energies

MDPI

**Supplementary data**

# Preparation of N, O and S-tridoped biochar by one-pot pyrolysis of poplar and urea formaldehyde and its enhanced tetracycline removal from wastewater

**Wenran Gao [a], Zixiang Lin [a], Shanshan Yan [a], Yaxuan Gao [a], Hong Zhang [a], Xun Hu[c], Hongqi Sun [d] and Shu Zhang [a,d,*]**

[a] Joint International Research Laboratory of Biomass Energy and Materials, Co-Innovation Center of Efficient Processing and Utilization of Forest Resources, College of Materials Science and Engineering, Nanjing Forestry University, Nanjing 210037, China
[c] School of Material Science and Engineering, University of Jinan, Jinan 250022, Shandong, China
[d] School of Engineering, Edith Cowan University, 270 Joondalup Drive, Joondalup, Western Australia 6027, Australia
* Correspondence: Authors. *E-mail*: s.zhang@njfu.edu.cn; *Tel.*: +86-025-85428330 (S. Zhang)

A manuscript for submission to *Energies* for consideration of publication

**Table S1.** Elemental analysis of S-containing urea formaldehyde.

| Elemental analysis (wt %, ar [a]) | | | | |
|---|---|---|---|---|
| C | H | O [b] | N | S |
| 25.05 | 6.17 | 41.89 | 21.93 | 4.96 |

[a] as received basis; [b] by difference.

**Table S2.** Summary of maximum adsorption capacities ($Q_{max}$) of various adsorbents in literature for TC.

| Adsorbent | $Q_{max}$ of TC (mg/g) | Refs |
|---|---|---|
| Vine wood | 1.98 | [1] |
| Peanut hulls | 28.0 | [2] |
| Salix | 25.4 | [3] |
| Auricularia auricula dregs | 11.9 | [4] |
| Pinus taeda | 274.8 | [5] |
| Rice straw | 13.85 | [6] |
| Waste Fiberboard | 13.72 | [7] |
| Popla and urea formaldehyde | 28.74 | This study |

**Table S3.** Relationship between selected properties of biochar and adsorption capacity.

| Properties | Surface area | Elemental content | | | Surface elemental content | | | N-containing functional groups | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | O content | S content | N content | Surface O | Surface S | Surface N | N-G | N-6 | N-5 | N-O |
| $R^2$ | 0.478 | 0.741 | 0.635 | 0.847 | 0.636 | 0.882 | 0.385 | 0.985 | 0.262 | -0.444 | 0.882 |

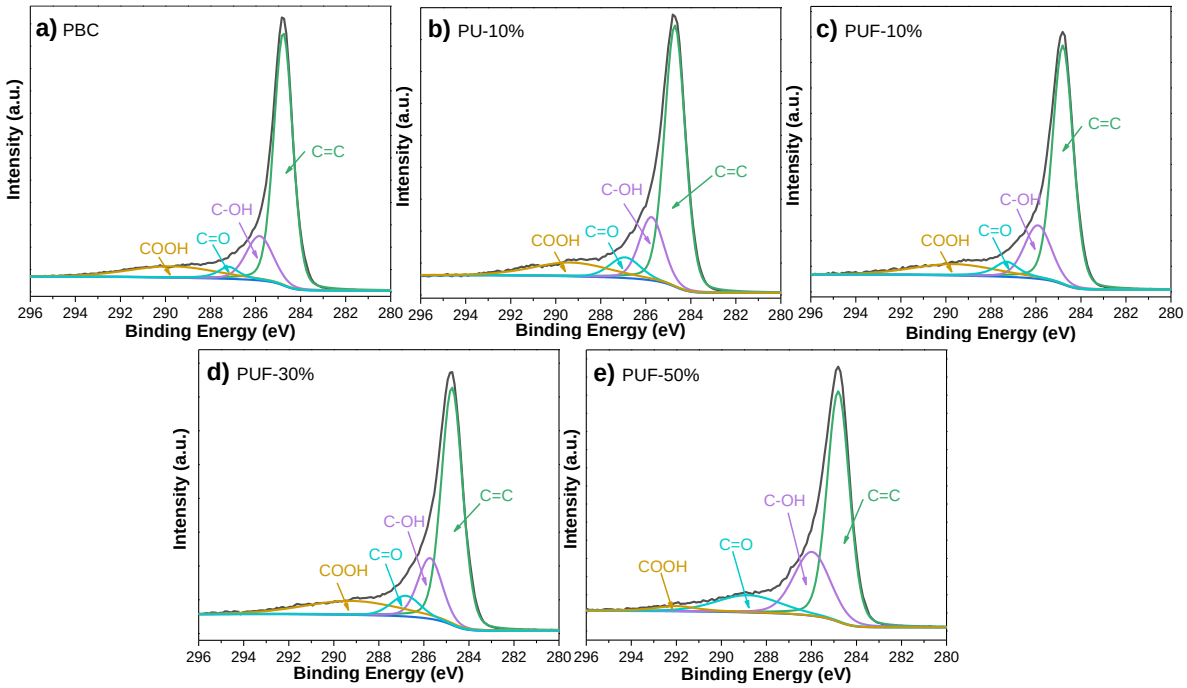


**Figure S1.** The C1s spectra of a) PBC, b) PU-10%, c) PUF-10%, d) PUF-30%, and e) PUF-50%. PBC stands for biochar prepared by poplar; PU1 stands for biochar prepared by poplar and urea with the mass ratio of urea being 10%; PUF-X stands for biochar prepared by poplar and urea formaldehyde with the mass ratio of urea formaldehyde being 10%, 30% and 50%.

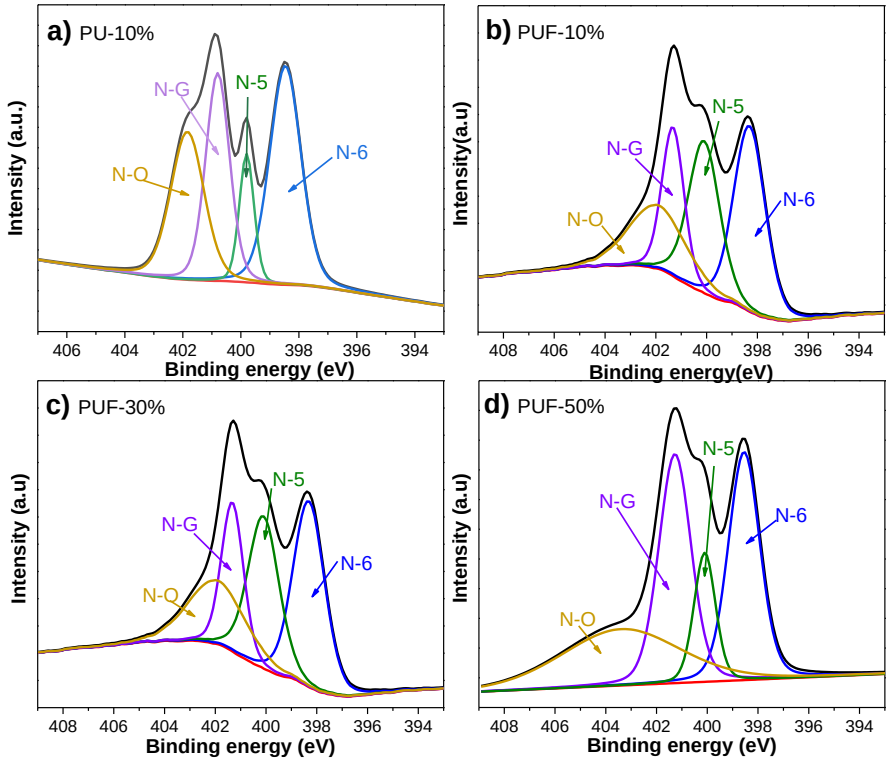


**Figure S2.** The N1s spectra of a) PU-10%, b) PUF-10%, c) PUF-30%, and d) PUF-50%.

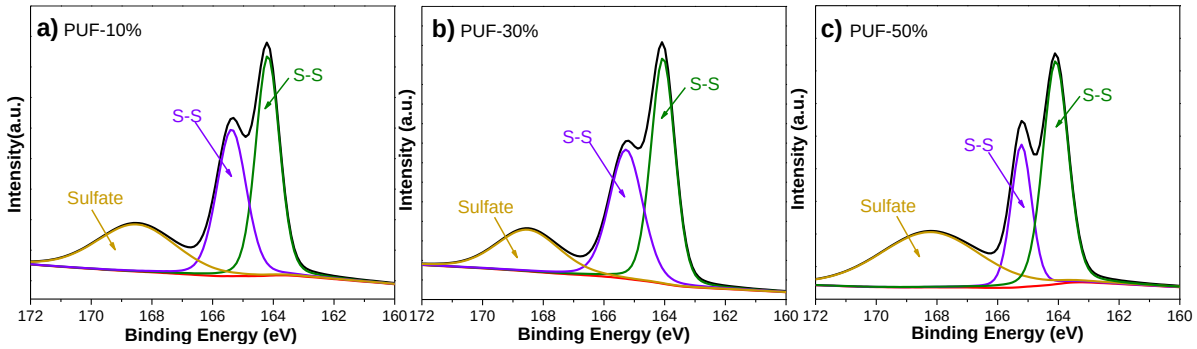


**Figure S3.** The S2p spectra of a) PUF-10%, b) PUF-30%, and c) PUF-50%.

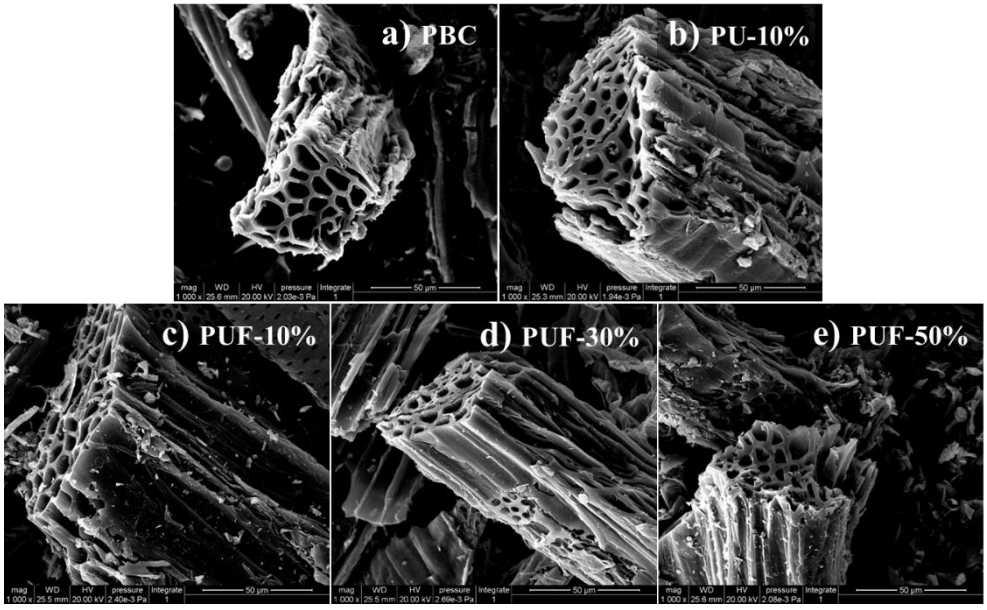


**Figure S4.** SEM images of a) PBC, b) PU-10%, c) PUF-10%, d) PUF-30%, and e) PUF-50%.

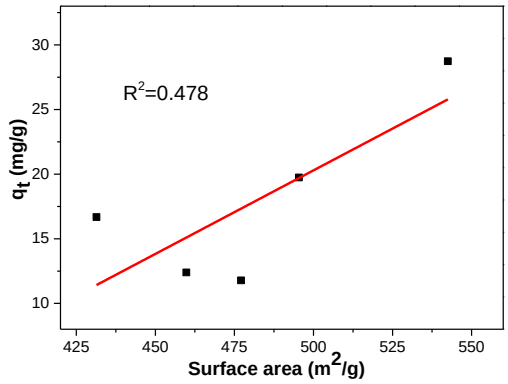


**Figure S5.** The correlations between surface area of biochar and adsorption capacity.

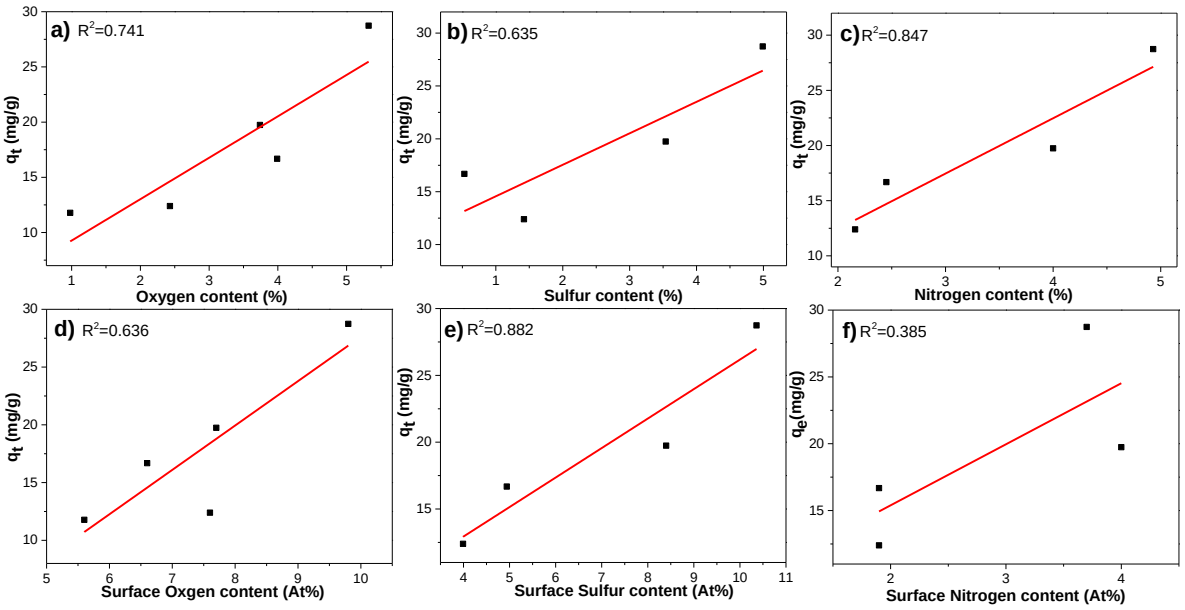


**Figure S6.** The correlations between a) oxygen content, b) sulfur content, c) nitrogen content, d) surface oxygen content, e) surface sulfur content, and f) surface nitrogen content of biochar and adsorption capacity.

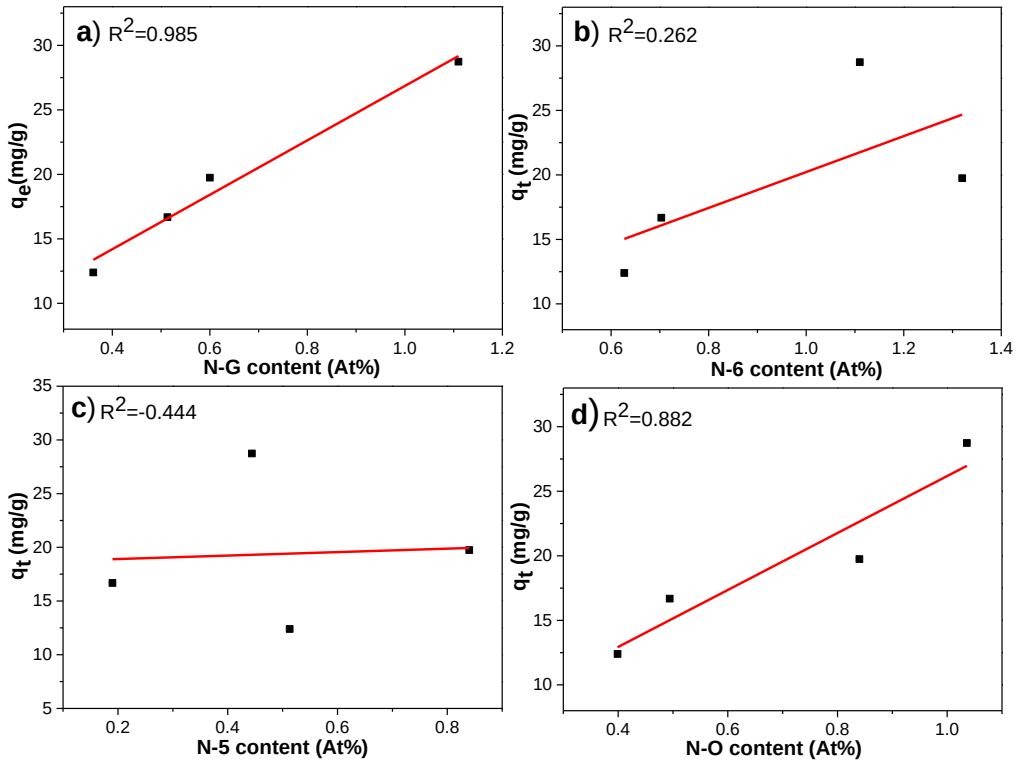


**Figure S7.** The correlations between a) N-G content, b) N-6 content, c) N-5 content, and d) N-O content of biochar and adsorption capacity.

**References:**

[1] H.R. Pouretedal and N. Sadegh,Effective removal of Amoxicillin, Cephalexin, Tetracycline and Penicillin G from aqueous solutions using activated carbon nanoparticles prepared from vine wood,*Journal of Water Process Engineering.* 1 (2014), 64-73.

[2] J. Torres-Pérez, C. Gérente and Y. Andrès,Sustainable Activated Carbons from Agricultural Residues Dedicated to Antibiotic Removal by Adsorption,*Chin. J. Chem. Eng.* 20 (2012), 524-529.

[3] X. Zhu, Y. Liu, F. Qian, et al.,Preparation of magnetic porous carbon from waste hydrochar by simultaneous activation and magnetization for tetracycline removal,*Bioresour. Technol.* 154 (2014), 209-214.

[4] Y. Dai, J. Li and D. Shan,Adsorption of tetracycline in aqueous solution by biochar derived from waste Auricularia auricula dregs,*Chemosphere.* 238 (2020), 124432.

[5] H.M. Jang, S. Yoo, Y.K. Choi, et al.,Adsorption isotherm, kinetic modeling and mechanism of tetracycline on Pinus taeda-derived activated biochar,*Bioresour. Technol.* 259 (2018), 24-31.

[6] H. Wang, Y. Chu, C. Fang, et al.,Sorption of tetracycline on biochar derived from rice straw under different temperatures,*PLoS ONE.* 12 (2017), e0182776.

[7] D. Xu, Y. Gao, Z. Lin, et al.,Application of Biochar Derived From Pyrolysis of Waste Fiberboard on Tetracycline Adsorption in Aqueous Solution,*Front Chem.* 7 (2019), 943.