Task 3.2 - P-recovery from LFD with Fe-modified biochar

Objective

The objective of this task is to assess the applicability of Fe-modified biochar as an adsorbent for phosphate recovery from liquid fraction of digestate (LFD). Although biochar is a relatively inexpensive adsorbent, its negatively charged surface makes it unsuitable for phosphate adsorption. To enhance its phosphate adsorption efficiency, biochar is generally modified with iron (Michalekova-Richveisova et al., 2017). In this study, biochar samples derived from corncobs, whose phosphate affinity is enhanced by iron modification, were tested in bench-scale batch experiments using synthetic and real digestate samples for phosphate recovery.

Set-up/Parameters

Preparation of Fe-modified biochar:

Biochar was produced from ground corncob through pyrolysis at 550 °C for 2 hours in a nitrogen atmosphere. The modification process followed the method described by Yang et al. (2018) (Figure 1).

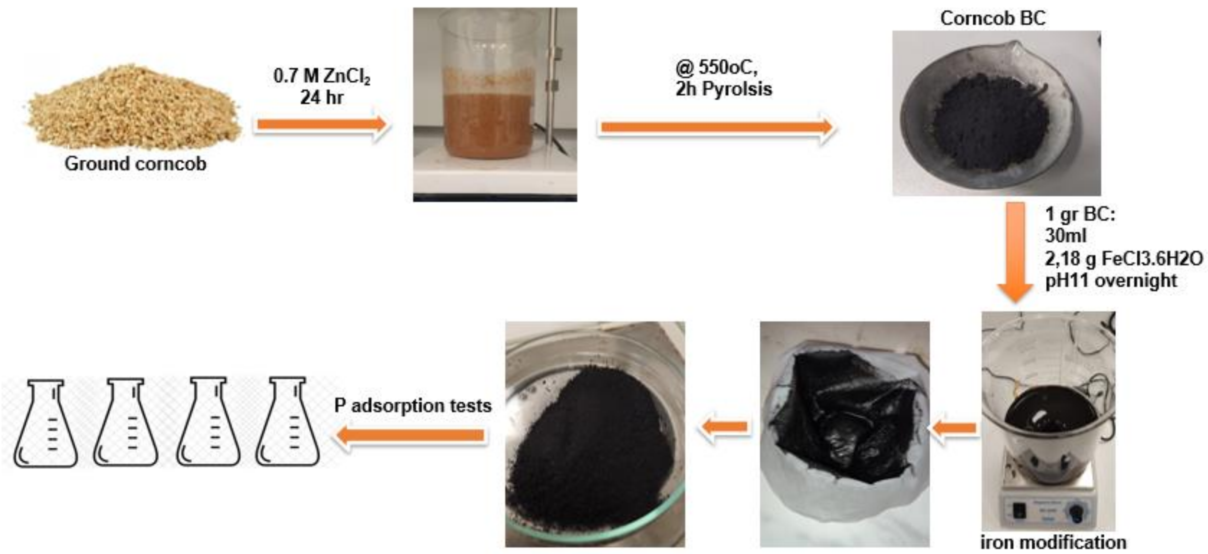

Figure 1. Fe-modified biochar production diagram.

Adsorption kinetics and isotherm models:

To assess the phosphate adsorption performance of Fe-modified biochar, kinetics experiments and adsorption isotherm tests were conducted using a synthetic phosphate solution. For the kinetics experiments, 100 ml of a synthetic solution containing 22.5 mg/L of PO_4^{-3}-P was used. Approximately 0.2 g of Fe-modified biochar was added to flasks, which were then shaken for 5 hours. Samples were periodically taken from the flasks for phosphate analysis.

The isotherm experiments were performed in 100-ml flasks with 50 ml of solution containing varying concentrations of phosphate (10-1000 mg/L PO_4^{-3}-P) at pH 7. About 0.1 gr of Fe-modified biochar was added to each flask, which was then agitated on an orbital shaker for 24 hours. The phosphate adsorption performance of Fe-modified biochar was further tested with real digestate collected from a laboratory-scale chicken manure digester, which contains 230 mg/L PO_4^{-3}-P. Experiments were conducted with 50 ml of digestate and different dosages of biochar (2-52 g/L).

Results

Figure 2 shows the kinetics of phosphorus (P) adsorption onto Fe-modified biochar from synthetic solutions. The kinetic tests lasted for 5 hours, indicating that the adsorption equilibrium for phosphate was reached within the initial 90 minutes, with a 40% phosphate removal efficiency. Beyond 90 minutes, only a slight increase was observed in adsorption capacity.

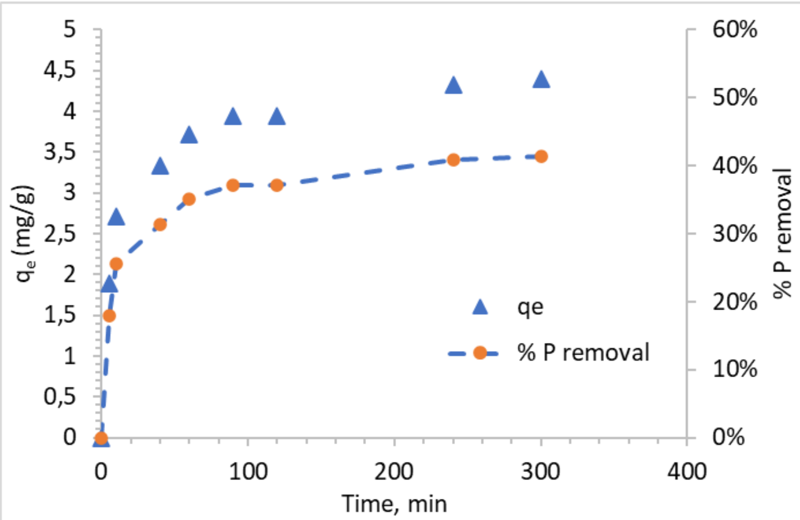

Figure 2. Kinetics of phosphorus (P) adsorption onto Fe-modified biochar.

Adsorption isotherm experiments were performed at pH 7 for 24 h, a duration considered highly sufficient to reach equilibrium according to the kinetic tests (Figure 2). The isotherm results are presented in Table 1, while the model parameters obtained from fitting the experimental data are summarized in Table 2.

Table 1. Adsorption isotherm results

Flask No	C_o (mgP/L)	C_e (mgP/L)	q_e (mgP/gBC)
1	10	4.9	2.4
2	20	11.5	4.0
3	50	36.3	6.2
4	100	82.3	7.9
5	150	126.9	10.0
6	200	172.3	12.2
7	500	457.6	17.2
8	700	647.4	23.1
9	1000	926.4	27.2

Table 2. Isotherm model parameters

Langmuir parameters			Freundlich parameters		
q_m (mg/g)	K_L (L/mg)	R^2	K_F ($mg^{(1-n)}L^n kg^{-1}$)	n	R^2
33	0.0035	0.95	0.998	2.08	0.99

Comparisons of the experimental data and model fits of the two isotherms for phosphate are presented in Figure 3. The results indicate that the Freundlich isotherm provides a superior fit for phosphate adsorption, as evidenced by its higher R^2 value (R^2=0.99) compared to the Langmuir isotherm (R^2=0.95). This suggests that the adsorption of phosphate was occurring in both monolayer and multilayer fashion.

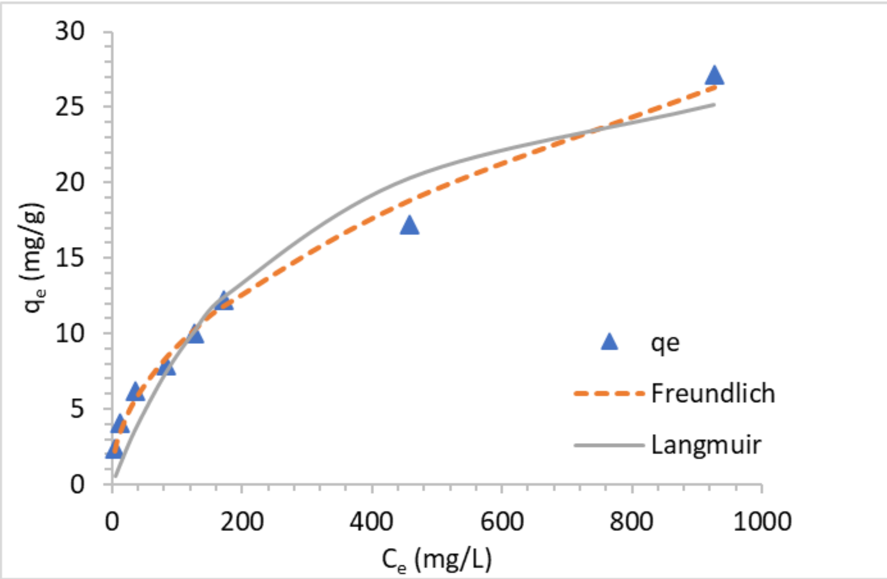

Figure 3. Phosphate adsorption isotherms of Fe-modified biochar

The results of phosphate adsorption from chicken manure digestate are shown in Figure 3. As the biochar dosage increased, phosphate removal also increased, reaching up to 93%. However, it is noted that the phosphate adsorption capacity of the Fe-modified biochar decreased with an inverse proportion to the removal rate (Figure 4).

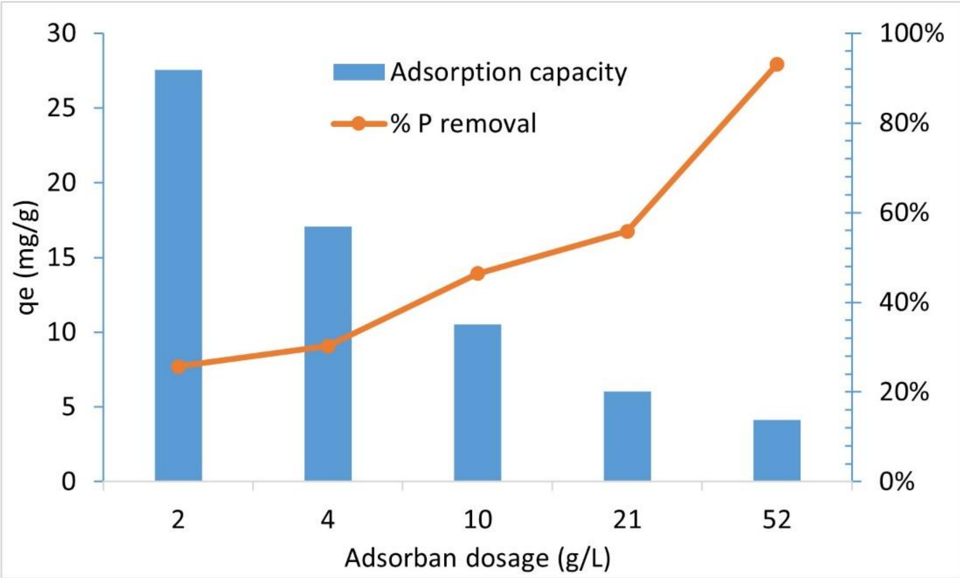

Figure 4. Phosphate adsorption performance of Fe-modified biochar from chicken manure digestate

Conclusions/Remarks

- Fe-modified biochar demonstrated effective phosphate removal performance.
- Its adsorption capacity for phosphate was estimated at about 33 mg/g according to the Langmuir adsorption model.
- Fe-modified biochar shows potential as a promising adsorbent for phosphate recovery.

References:

Micháleková-Richveisová, B., Frišták, V., Pipíška, M., Ďuriška, L., Moreno-Jimenez, E., Soja, G. (2017). Iron-impregnated biochars as effective phosphate sorption materials. Environ. Sci. Pollut. Res. 24(1), 463-475.

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More information about the project: check out the project website.

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