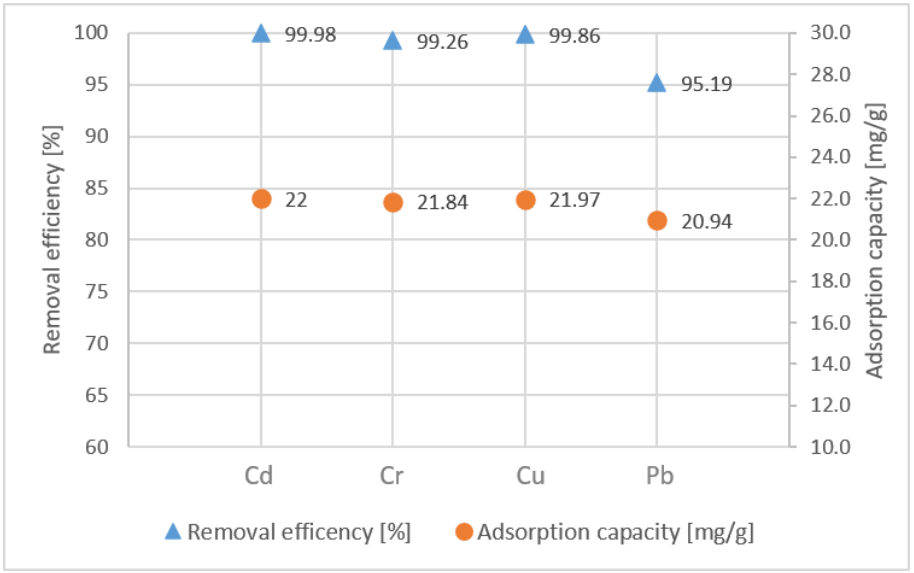
- <u>Adsorption of Pharmaceuticals</u>
  - Removal efficiency: 37.25% (zidovudine) → 58.50% (indomethacin)
  - Adsorption capacity: 4.97 mg/g (zidovudine) → 7.80 mg/g (indomethacin)

- <u>Adsorption of Nutrients (PO_4^{3-} and NH_4^+)</u>
  - Phosphate: 97.78% removal; 17.60 mg/g adsorption capacity
    - Very high removal → strong biochar affinity
  - Ammonium: 26.47% removal; 21.18 mg/g adsorption capacity
    - Lower removal despite slightly higher adsorption capacity
  - Removal efficiency and adsorption capacity do not necessarily correlate directly
  - Differences in adsorption capacity partly reflect the experimental setup



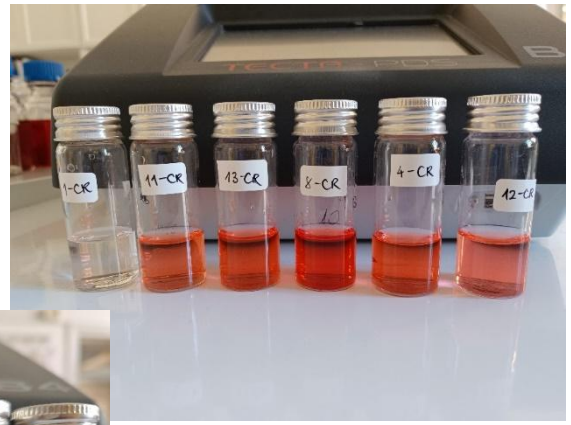


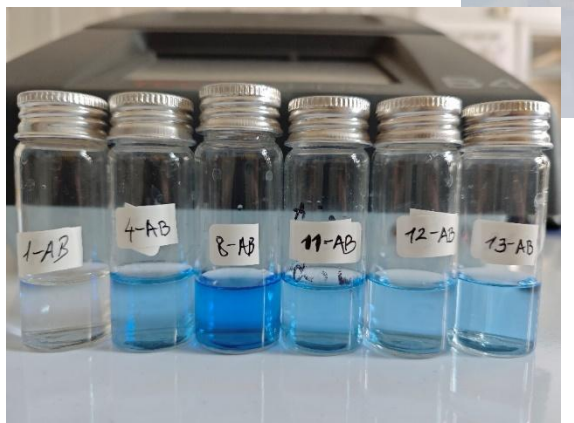
Results – batch adsorption experiments



- <u>Adsorption of Heavy Metals</u>
  - Cd, Cr & Cu: >99% removal; adsorption capacity ≈22.00 mg/g
  - Pb: 95.19% removal | adsorption capacity 20.94 mg/g
  - Overall very high metal removal efficiency

- <u>Adsorption of Pesticides</u>
  - Acetamiprid removal efficiency: 22.96% average (max 54.2%)
  - Adsorption capacity: 21.15 mg/g average (max 187 mg/g)
  - Overall: high variability in acetamiprid adsorption performance strongly dependent on experimental conditions.





- <u>Additional experiments on dye removal</u>

Conclusions

- Demonstrated the potential of pristine (unmodified), gasification-derived SS biochar for the removal of various types of contaminants from synthetic wastewater and main influencing factors for the removal of different contaminants were preliminarily identified

- Further research is needed:
  - to confirm the treatment efficiency under real wastewater conditions,
  - to more thoroughly assess the environmental safety of the spent biochar, particularly regarding the risk of secondary pollution, and
  - to extend the investigation to continuous-flow column filtration systems with greater potential for practical application.

- Further research should also address the potential for safe long-term disposal or beneficial reuse of the spent adsorbent (biochar), for example, through its incorporation into construction materials.

AdSorB

THANK YOU FOR YOUR ATTENTION !

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Emerging Technologies and Practices for Sewage Sludge Management

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Submission Deadline: 31 March 2027

The management of sewage sludge is a pressing challenge in modern wastewater treatment, driven by urbanization, stricter regulations, and sustainability goals. Once seen as waste for disposal, sludge is now recognized for its resource recovery potential.

Recent advances in treatment technologies, operational practices, and management strategies—particularly thermal, biological, chemical, and hybrid approaches—are reshaping conventional disposal concepts, with integrated frameworks supporting more circular solutions. However, practical implementation, regulatory constraints, and social acceptance remain critical factors influencing feasibility.

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