

## Response to reviewer comments for final defense

Prof. Dr. Endre Kiss

I would like to express my sincere gratitude to Prof. Dr. Endre Kiss for his valuable comments and insightful suggestions on my dissertation. His critical feedback and thoughtful observations significantly contributed to enhancing the quality and clarity of my work. I deeply appreciate the time and expertise he devoted to reviewing my dissertation, and I am truly thankful for his support and encouragement throughout this process.

1. How much banana peel can be collected, and what kind of shops can provide that? It can be a sustainable active carbon source? Do you have some intention to utilize common plants, weeds for that purpose?

Globally, the banana is the second most farmed fruit, with a total production of 124.97 million tons in 2021 [1]. The cultivation of bananas results in the production of a significant quantity of biomass that is not intended for use, including rachis, leaves, pseudostem, and fruit peels. It has been estimated that the bulk of the fruit accounts for just twelve percent of the overall mass of the banana tree [2]. The peels account for between 35 and 50% of the overall weight of the fruit. Thus, the total waste from banana peels, based on the production of 124.97 million tons, ranges between approximately 43.74 million tons and 62.49 million tons annually.

### References

- [1] FAO, *Food and Agriculture Organization of the United Nations Crops and Livestock Products. 2021*. [Online]. Available: <https://www.fao.org/faostat/en/#data/QCL/visualize>
- [2] M. S. Ahmed, T. Attia, A. A. Abd El-Wahab, R. Elgamsy, and M. H. Abd El-latif, "Assessment of the physical properties of banana pseudo stem/ABS composites," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 634, no. 1, p. 012023, Oct. 2019, doi: 10.1088/1757-899X/634/1/012023.

The collection of banana peels was a personal endeavor (I mean, I bought bananas for personal consumption and kept the peels for the purpose of the experimental run).

### **Industrial Scale Perspective**

The food and beverage industry worldwide is a major consumer of bananas. For example:

**Fresh Produce:** The retail and wholesale markets that sell bananas as fresh fruit are among the largest consumers. Supermarkets, grocery stores, and fruit vendors account for a significant portion of this market.

**Processed Foods:** Banana-based products such as banana chips, dried bananas, banana purée, and banana smoothies are widely consumed in the processed food sector.

**Juice and Beverage Production:** Bananas are used in smoothies, fruit juices, and flavored beverages, particularly in tropical regions or as part of the growing trend of healthy drinks.

### **There are multiple evidence supporting the sustainability of banana peels as a source for activated carbon:**

1. Utilization of Agro-Industrial Waste: The thesis highlights that banana peels, a significant biomass waste product, can be effectively converted into activated carbon. This process contributes to waste management and sustainability by repurposing organic residues that would otherwise be discarded.
2. The production cost of BPAC was \$4.27/kg, significantly lower than commercial activated carbon (\$135/kg), confirming its viability as a cost-effective and environmentally friendly alternative.
3. Efficient Pollutant Removal: The BPAC demonstrates that activated carbon derived from banana peels effectively removes pharmaceuticals (amoxicillin and carbamazepine) from different water sources (MQ water, lake water, and wastewater) [3]. The adsorption efficiency remains high over multiple cycles, indicating its reusability and long-term sustainability.

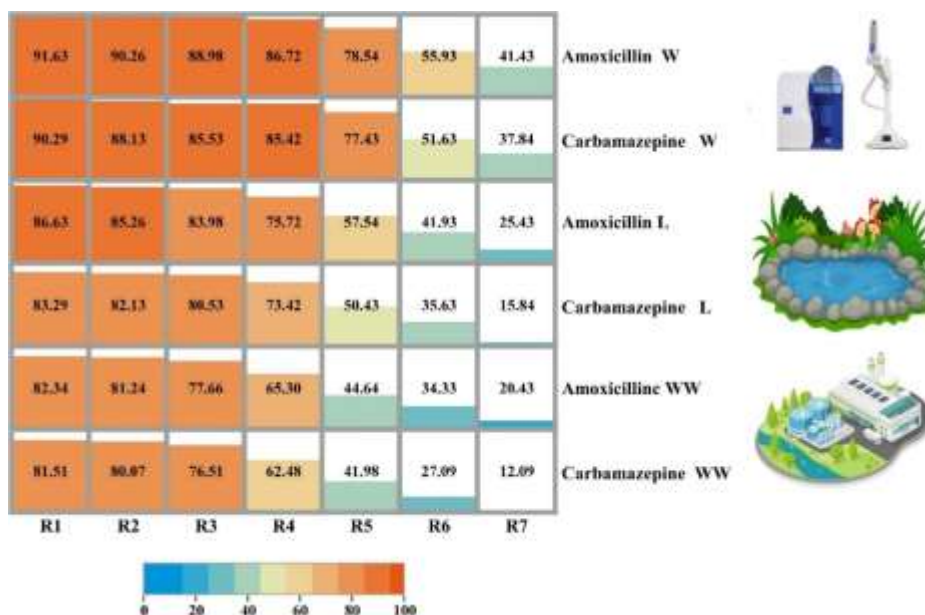


Figure 1 The removal percentage for amoxicillin and carbamazepine using MQ water, lake water (Lake Balaton, Hungary), and wastewater. The SD was less than 3.18% within all cycles. W refers to water, L is lake water, and WW is wastewater

### References

[3] O. J. Al-sareji, R. A. Grmasha, M. Meiczinger, R. A. Al-Juboori, V. Somogyi, and K. S. Hashim, "A Sustainable Banana Peel Activated Carbon for Removing Pharmaceutical Pollutants from Different Waters: Production, Characterization, and Application," *Materials*, vol. 17, no. 5, p. 1032, Feb. 2024, doi: 10.3390/ma17051032.

As for future directions, I am indeed interested in expanding this work to include common plants and invasive weeds, which are abundant, underutilized, and often problematic in local ecosystems. Examples could include water hyacinth, algae, or reed grass. These materials, subject to proper pretreatment and activation, have the potential to further diversify the portfolio of low-cost and sustainable adsorbents for water purification.

2. In removal of pharmaceuticals what is characteristic the active charcoal is showing catalytical like behaviour, and can be used many times, or it could be used only ones? Do you have some experimental results on it?

The adsorption behavior of different activated carbons for pharmaceutical contaminants removal was evaluated based on isotherm models, kinetic models, removal efficiency, and recyclability. They retained high adsorption performance over multiple cycles, suggesting a strong stability and reusability profile.

- 1- OSAC follows the Langmuir isotherm and pseudo-first-order kinetics, achieving high removal efficiency (~99%) for diclofenac and ciprofloxacin in MQ water, lake water, and wastewater. It is recyclable for 7 cycles.
- 2- BPAC also fits the Langmuir isotherm but follows a pseudo-second-order kinetic model, with slightly lower removal efficiency (~82-91%) for amoxicillin and carbamazepine across different water sources. It is recyclable for 7 cycles.
- 3- FPWAC follows the Freundlich isotherm, with mixed kinetic behavior (pseudo-second-order for ciprofloxacin and pseudo-first-order for diclofenac). It shows moderate removal efficiency (~88-96%) and is recyclable for 6 cycles.

Adsorbent	Best Fit Isotherm	Best Fit Kinetics	Removal Efficiency (%)*	Recyclability (Cycles)
OSAC	Langmuir	Pseudo-first-order	MQ water and Lake water (99.63 and 99.29 for diclofenac and ciprofloxacin, respectively)  Wastewater (99.34 and 99.51 for diclofenac and ciprofloxacin, respectively)	7
BPAC	Langmuir	Pseudo-second-order kinetic model	MQ water (91.63 and 90.29 for amoxicillin and carbamazepine, respectively)  Lake water (86.63 and 83.29 for amoxicillin and carbamazepine, respectively)  Wastewater (82.34 and 81.51 for amoxicillin and carbamazepine, respectively)	7

FPWAC	Freundlich	Pseudo-second-order model (ciprofloxacin ) pseudo-first-order (diclofenac)	MQ water (95.93 and 95.04 for diclofenac and ciprofloxacin respectively)  wastewater (90.64 and 88.12 for diclofenac and ciprofloxacin respectively)	6
-------	------------	--	--	---

\* Removal percentages are for the first cycle

Yes, experimentally, it can be used for up to 6-7 cycles

**1- OSAC is recyclable for 7 cycles.**

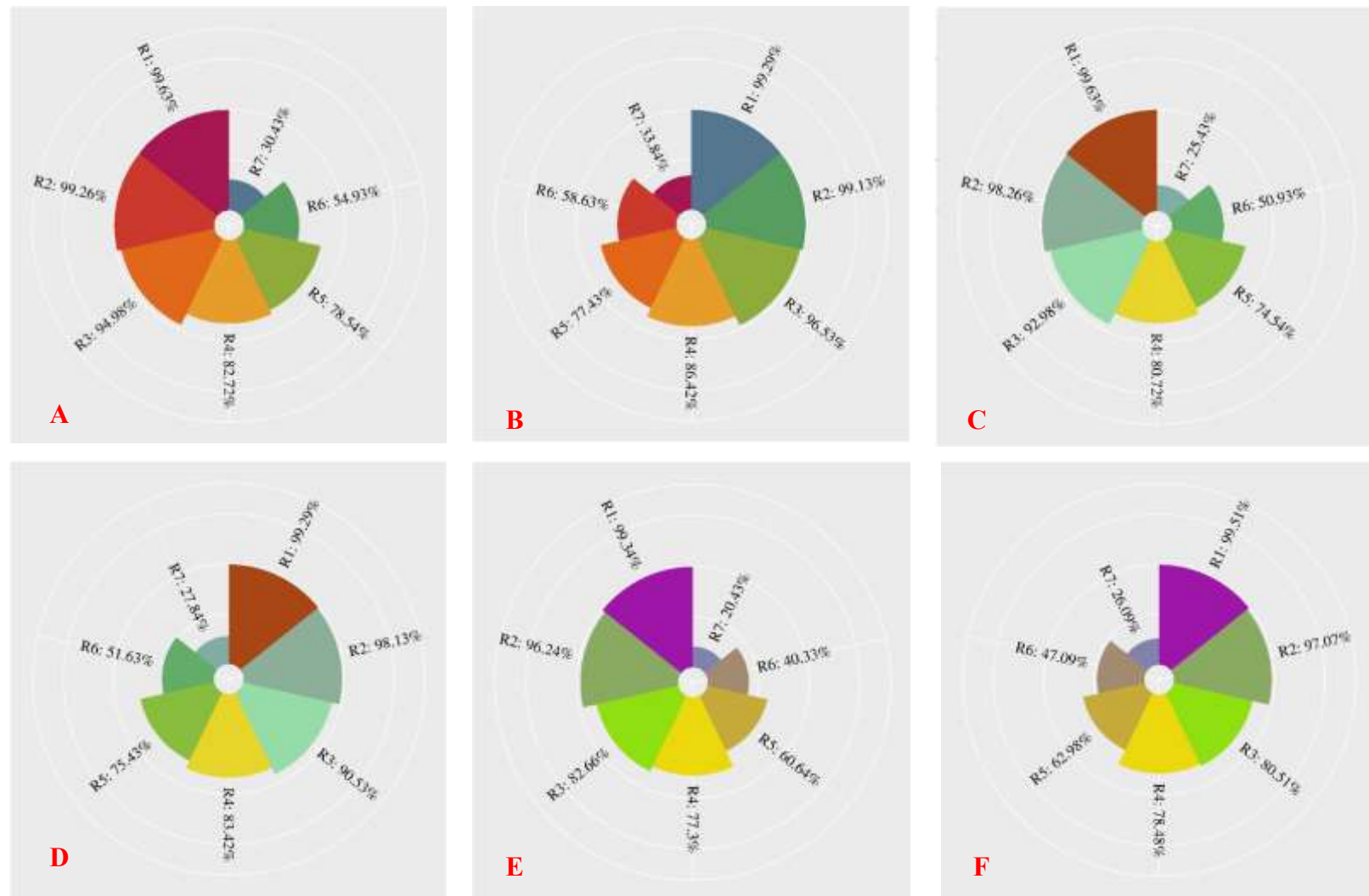


Figure 2 The removal efficiency of diclofenac in MQ water (A), ciprofloxacin in MQ water (B), diclofenac in lake water (Lake Balaton, Hungary) (C), ciprofloxacin in lake water (Lake Balaton, Hungary) (D), diclofenac in secondary effluent (E), and ciprofloxacin in secondary effluent (F), over sequential seven cycles. The standard deviations were between 1.53 % for cycles

**2- BPAC is recyclable for 7 cycles.**

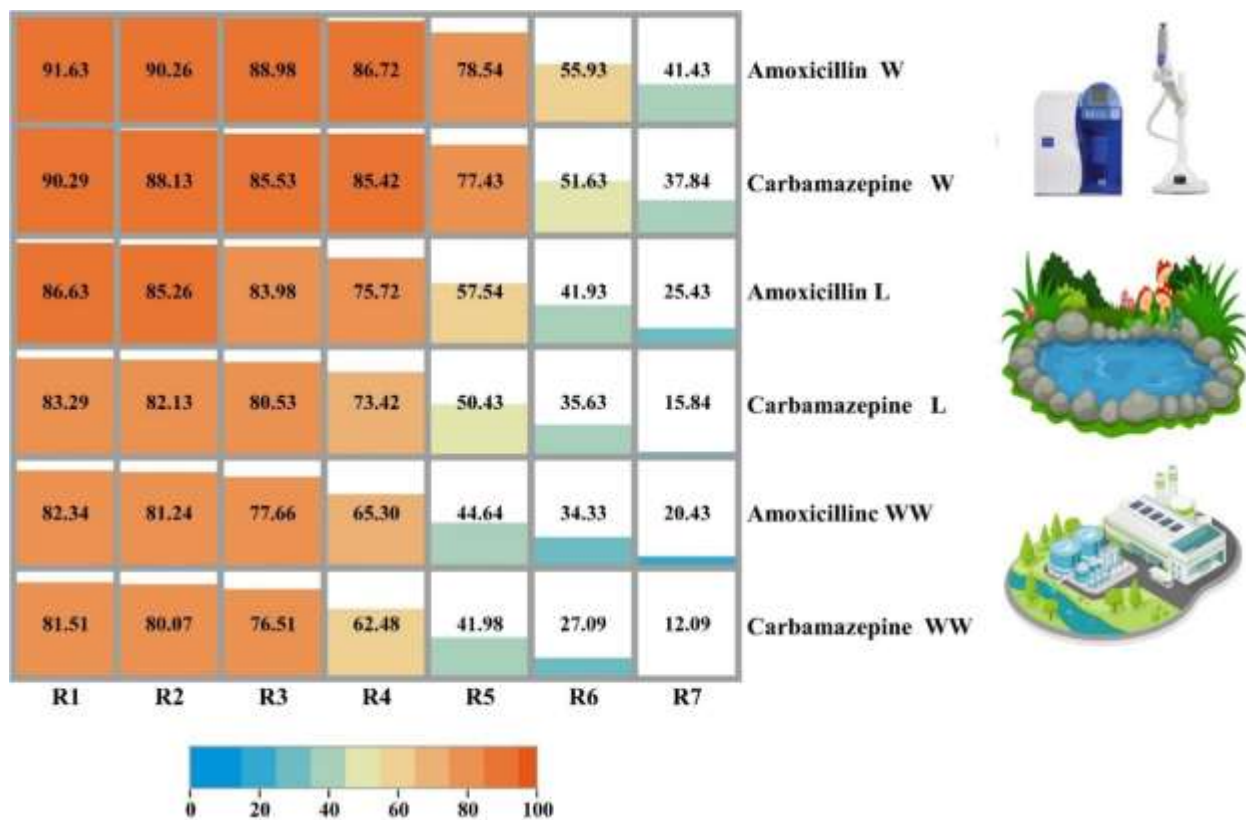


Figure 1 The removal percentage for amoxicillin and carbamazepine using MQ water, lake water (Lake Balaton, Hungary), and wastewater. The SD was less than 3.18% within all cycles. W refers to water, L is lake water, and WW is wastewater

3- FPWAC is recyclable for 6 cycles.

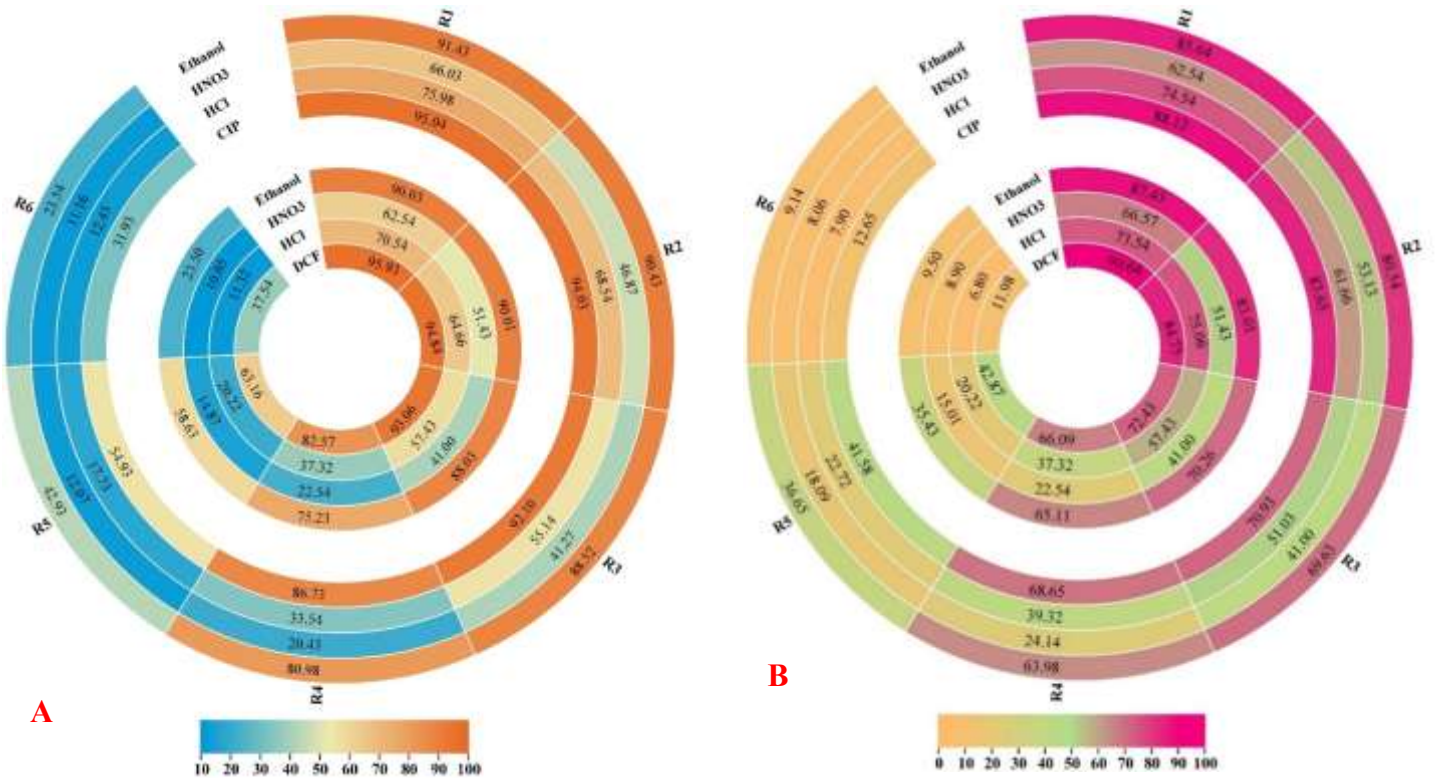


Figure 3 Recyclability of FPWAC (removal percentages %) for diclofenac (DCF) and ciprofloxacin (CIP) along with used desorption agents for water (A) and wastewater(B).

To conclude, the developed ACs are not single-use materials; rather, they demonstrate excellent reusability, which makes them cost-effective and environmentally sustainable for practical applications.

Osamah Al-sareji

Osamah Jaber Oudah Al-sareji  
20/5/2025