Supplementary Information

Preparation of Fe-Modified Diatomite-Based Ceramsite for Efficient Phosphate Adsorption: Utilizing Diatomite's Distinctive Porous Structure and Surface Silanol Groups

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Contents

In this study, the cylinder compression strength, bulk density, water absorption and apparent density of ceramsite were mainly tested with reference to the standard GB/T 17431.2-2010.

The test of cylinder compression strength: using a microcomputer-controlled universal testing machine, the pressure readings were recorded when the depth of pressing into the pressurized container reached 20 mm. To calculate the compaction strength, the recorded pressure value is divided by the contact area between the press mold and the pressurized surface to obtain the required data.

Testing of packing density: The dried sample is poured slowly from a height of approximately 50 mm from the mouth of the container to ensure a uniform distribution of the sample. A spatula is used to flatten the surface of the sample inside the container. Subsequently, the full container is weighed to calculate the bulk density of the sample.

For the test of apparent density, the samples were first immersed in water for a duration of 1 hour to ensure adequate water absorption. Afterwards, it was extracted and placed on a filter to allow the water to filter out naturally for approximately 1 to 2 minutes. Next, the sample was transferred to a pre-wrung wet towel and the ends of the towel were gently held and gently rolled back and forth to remove excess water from the sample surface. The treated sample was then gently poured into a measuring cylinder with a volume of 1000 mL. The apparent density of the material is obtained by recording the dry mass of the sample and calculating the volume it occupies. This is calculated by dividing the dry mass of the sample by its excluded volume.

Determination of the water absorption of the material: the sample was first completely immersed in water and maintained for 1 hour to ensure adequate water absorption. After removing the sample, it was allowed to drip naturally on a strainer for 1 to 2 minutes to remove excess water from the surface. Then, the sample was gently placed on a pre-wrung wet towel and the ends of the towel were gently held and the sample was gently rolled to further homogenize the moisture on the sample surface. Subsequently, the mass of the treated sample was accurately measured and the data recorded. The water absorption rate is obtained by making a difference between the mass of the absorbed sample and the mass of the original dry state, and then dividing this difference by the mass of the sample in the dry state.

Figure S1. Flow chart of preparation of Fe-DC and related physical drawings.

Figure S2. SEM image and EDS spectra of Fe-DC-P and EDS element maps (Si, Fe, P).

Table S1. Chemical composition of DE， Fe-DC and Fe-DC-P by XRF(Mass percentage m/m%).

Table S2. Comparison of Phosphorus Adsorption Properties between Different Modified Ceramsites and Similar Materials.

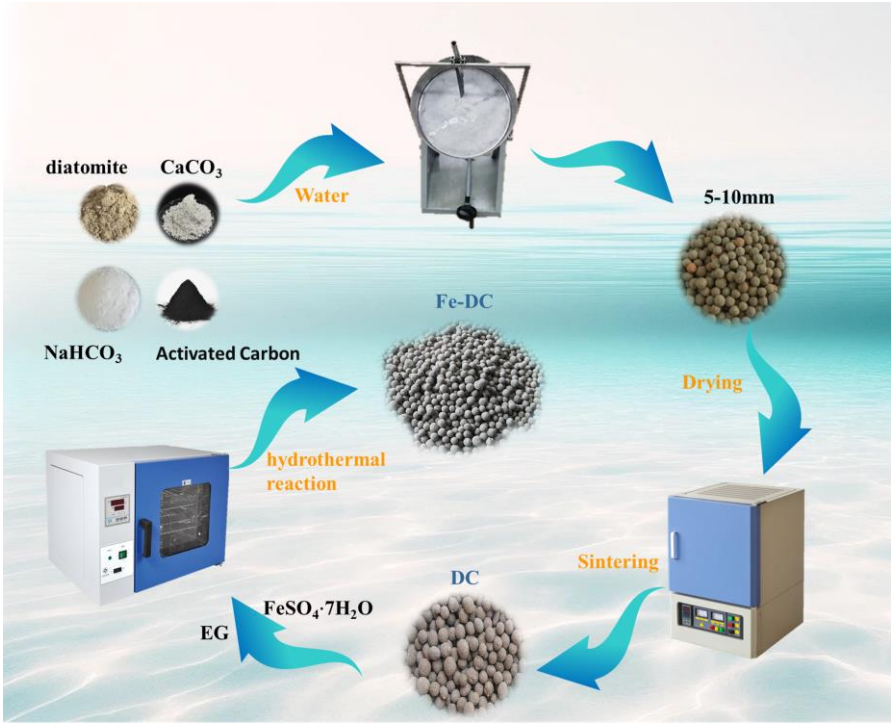
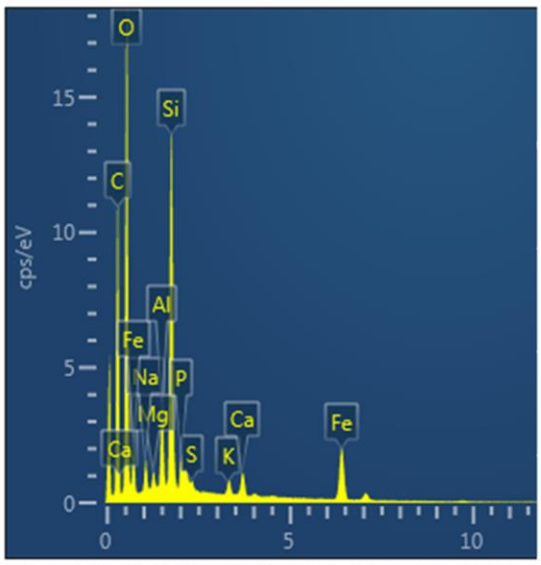


Figure S1. Flow chart of preparation of Fe-DC and related physical drawings.



Element	Wt%
Si	8.14%
O	34.89%
Fe	9.73%
P	1.68%

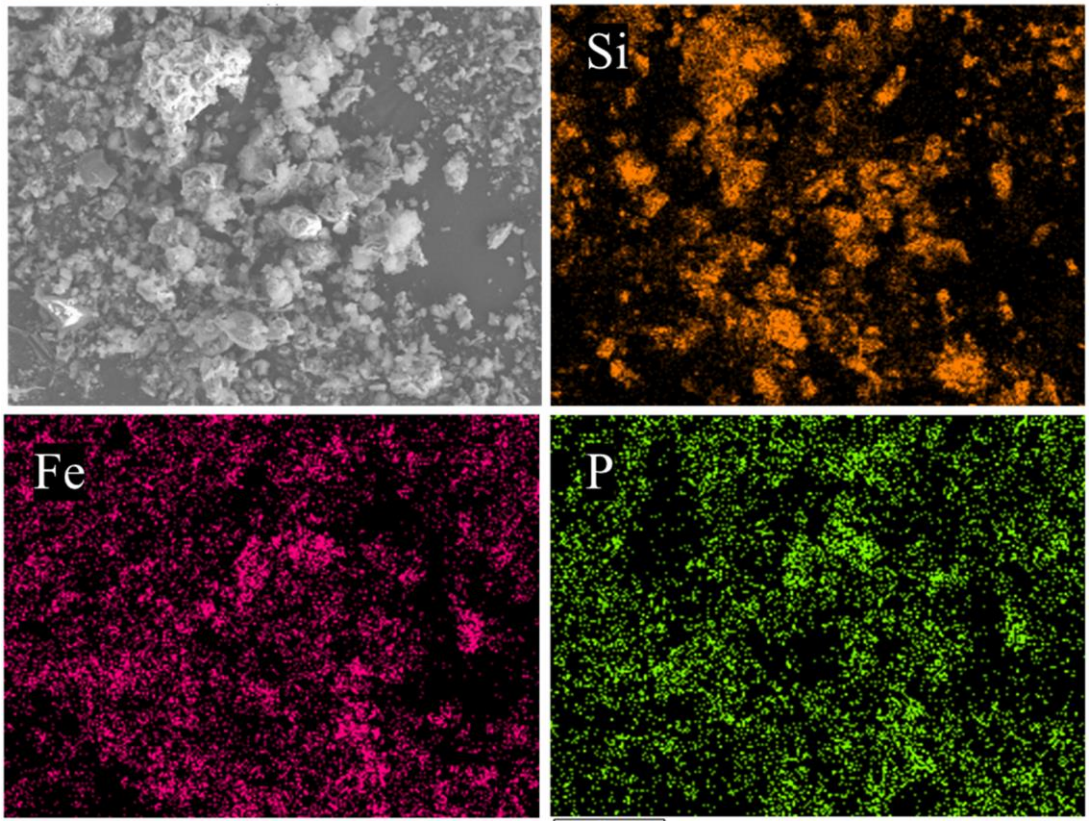


Figure S2. SEM image and EDS spectra of Fe-DC-P and EDS element maps (Si, Fe, P).

Table S1. Chemical composition of DE , Fe-DC and Fe-DC-P by XRF(Mass percentage m/m%).

Composition	**SiO_2**	**Al_2O_3**	**CaO**	**Fe_2O_3**	**MgO**	**Na_2O**	**K_2O**	**P_2O_5**
DE	73.25	16.38	0.50	4.95	1.39	0.70	1.83	0.07
Fe-DC	62.64	16.67	4.17	13.22	4.11	6.02	1.47	0.11
Fe-DC-P	49.14	12.70	3.14	13.94	2.00	4.97	1.28	2.68

Note: Some elements that are irrelevant to the adsorption or reaction processes and elements with low content are not included in the table.

Table S2. Comparison of Phosphorus Adsorption Properties between Different Modified Ceramsites and Similar Materials.

Adsorbents	**Intermediate material**	**Size (mm)**	**pH_{pzc}**	**Adsorption capacity (mg P/g)**	**Reference**
HCl+Fe/zeolite	Purchased zeolite	0.45-0.6	3.87	0.186	[1]
Na+Fe/zeolite	Purchased zeolite	0.45-0.6	4.13	0.178	[1]
extracts+Fe+Na/zeolite	Purchased zeolite	0.13	N.A.	1.26	[2]
Zn/Fe-LDH/zeolite	Purchased zeolite	2.0–4.0	N.A.	0.535	[3]
Zr/Zn NCs/ceramsite	Purchased ceramsite	2-6	7.40	5.12	[4]
La/ceramsite	Sewage sludge, fly ash ceramsite	2.0–3.0	N.A	0.952	[5]
Fe/ceramsite	Purchased ceramsite	3.0	7.0	2.44	[6]
Fe/ceramsite	Purchased ceramsite	3.0	N.A.	3.15	[7]
Fe/Mn/ceramsite	Purchased ceramsite	3.0	7.5	2.75	[6]
Fe/	Diatomite ceramsite	5-10	2.8	4.06	This study

Note: N.A. indicates that it is not mentioned in the study.

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