Electronic Supplementary Material (ESI) for Environmental Science: Nano.

Supplementary materials

Biowaste valorization: multifunctional hybrid Lignin/TiO_2 nanostructures for bacterial-biocide disinfection and dye removal.

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Summary

S.1. Experimental Setup

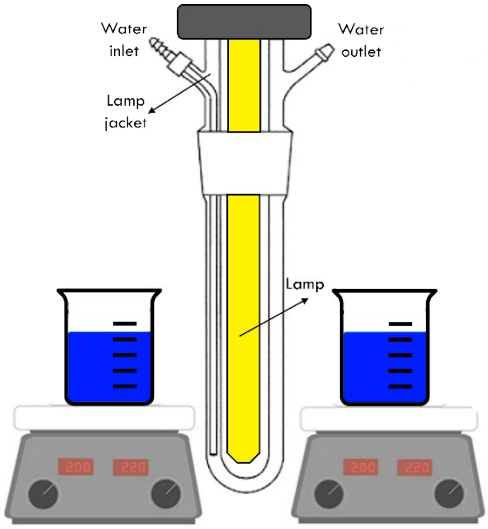

Figure S-1. Schematic illustration of the experimental set-up used for the photodegradation experiments.

S.2. Materials characterization

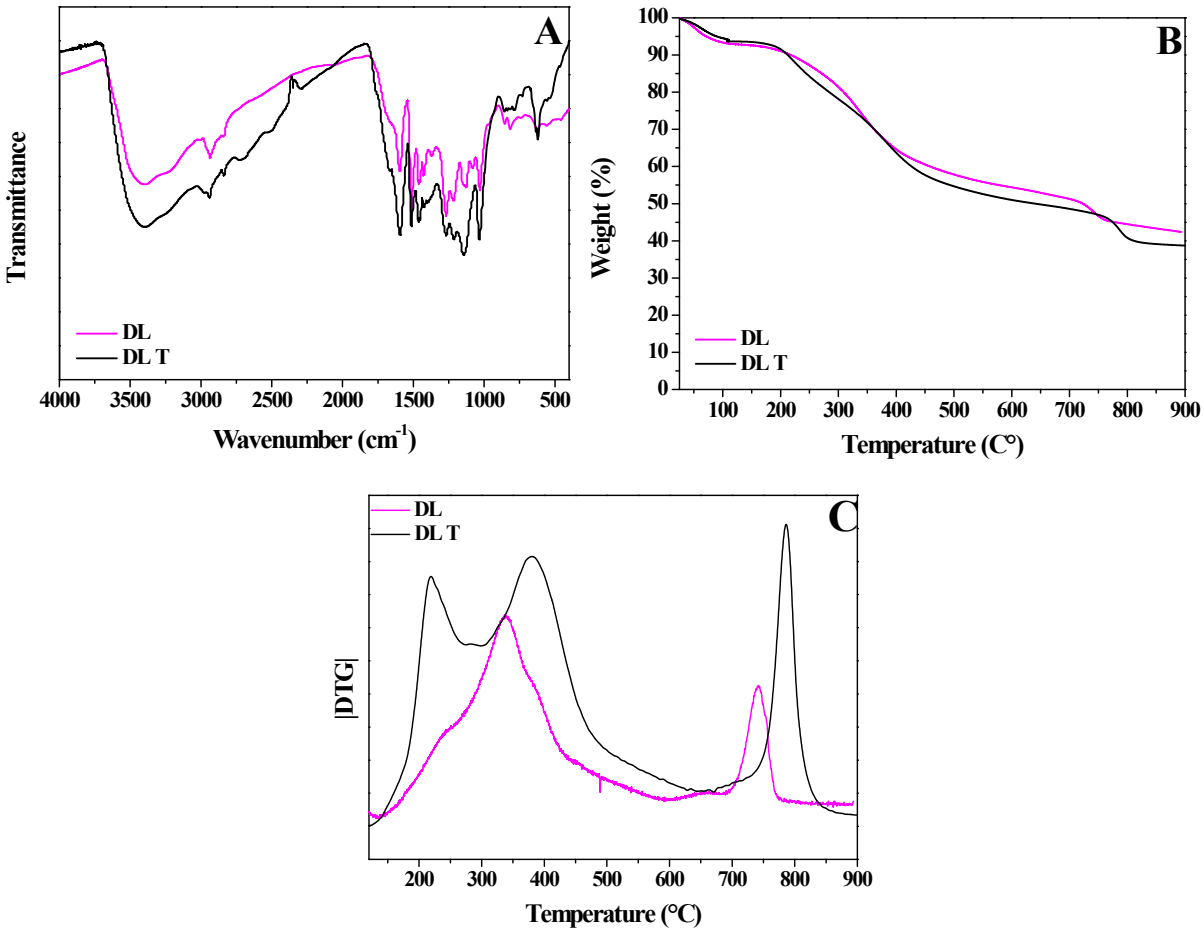

Figure S-2. FT-IR curves of DL and DL T (Panel A); TGA curves of DL and DL T samples (Panel B); DTG curves of DL and DL T samples (Panel C).

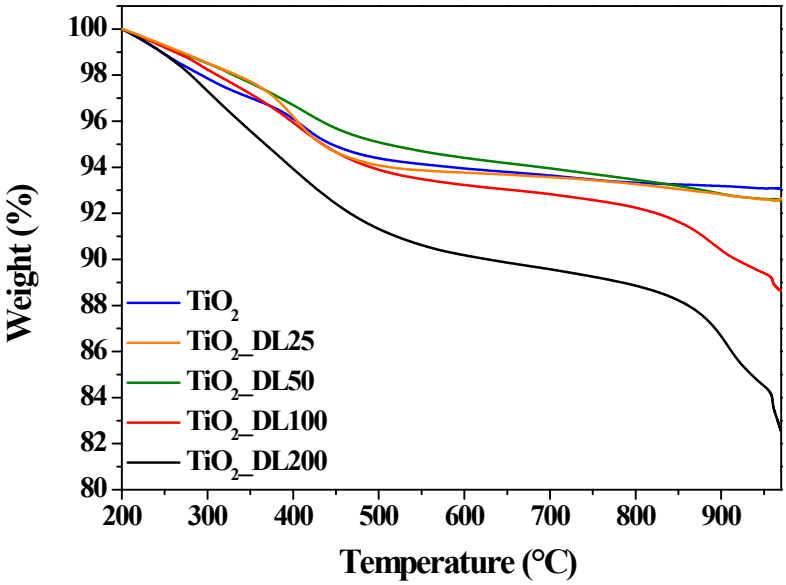

Figure S-3. TGA Curves of Bare TiO_2 and hybrid nanoparticles.

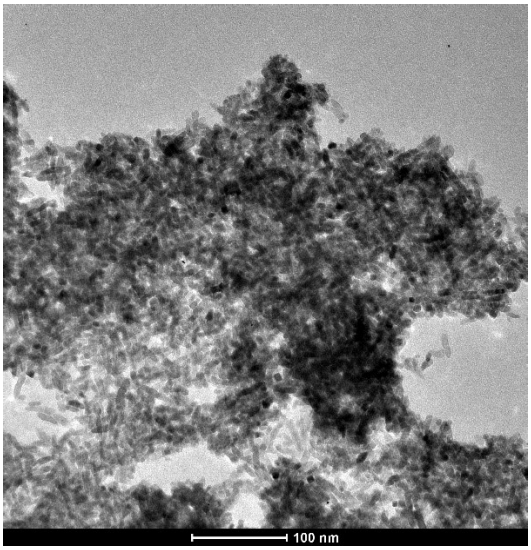

Figure S-4. TEM Micrograph of TiO_2 nanoparticles.

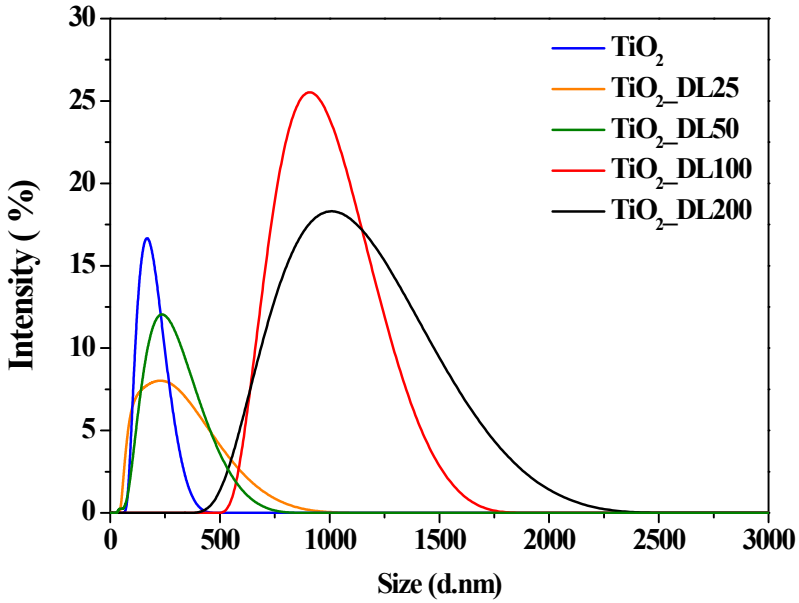

Figure S-5: Size distribution of bare TiO_2 and hybrid TiO_2_DL nanoparticles.

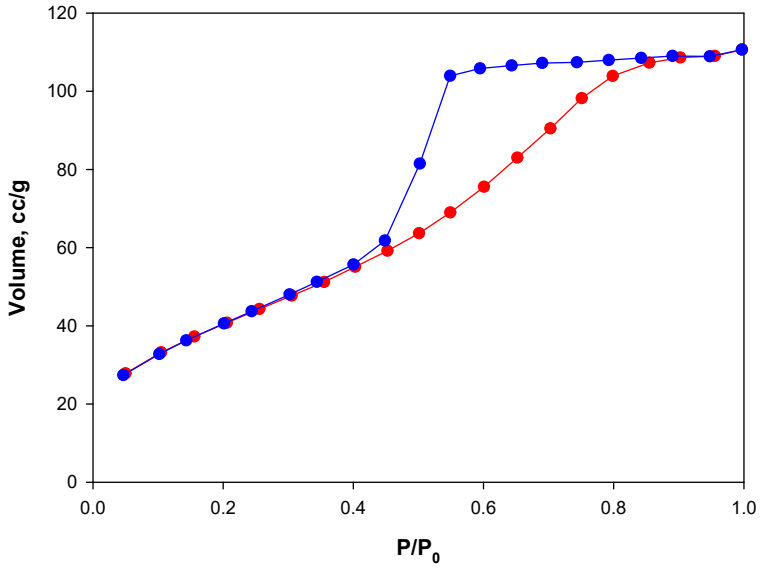

Figure S-6. N_2 adsorption isotherms at 77 K representative of all nanoparticles.

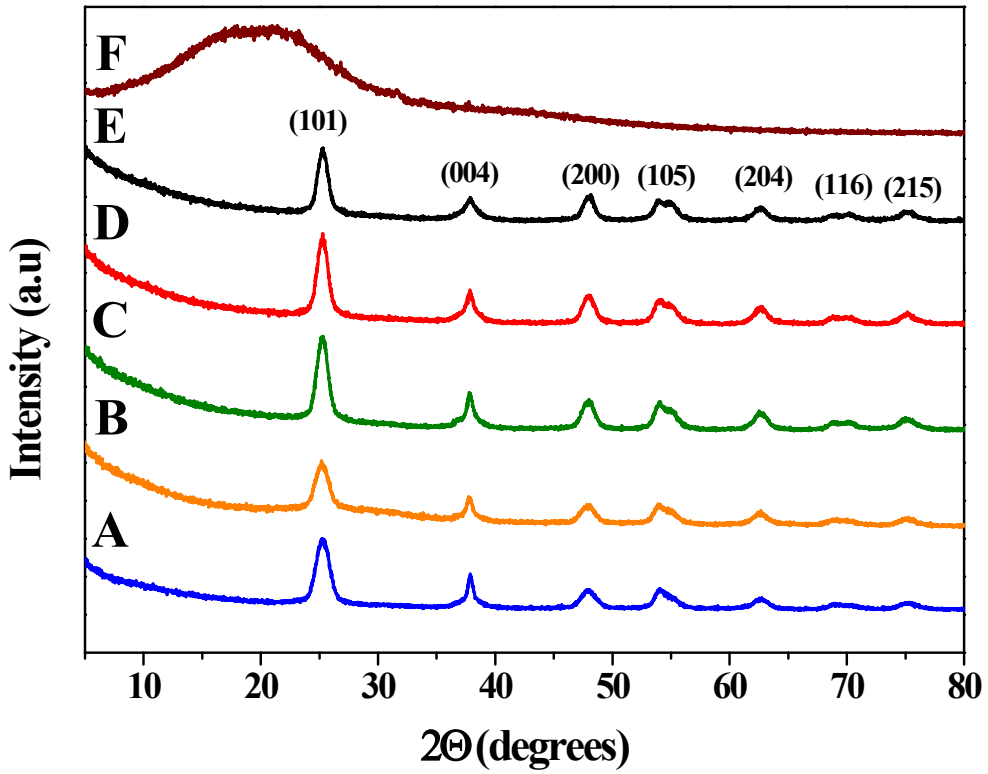

Figure S-7. XRD Spectra of: A) TiO_2, B) TiO_2_DL25, C) TiO_2_DL50, D) TiO_2_DL100, E) TiO_2_DL200, F) DL T.

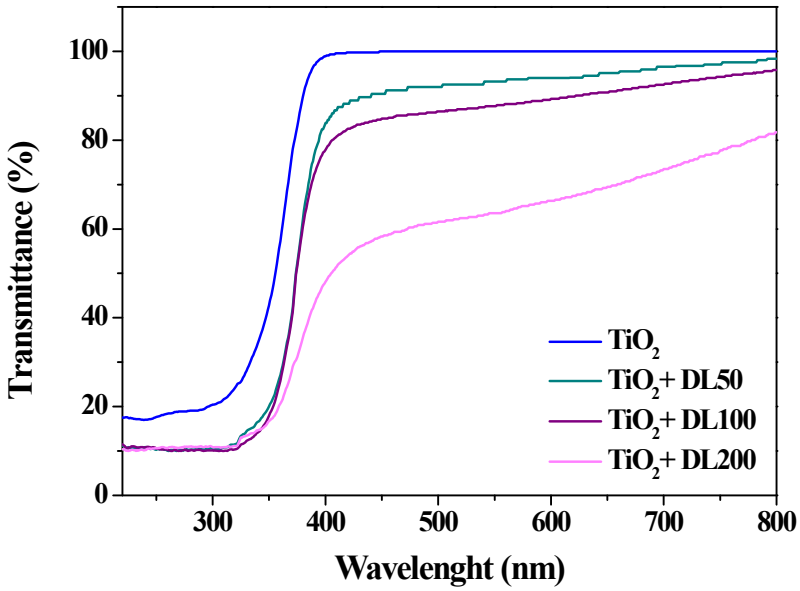

Figure S-8. Transmittance spectra of bare TiO_2 and of physical mixtures of TiO_2 + DL50, TiO_2 + DL100 and TiO_2 + DL200 nanoparticles.

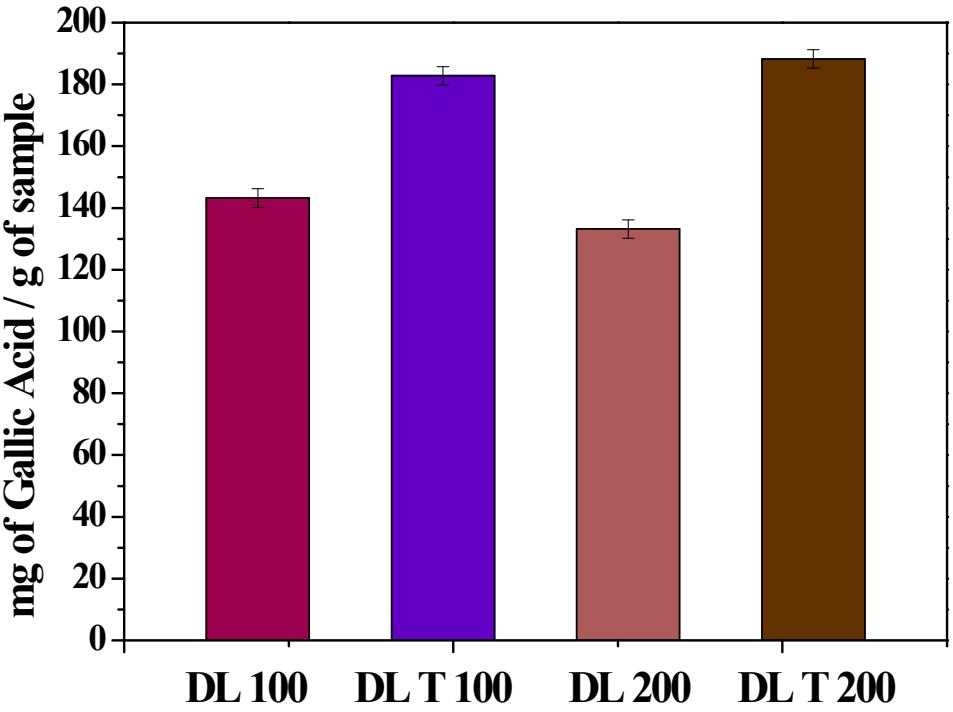

Figure S-9. Total phenolic content of DL100, DL T100, DL200, DL T200 solutions.

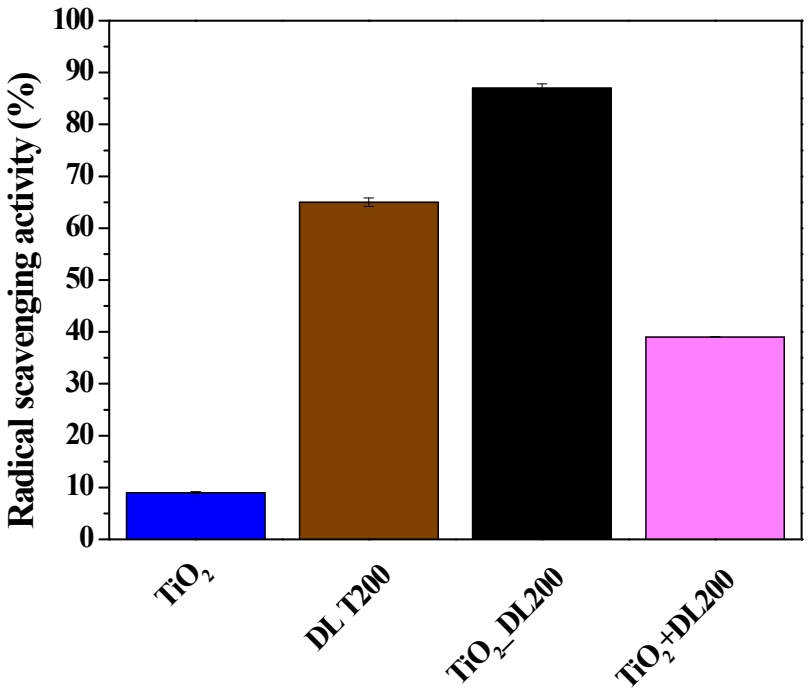

Figure S-10. ABTS radical scavenging activity of TiO_2, DL T200, TiO_2_DL200 and TiO_2 + DL200. samples.

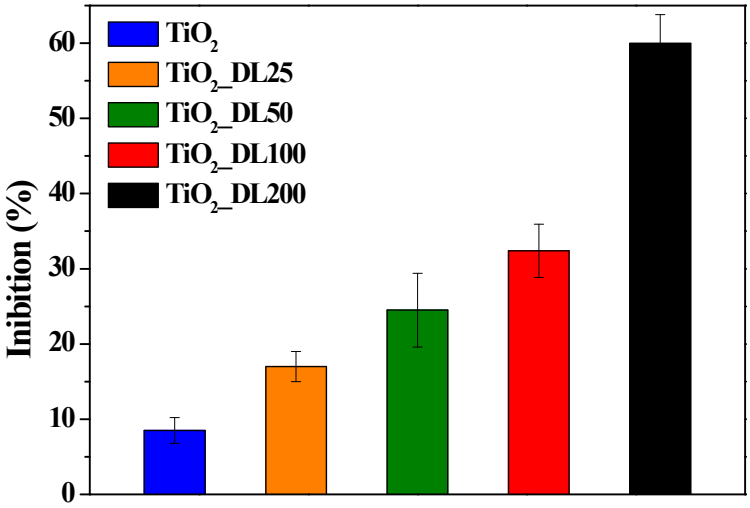

Figure S-11: DPPH analysis on TiO2, TiO2_DL100 and TiO2_DL200 nanomaterials.

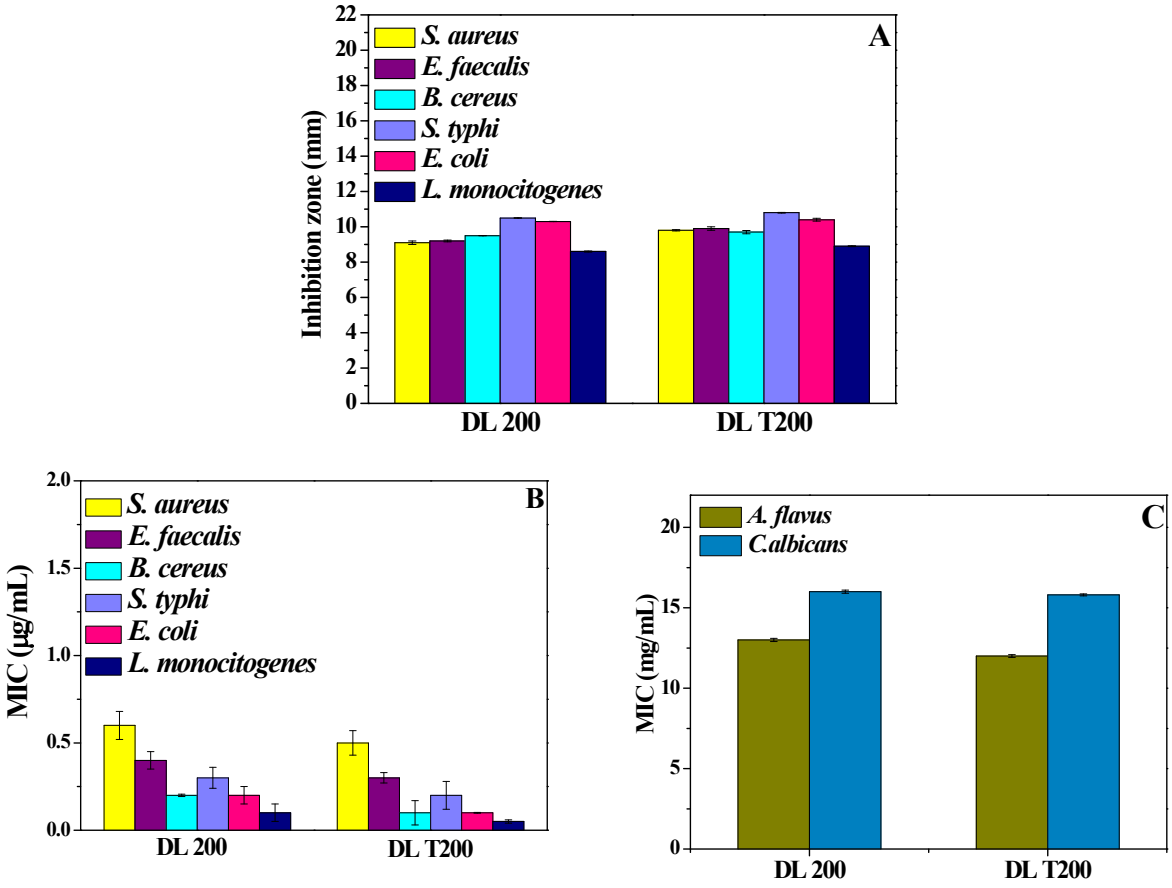

Figure S-12. DDK results (A), MIC against Gram (+) and Gram (-) bacterial (B), MIC against fungi of neat lignin aqueous solution (DL 200) and lignin aqueous solution after the hydrothermal treatment (DL T200) (C).

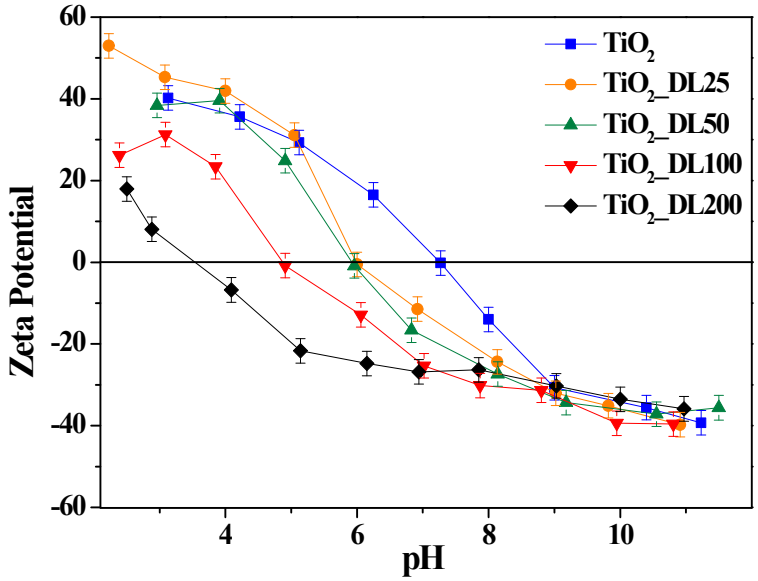

Figure S-13. pH_{zpc} of all nanoparticles.

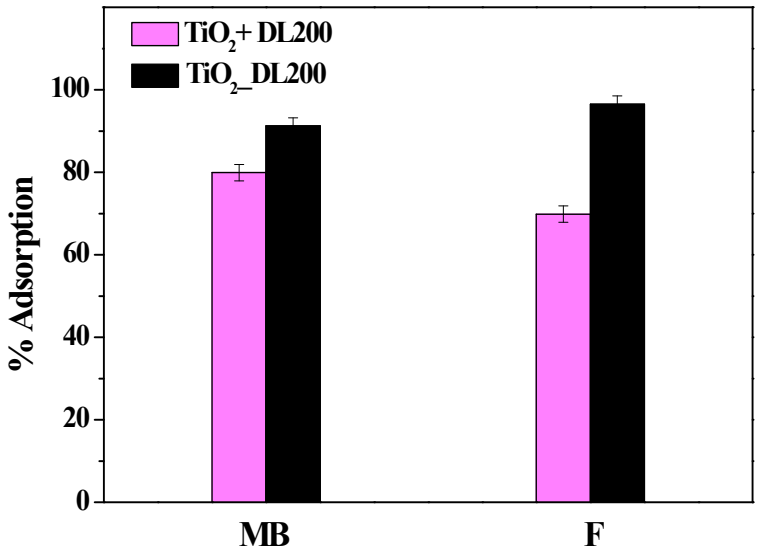

Figure S-14. % MB and % F adsorption capacity of TiO_2_DL200 hybrid nanoparticles and TiO_2 + DL200 physical mixture; t = 60 min; pH = 5.0; T = 25 °C.

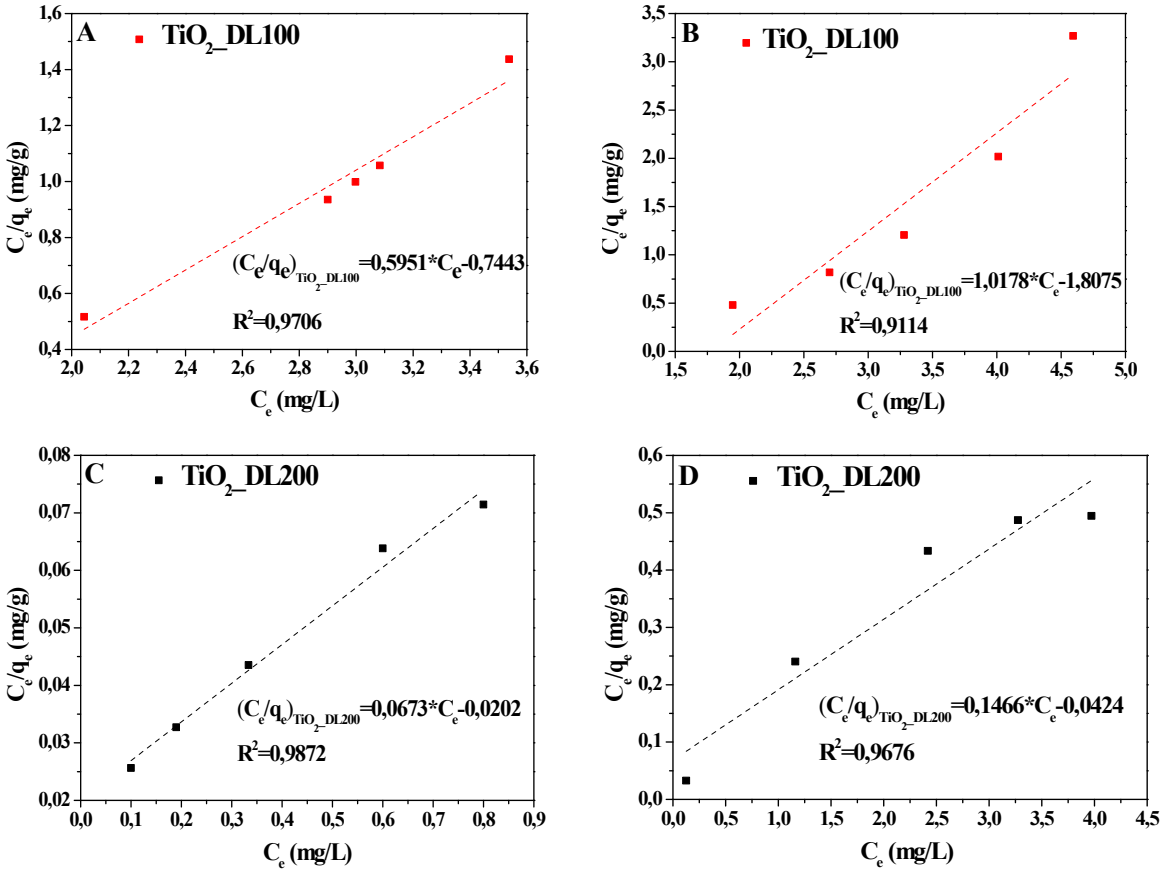

Figure S-15. Langmuir adsorption isotherms for MB (A, C) and F (B, D) dyes in the case of TiO_2_DL100 and TiO_2_DL200 nanoparticles; pH = 5.0; T = 25°C.

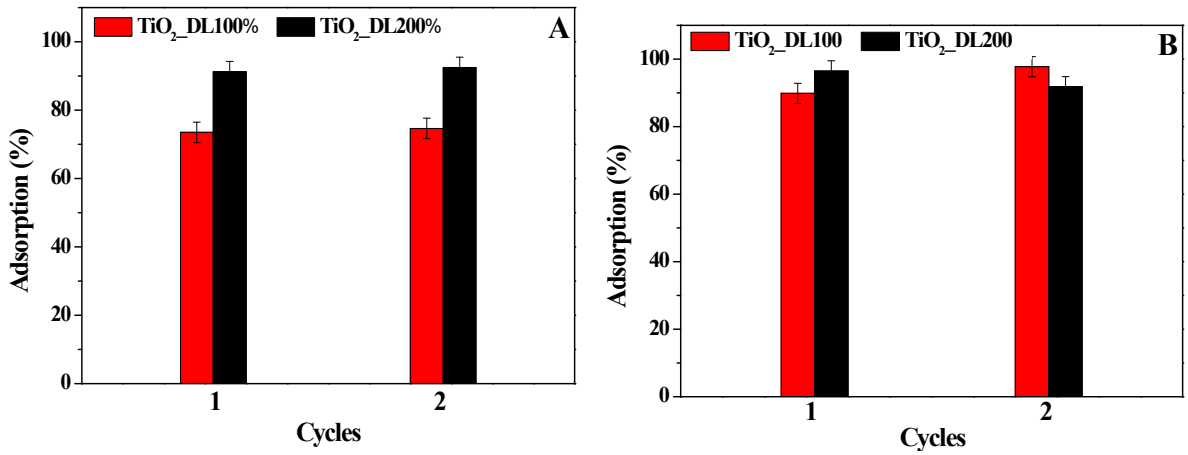

Figure S-16. Operational stability of TiO_2_DL100 and TiO_2_DL200 after two cycles for A) MB and B) F adsorption. t = 60 minutes; pH = 5.0; T = 25 °C.

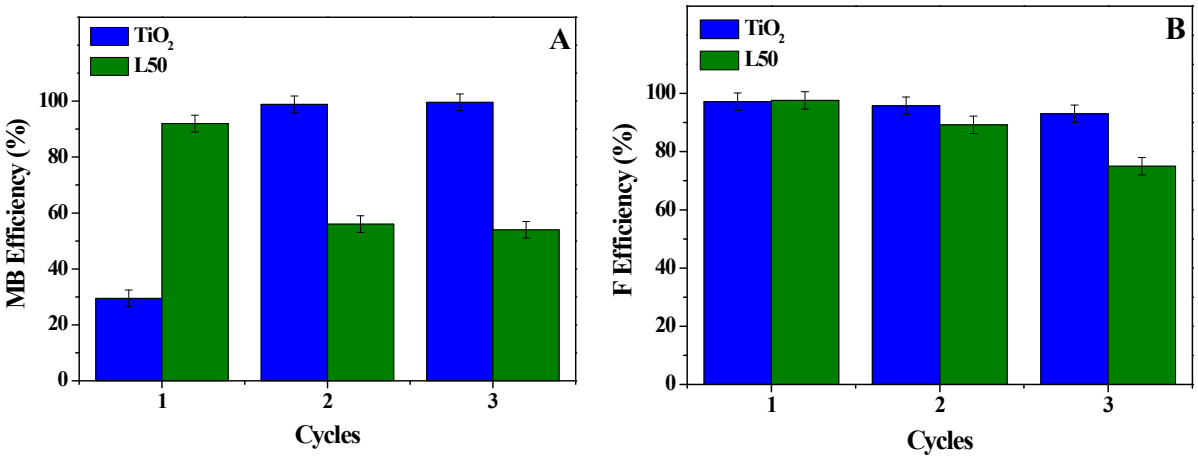

Figure S-17. Operational stability of TiO_2 and TiO_2_DL50 after up to three cycles for A) MB and B) F photocatalytic removal. Reaction time = 120 minutes.

Table S-1: Assignment of FTIR bands of lignin.

Functional group assignment	**Wavenumber (cm^{-1})**
-OH stretching vibration in aromatic and aliphatic hydroxyl groups	3425
C–H asymmetrical and symmetrical vibrations of the methyl (-CH_3)	2940
C–H asymmetrical and symmetrical vibrations of the methylene (-CH_2)	2842
Vibration of aromatic rings	1590, 1510, and 1420
Methoxyl C–H bending	1461
Aromatic C–O stretching of Syringyl units	1350
Aromatic C–O stretching of Guaiacyl units	1265
Phenolic -OH units	1220
Aromatic C-H in plain deformation of the syringyl unit	1128
C-O stretching of secondary alcohol	1084
C-O stretching of primary alcohol	1012
Stretching vibration of aliphatic OH/ether	1030
Aromatic C-H vibration out of plain deformation	852 and 810
Out-of-plane bending of C–OH	620

Table S-2. Hydrodynamic diameters and Zeta potential values of nanoparticles

Sample	**Hydrodinamic diameter (D_h) (nm)**	**Standard deviation**	**Zeta Potential (mV)**	**Standard deviation**
TiO_2	165	± 2.9	25	± 2
TiO_2_DL25	226	± 4.6	23	± 1

TiO_2_DL50	236	± 4.3	-1	± 1
TiO_2_DL100	910	± 1.4	-15	± 1
TiO_2_DL200	1016	± 4.0	-17	± 2

Table S-3. Mean crystalline size of all nanoparticles.

Sample	**Crystalline size (nm)**
TiO_2	≈ 7
TiO_2_DL25	≈ 7
TiO_2_DL50	≈ 7
TiO_2_DL100	≈ 8
TiO2_DL200	≈ 12