Supplemental Materials

Biopolymer-based N-doped carbonaceous bifunctional material for phenol removal: synergistic performance of adsorption and catalytic degradation

Fig. S1. The EDX spectra of (a) uncoated sand, (b) chitosan-coated sand and (c) CCS-500 sample.

Fig. S2. SEM-EDX mapping of the shown representative area of uncoated sand sample with its elemental composition of C, O, Al, and Si. The scale bar represents 8 μm in all images.

Fig. S3. SEM-EDX mapping of the shown representative area of chitosan-coated sand sample with its elemental composition of C, O, Al, and Si. The scale bar represents 100 μm in all images.

Fig. S4. SEM-EDX mapping of the shown representative area of CSS-500 sample with its elemental composition of C, O, Al, and Si. The scale bar represents 100 μm in all images.

Fig. S5. Wide scan XPS spectra of (a) chitosan coated sand sample, (b) uncoated sand sample and (c) CSS-500 sample.

Fig. S6. C 1s, N 1s and Si 2p XPS spectra of (a) chitosan coated sand sample, (b) uncoated sand sample and (c) CSS-500 sample.

Fig. S7. Effect of catalyst content on phenol removal by adsorption and catalytic oxidation of the CCS-500 sample. Operation parameters: $[Phenol]_0$ = 50 ppm, catalyst = 100 g/L, PMS = 0.5 g/L, and temperature = 24 °C.

Fig. S8. Effect of PMS dosage on phenol removal by adsorption and catalytic oxidation of the CCS-500 sample. Operation parameters: $[Phenol]_0$ = 50 ppm, catalyst = 100 g/L, PMS = 0.5 g/L, and temperature = 24 °C.

Fig. S9. Effect of initial phenol concentration on its removal by adsorption and catalytic oxidation of the CCS-500 sample. Operation parameters: $[Phenol]_0$ = 50 ppm, catalyst = 100 g/L, PMS = 0.5 g/L, and temperature = 24 °C.

Fig. S10. Effect of initial solution pH on phenol removal by adsorption and catalytic oxidation of the CCS-500 sample. Operation parameters: $[Phenol]_0$ = 50 ppm, catalyst = 100 g/L, PMS = 0.5 g/L, and temperature = 24 °C.

Fig. S11. Baseline-corrected Raman spectra of the CCS-600 sample measured at the indicated 5 positions.

Fig. S12. Baseline-corrected Raman spectra of the CCS-700 sample measured at the indicated 5 positions.

Fig. S13. Baseline-corrected Raman spectra of the CCS-800 sample measured at the indicated 5 positions.

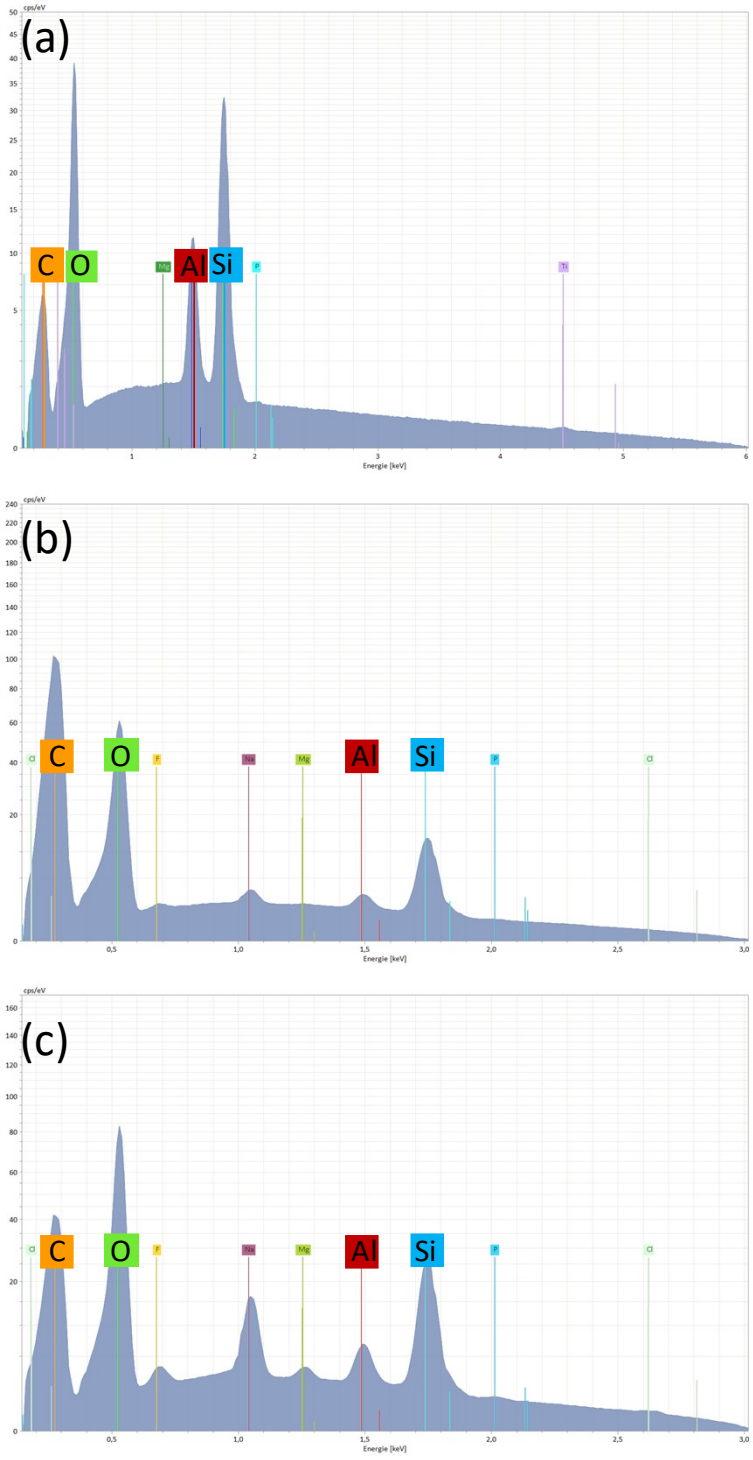

Fig. S1. The EDX spectra of (a) uncoated sand, (b) chitosan-coated sand and (c) CCS-500 sample.

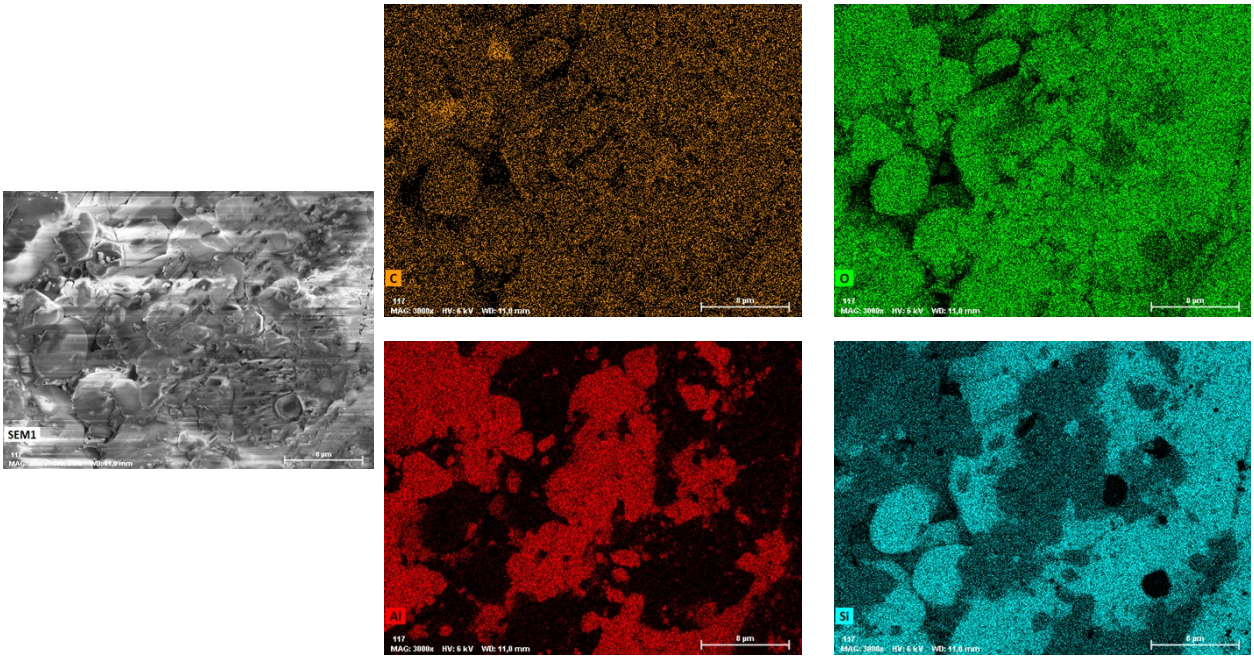

Fig. S2. SEM-EDX mapping of the shown representative area of uncoated sand sample with its elemental composition of C, O, Al, and Si. The scale bar represents 8 µm in all images.

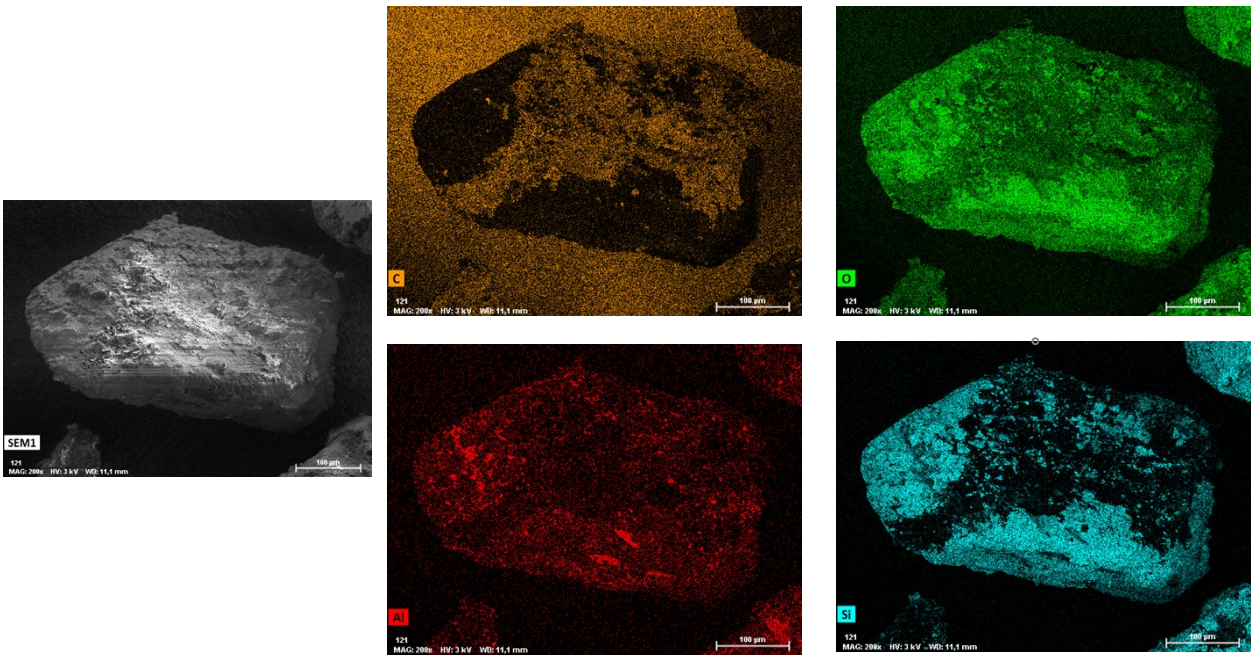

Fig. S3. SEM-EDX mapping of the shown representative area of chitosan-coated sand sample with its elemental composition of C, O, Al, and Si. The scale bar represents 100 µm in all images.

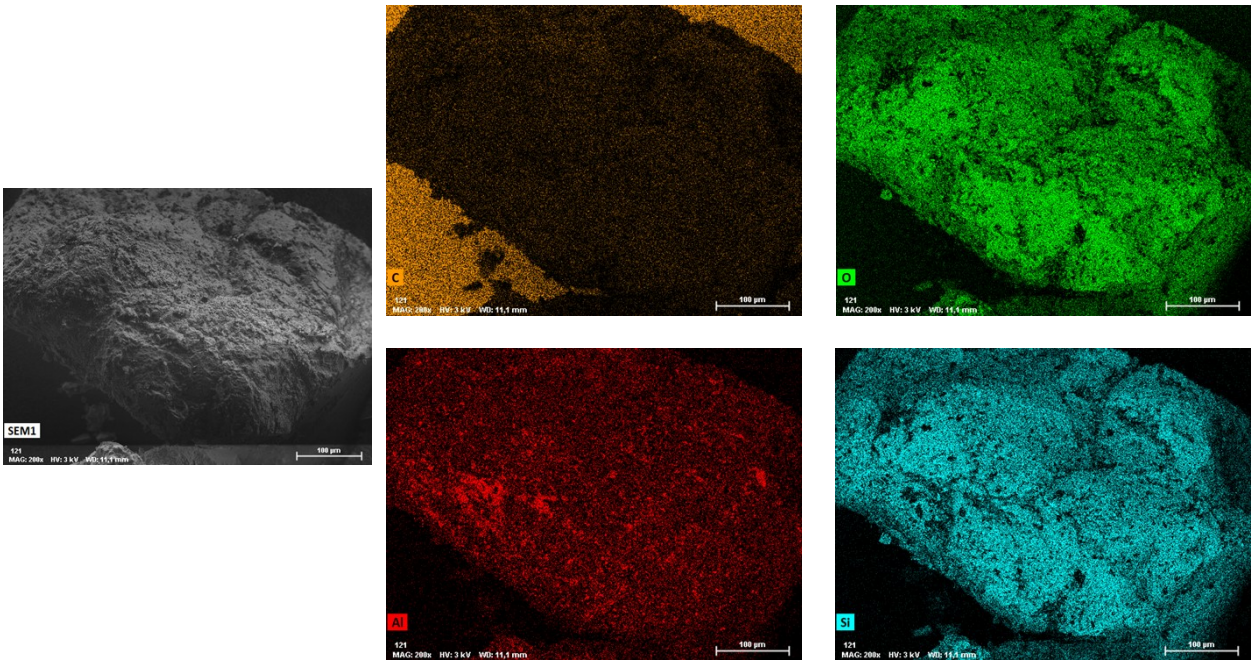

Fig. S4. SEM-EDX mapping of the shown representative area of CSS-500 sample with its elemental composition of C, O, Al, and Si. The scale bar represents 100 μm in all images.

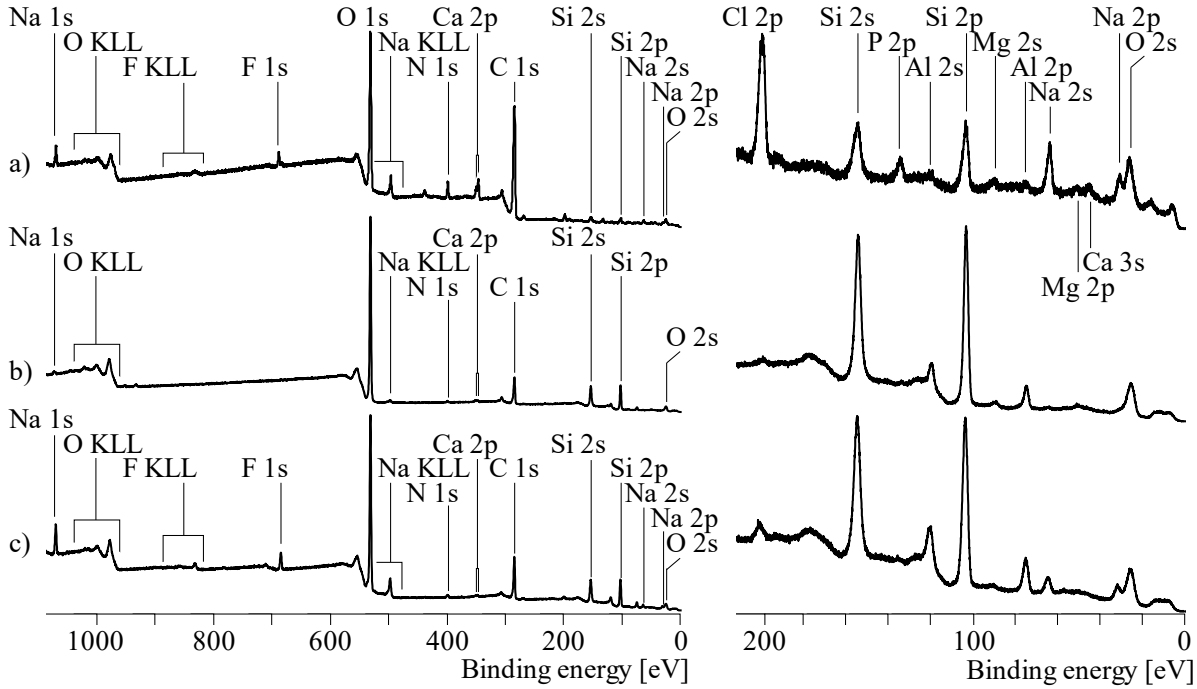

Fig. S5. Wide scan XPS spectra of (a) chitosan coated sand sample, (b) uncoated sand sample and (c) CSS-500 sample.

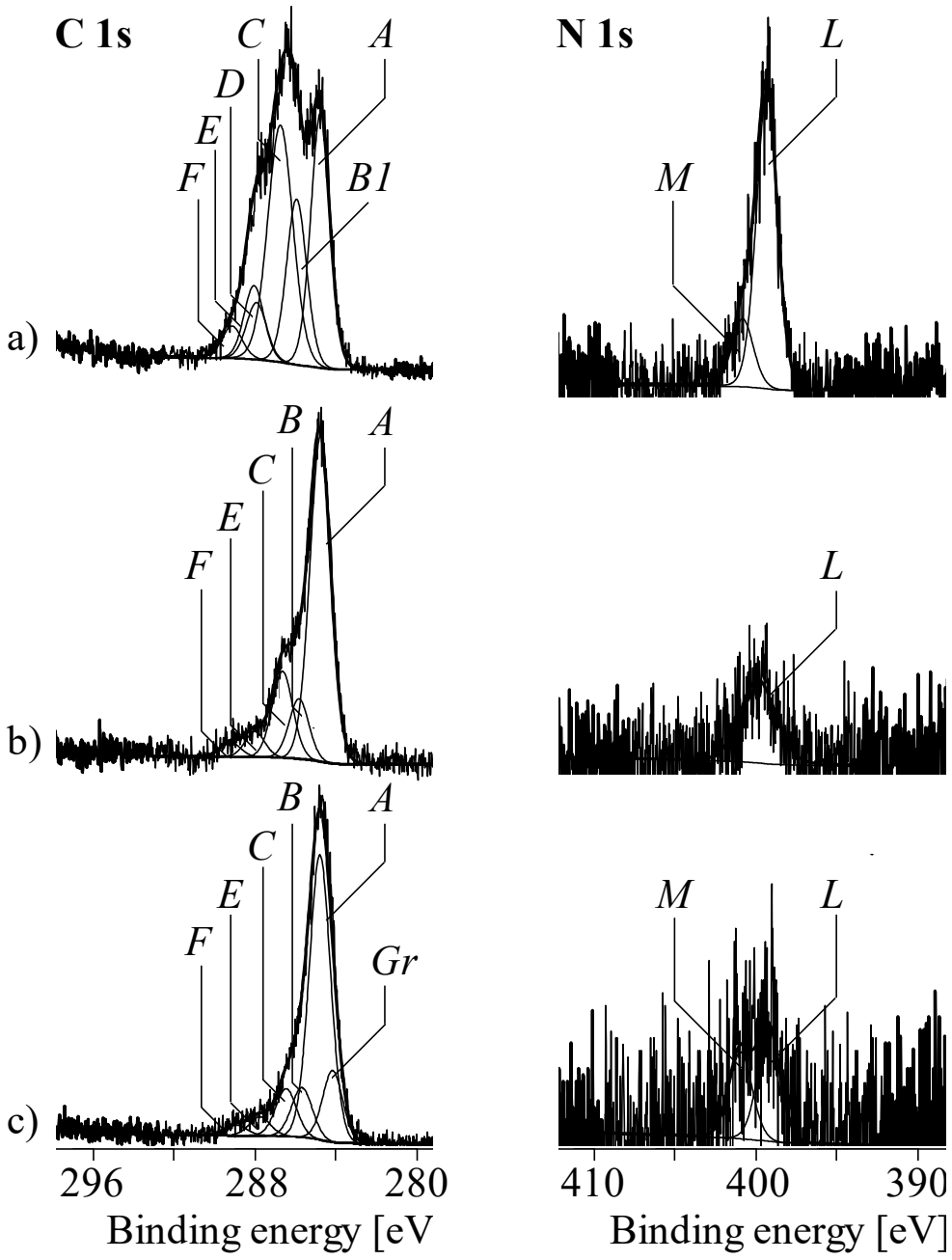

Fig. S6. C 1s, N 1s and Si 2p XPS spectra of (a) chitosan coated sand sample, (b) uncoated sand sample and (c) CSS-500 sample.

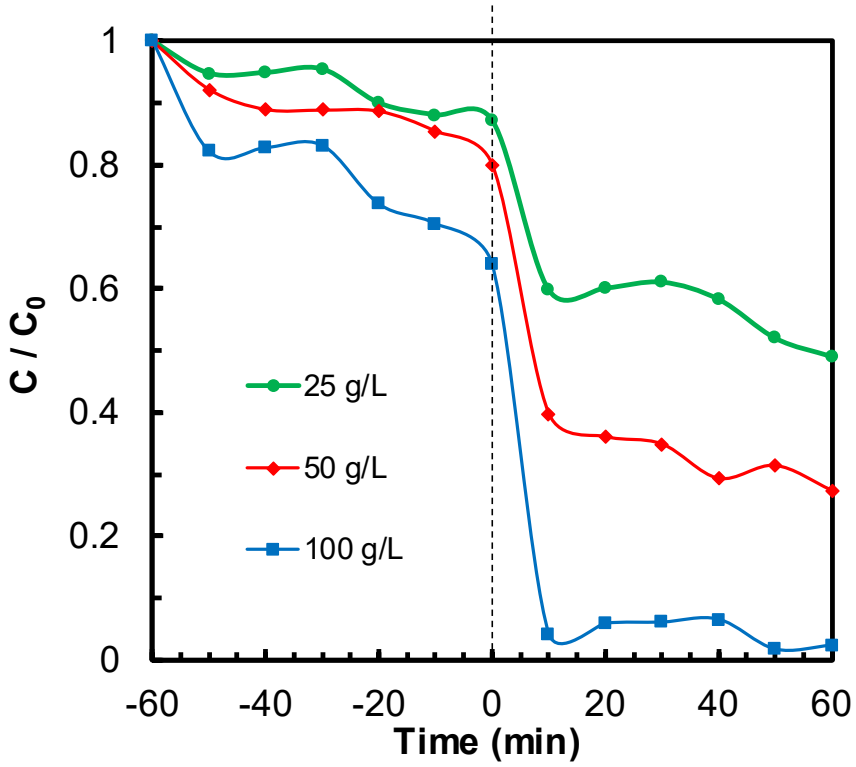

Fig. S7. Effect of catalyst content on phenol removal by adsorption and catalytic oxidation of the CCS-500 sample. Operation parameters: $[Phenol]_0$ = 50 ppm, catalyst = 100 g/L, PMS = 0.5 g/L, and temperature = 24 °C.

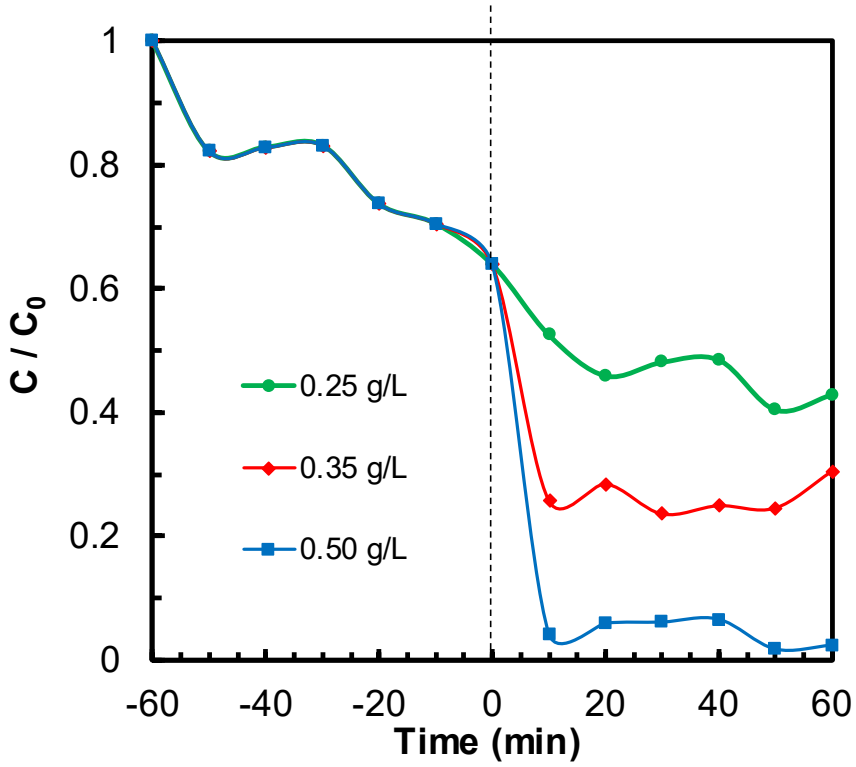

Fig. S8. Effect of PMS dosage on phenol removal by adsorption and catalytic oxidation of the CCS-500 sample. Operation parameters: $[Phenol]_0$ = 50 ppm, catalyst = 100 g/L, PMS = 0.5 g/L, and temperature = 24 °C.

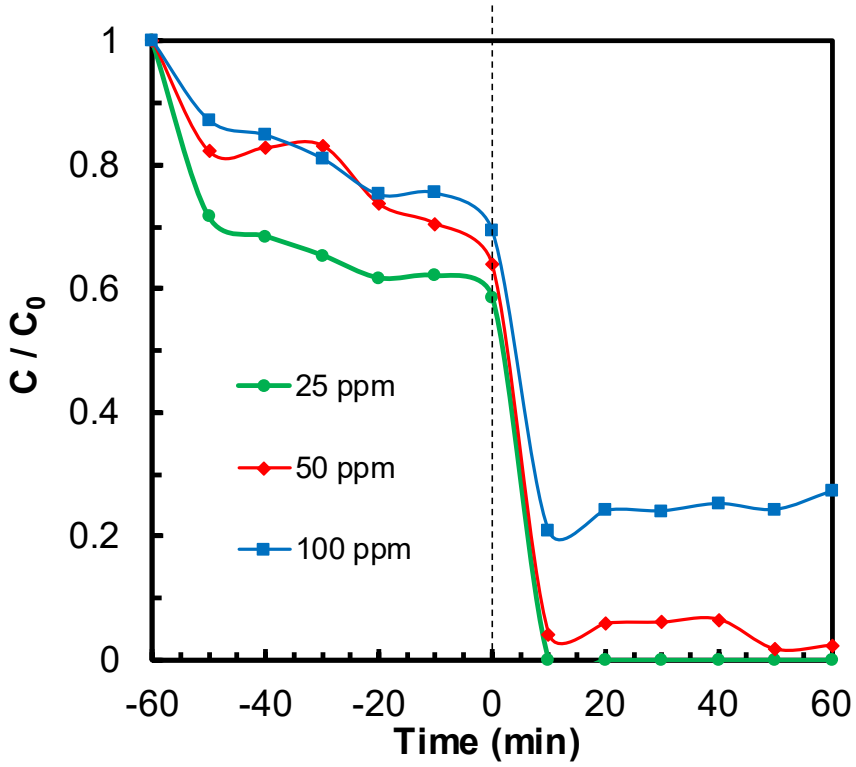

Fig. S9. Effect of initial phenol concentration on its removal by adsorption and catalytic oxidation of the CCS-500 sample. Operation parameters: $[Phenol]_0$ = 50 ppm, catalyst = 100 g/L, PMS = 0.5 g/L, and temperature = 24 °C.

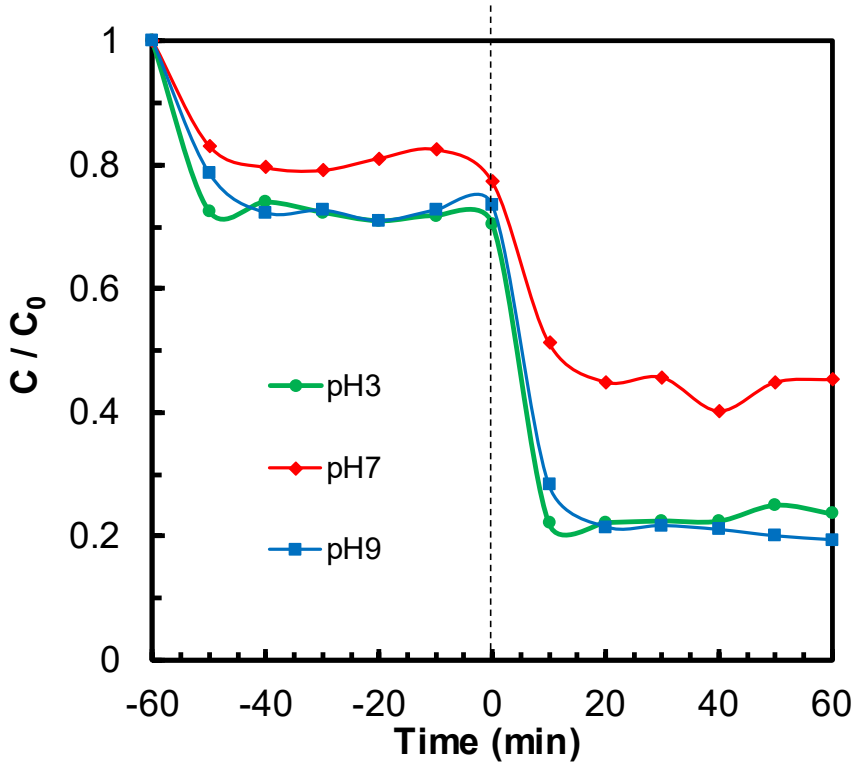

Fig. S10. Effect of initial solution pH on phenol removal by adsorption and catalytic oxidation of the CCS-500 sample. Operation parameters: $[Phenol]_0$ = 50 ppm, catalyst = 100 g/L, PMS = 0.5 g/L, and temperature = 24 °C.

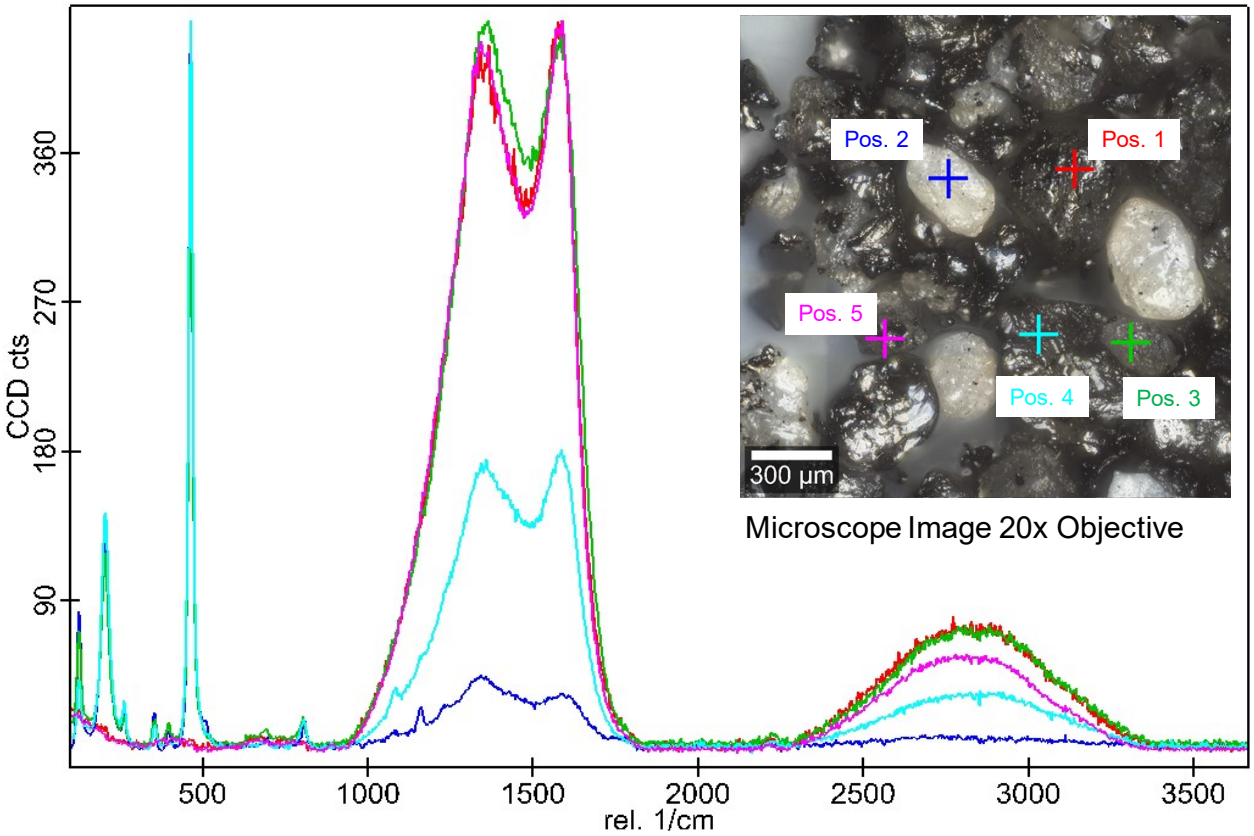

Fig. S11. Baseline-corrected Raman spectra of the CCS-600 sample measured at the indicated 5 positions.

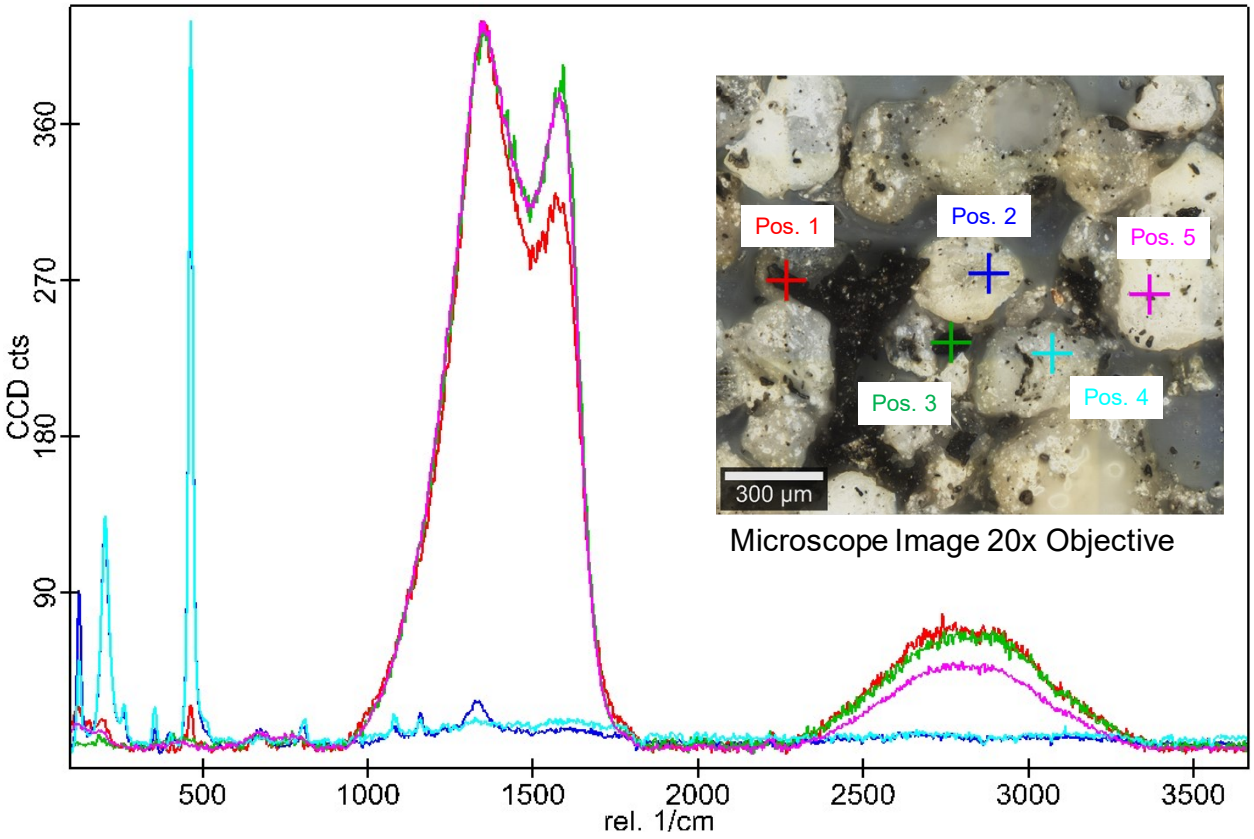

Fig. S12. Baseline-corrected Raman spectra of the CCS-700 sample measured at the indicated 5 positions.

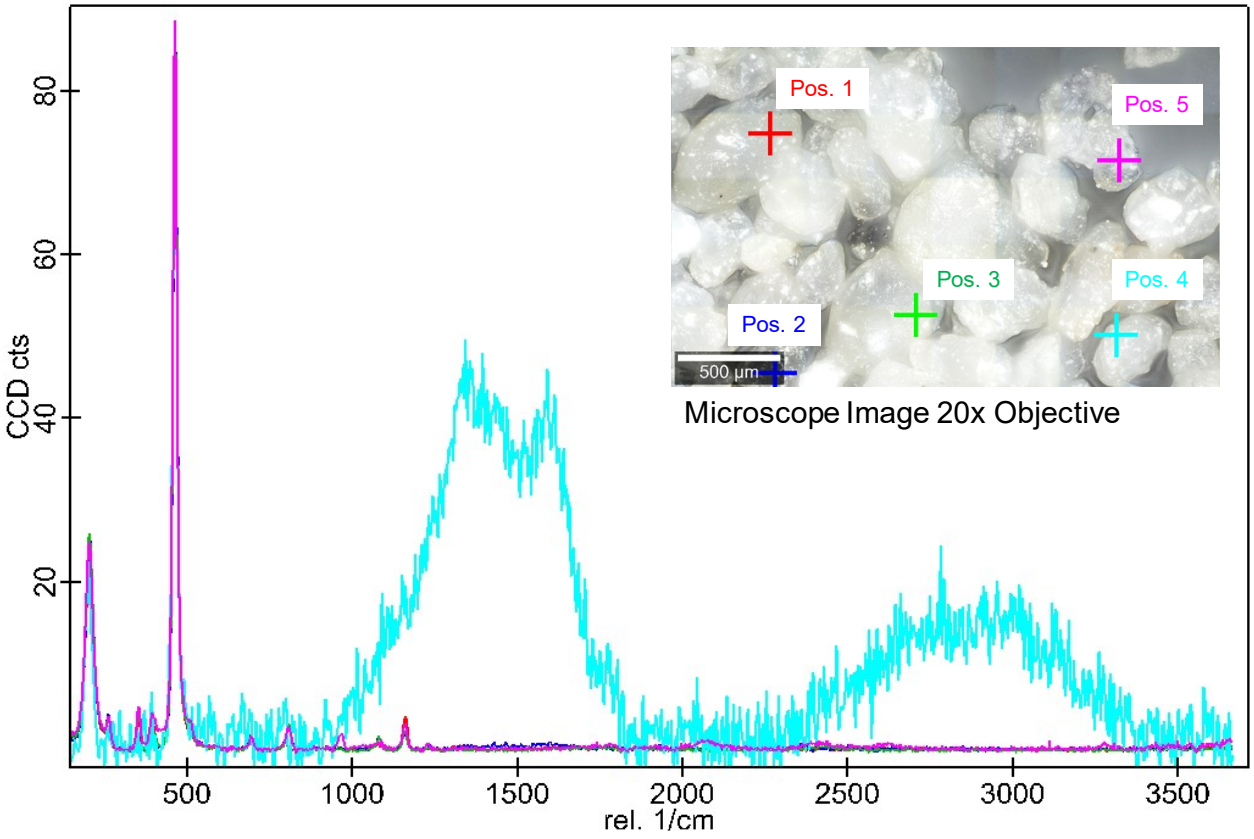

Fig. S13. Baseline-corrected Raman spectra of the CCS-800 sample measured at the indicated 5 positions.