Supporting information

Supplementary experimental section, 2 Tables and 15 Figures are included

Treated Rape Pollen: A Metal-free Visible-Light-Driven Photocatalyst from Nature for Efficient Water Disinfection

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Supplementary experimental section

Preparation of the other common waterborne bacteria

To prepare the other common waterborne bacteria for disinfection study, the other three bacterial strains including *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Bacillus pumilus* were inoculated in 50 mL LB broth (Lab M, Lancashire, UK) respectively. Then the bacteria were incubated at 37 °C in a shaking incubator for. After 16 h, 1 mL bacterial culture medium was collected and centrifuged by 13000 rpm for 5 min. The cell pellets were resuspended by 1 mL ultrapure water. To adjust all the bacterial concentration to 1×10^7 cell/mL, 100 uL of *P. aeruginosa*, 800 uL of *S. aureus* and 1000 uL of *B. pumilus* were added into 50 mL saline then mixed well, respectively.

Table S1. Comparison of the photocatalytic water disinfection performance between the TRP in this study and other recently reported photocatalysts.

Photocatalysts	Light source	Intensity (W/m^2)	Bacterial species	Disinfection performance	Ref.
TRP in this study (0.5 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1000	*E. coli* K-12 (1×10^7 CFU/mL)	~ 7 log in 4h	
HTCC (glucose) (0.2 g/L)	300W Xe lamp ($\lambda > 420$ nm)	2000	*E. coli* K-12 (1×10^7 CFU/mL)	no activity	[1]
I-HTCC (straw) (0.2 g/L)	300W Xe lamp ($\lambda > 420$ nm)	2000	*E. coli* K-12 (1×10^7 CFU/mL)	~ 2 log in 3h	[1]
I-HTCC (grass) (0.2 g/L)	300W Xe lamp ($\lambda > 420$ nm)	2000	*E. coli* K-12 (1×10^7 CFU/mL)	~ 4 log in 3h	[1]
I-HTCC (starch) (0.2 g/L)	300W Xe lamp ($\lambda > 420$ nm)	2000	*E. coli* K-12 (1×10^7 CFU/mL)	~ 6 log in 3h	[1]
g-C_3N_4 (CN-12) (1.0 g/L)	300W Xe lamp ($\lambda > 400$ nm)	NA	*E. coli* K-12 (2.5×10^6 CFU/mL)	~ 1 log in 6h	[2]
g-C_3N_4 (CN-128) (1.0 g/L)	300W Xe lamp ($\lambda > 400$ nm)	NA	*E. coli* K-12 (2.5×10^6 CFU/mL)	~ 6 log in 6h	[2]
g-C_3N_4 bulk (0.1 g/L)	500W Xe lamp ($\lambda > 400$ nm)	1000	*E. coli* K-12 (2×10^7 CFU/mL)	~ 3 log in 4h	[3]
g-C_3N_4 nanosheet (0.1 g/L)	500W Xe lamp ($\lambda > 400$ nm)	1000	*E. coli* K-12 (2×10^7 CFU/mL)	~ 5 log in 4h	[3]
g-C_3N_4 single layer (0.1 g/L)	500W Xe lamp ($\lambda > 400$ nm)	1000	*E. coli* K-12 (2×10^7 CFU/mL)	~ 7 log in 4h	[3]
Red phosphorus* (0.1 g/L)	300W Xe lamp ($\lambda > 420$ nm)	1930	*E. coli* K-12 (2×10^7 CFU/mL)	~ 7 log in 2h	[4]
Elemental α-S_8 (0.1 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1930	*E. coli* K-12 (2×10^6 CFU/mL)	~ 2 log in 4h	[5]
RGO/g-C_3N_4/α-S_8 (0.1 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1930	*E. coli* K-12 (2×10^6 CFU/mL)	~ 7 log in 4h	[5]
g-C_3N_4/RGO/α-S_8 (0.1 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1930	*E. coli* K-12 (2×10^6 CFU/mL)	~ 4 log in 4h	[5]
g-C_3N_4 wrapped α-S_8 (0.1 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1930	*E. coli* K-12 (2×10^6 CFU/mL)	~ 3 log in 4h	[5]
RGO wrapped α-S_8 (0.1 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1930	*E. coli* K-12 (2×10^6 CFU/mL)	~ 3 log in 4h	[5]
RGO/g-C_3N_4 nanosheets (0.1 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1930	*E. coli* K-12 (2×10^6 CFU/mL)	~ 3 log in 4h	[5]
TiO_2/g-C_3N_4 (1.0 g/L)	300W Xe lamp ($\lambda > 420$ nm)	300	*E. coli* (1×10^7 CFU/mL)	~ 7 log in 3h	[6]
Bi_2MoO_6/g-C_3N_4** nanosheets (0.1 g/L)	300W Xe lamp ($\lambda > 420$ nm)	NA	*E. coli* DH5α (2.5×10^7 CFU/mL)	~ 6 log in 4h	[7]
Ag(0.5)/g-C_3N_4 (0.1 g/L)	300W Xe lamp ($\lambda > 420$ nm)	NA	*E. coli* (1×10^7 CFU/mL)	~ 1 log in 1.5h	[8]
Ag(1)/g-C_3N_4 (0.1 g/L)	300W Xe lamp ($\lambda > 420$ nm)	NA	*E. coli* (1×10^7 CFU/mL)	~ 3 log in 1.5h	[8]
Ag(2)/g-C_3N_4 (0.1 g/L)	300W Xe lamp ($\lambda > 420$ nm)	NA	*E. coli* (1×10^7 CFU/mL)	~ 4 log in 1.5h	[8]

Bi_2O_4/g-C_3N_4 (0.25:1) (0.4 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1930	*E. coli* K-12 (1×10^6 CFU/mL)	~ 5 log in 2h	[9]
TiO_2/graphene (1.0 g/L)	450W Xe lamp (visible light)	NA	*E. coli* PTCC 1330 (NA)	~ 1 log in 7h	[10]
ZnO/graphene (3.3 g/L)	UV light	NA	*E. coli* KCCM12119 (1×10^5 CFU/mL)	~ 1 log in 3h	[11]
TiO_2/Ag_3PO_4/graphene (0.5 g/L)	350W Xe lamp ($\lambda > 420$ nm)	NA	*E. coli* (1×10^6 CFU/mL)	~ 5 log in 4h	[12]
TRP in this study (0.5 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1000	*S. aureus* (1×10^7 CFU/mL)	~ 7 log in 2h	
g-C_3N_4/TiO_2/kaolinite	8W fluorescent lamp	NA	*S. aureus* (1×10^7 CFU/mL)	~ 3 log in 5h	[13]
TiO_2/Ag_3PO_4/graphene (0.5 g/L)	350W Xe lamp ($\lambda > 420$ nm)	NA	*S. aureus* (1×10^6 CFU/mL)	~ 5 log in 4h	[12]
Polythiophene/MnO_2 (1 g/L)	Solar irradiation	NA	*S. aureus* (5×10^3 CFU/mL)	~ 1 log in 5h	[14]
TRP in this study (0.5 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1000	*B. pumilus* (1×10^7 CFU/mL)	~ 3 log in 4h	
TiO_2/Ag_3PO_4/graphene (0.5 g/L)	350W Xe lamp ($\lambda > 420$ nm)	NA	*B. pumilus* (1×10^6 CFU/mL)	~ 5 log in 4h	[12]
TRP in this study (0.5 g/L)	300W Xe lamp ($\lambda > 400$ nm)	1000	*P. aeruginosa* (1×10^7 CFU/mL)	~ 7 log in 1h	
TiO_2/Ag_3PO_4/graphene (0.5 g/L)	350W Xe lamp ($\lambda > 420$ nm)	NA	*P. aeruginosa* (1×10^6 CFU/mL)	~ 5 log in 4h	[12]
Ag-TiO_2 film	UV lamp	NA	*P. aeruginosa* (1×10^3 CFU/mL)	~ 3 log in 1h	[15]

NA: Not available

* Phosphate buffer solution (PBS, pH 7.0) is required in the experiment.

** Sacrificial agents are required

Table S2. Variation of the light intensity in the real solar experiment.

Time		Solar intensity (W m^{-2})	UVA (μW cm^{-2})	UVB (μW cm^{-2})	UVC (μW cm^{-2})
Day 1	11:00	620	675	685	29
	11:30	690	715	730	31
	12:00	750	780	795	34
	12:30	870	890	905	36
	13:00	900	930	950	37
	13:30	870	890	905	36
	14:00	850	870	895	35
	14:30	790	805	815	35
	15:00	700	720	730	32
Day 2	11:00	870	890	905	36
	11:30	960	985	995	39
	12:00	1020	1035	1050	40
	12:30	1070	1080	1100	42
	13:00	1100	1115	1125	43
	13:30	1020	1035	1050	40
	14:00	940	950	970	38
	14:30	890	905	920	37
	15:00	850	875	890	36
Day 3	11:00	770	795	805	34
	11:30	840	850	865	35
	12:00	940	950	970	38
	12:30	970	985	1000	39
	13:00	990	1105	1115	40
	13:30	910	920	935	38
	14:00	870	890	905	36
	14:30	830	845	855	35
	15:00	800	820	830	35

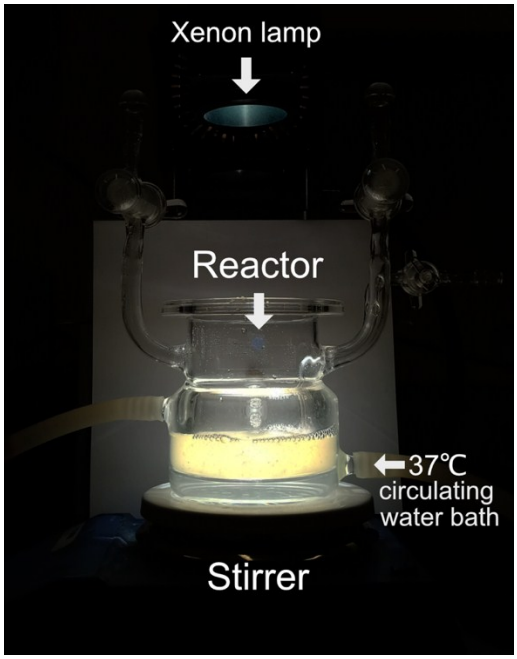

Figure S1. Setup of the photoreactor with temperature controller for photocatalytic disinfection study.

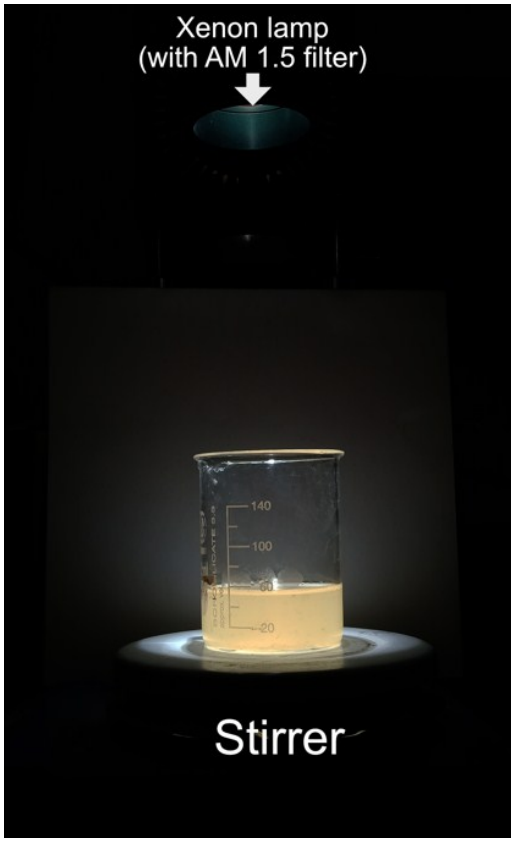

Figure S2. Setup of the practical application study under the simulated solar irradiation. No temperature controller is provided for the reaction.

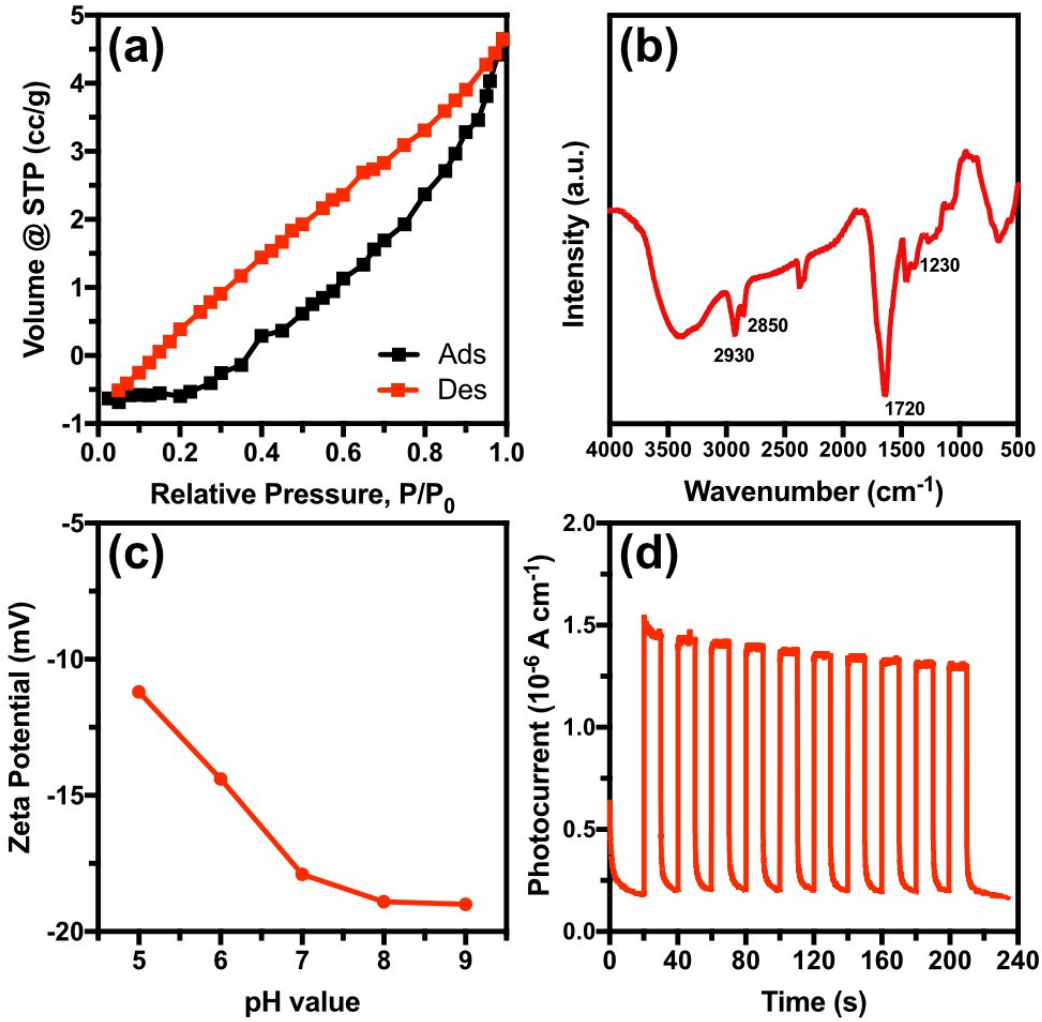

Figure S3. (a) BET specific surface area, (b) FTIR spectra, (c) Zeta-potential and (d) PEC characteristic of the TRP.

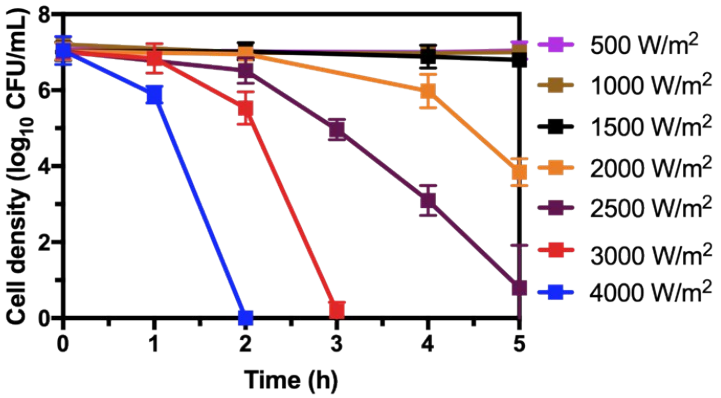

Figure S4. Viability of *E. coli* K-12 under the illumination of visible light with different intensities. The reaction temperature is controlled at 37 °C.

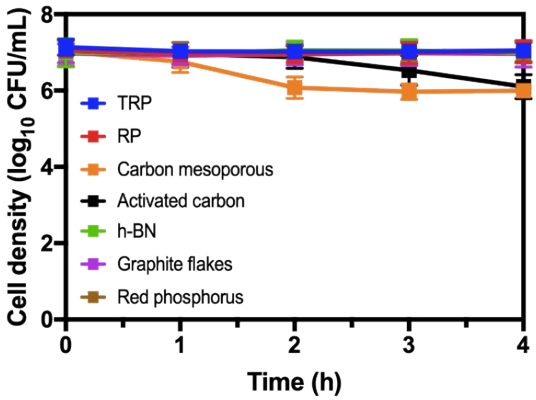

Figure S5. Viability of *E. coli* K-12 mixed with the TRP, RP, h-BN, graphite flakes, activated carbon, carbon mesoporous and red phosphorus in dark. The concentration of all the materials are 0.5 mg mL^{-1}. The reaction temperature is controlled at 37 °C.

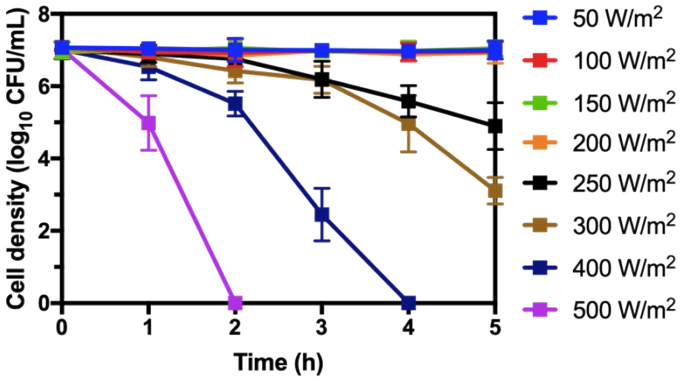

Figure S6. Viability of *E. coli* K-12 under the illumination of full spectrum (xenon lamp without filter) with different intensities. The reaction temperature is controlled at 37 °C.

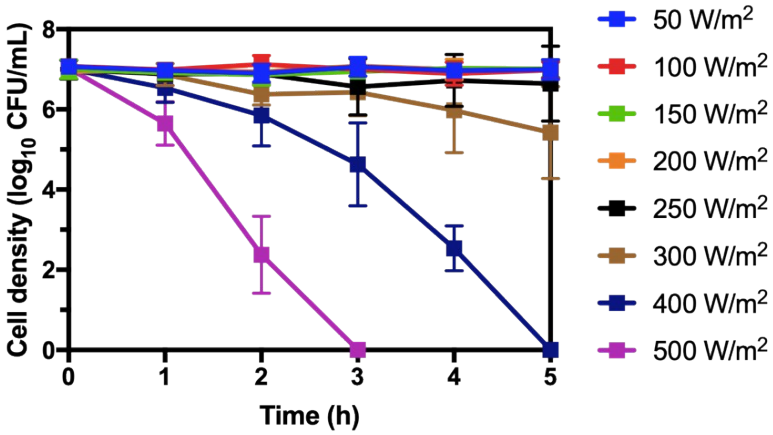

Figure S7. Viability of *E. coli* K-12 under the illumination of solar spectrum (xenon lamp with AM 1.5 filter) with different intensities. The reaction temperature is controlled at 37 °C.

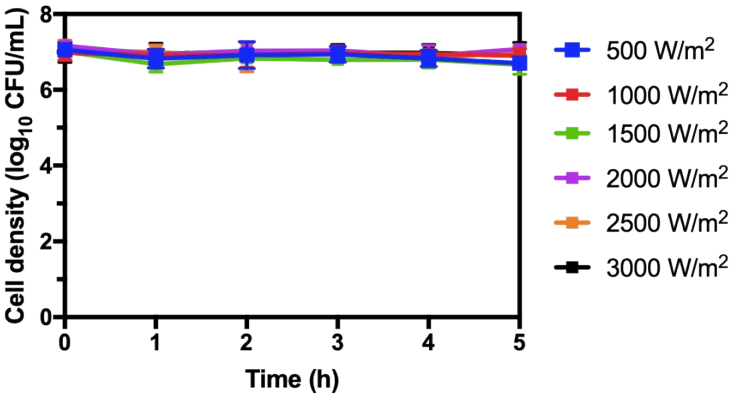

Figure S8. Viability of *E. coli* K-12 under the illumination of NIR spectrum (xenon lamp with NIR filter) with different intensities. The reaction temperature is controlled at 37 °C.

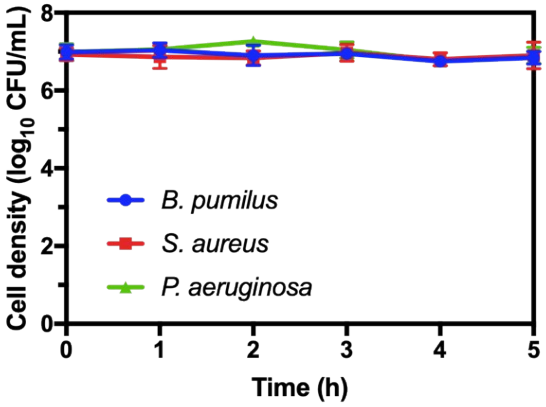

Figure S9. Viability of *B. pumilus*, *S. aureus* and *P. aeruginosa* mixed with the TRP in dark.

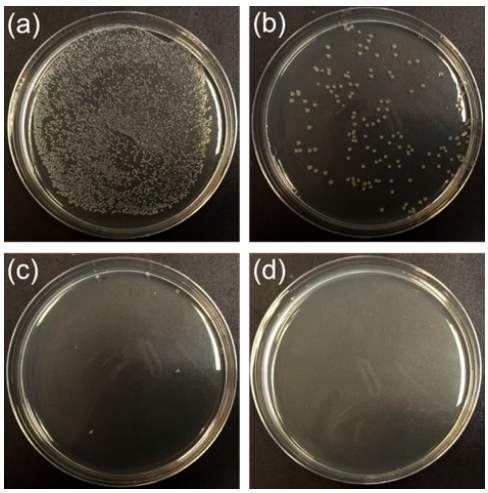

Figure S10. Spreading plate study of the *E. coli* K-12 collected at (a) 0 min, (b) 60 min (c) 120 min and (d) 240 min during the photocatalytic disinfection by TRP.

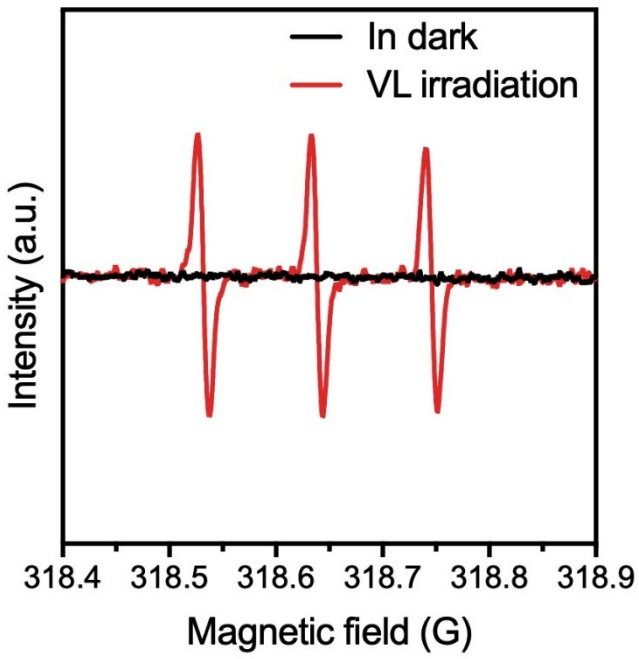

Figure S11. ESR analysis for $^1O_2$ generation by TRP under VL irradiation and in dark.

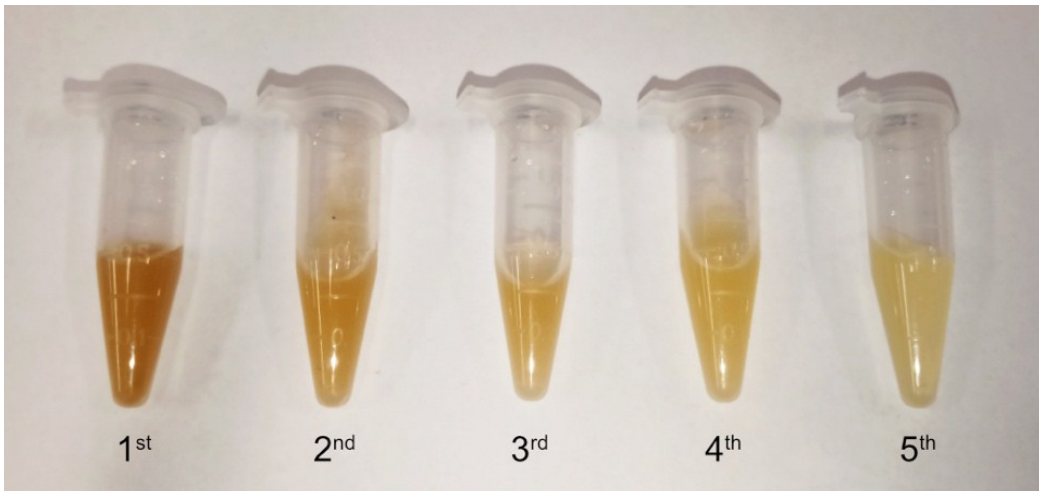

Figure S12. Color variation of the TRP disinfection system from 1st to 5th run under the irradiation of VL (1000 W m^{-2} provided by xenon lamp with UV cut-off filter).

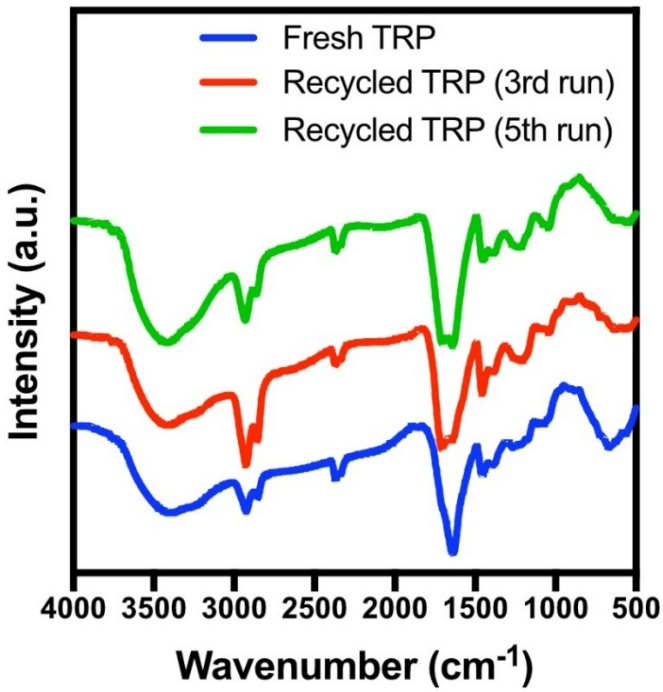

Figure S13. FTIR spectrum of the fresh TRP, recycled TRP from 3rd run and 5th run.

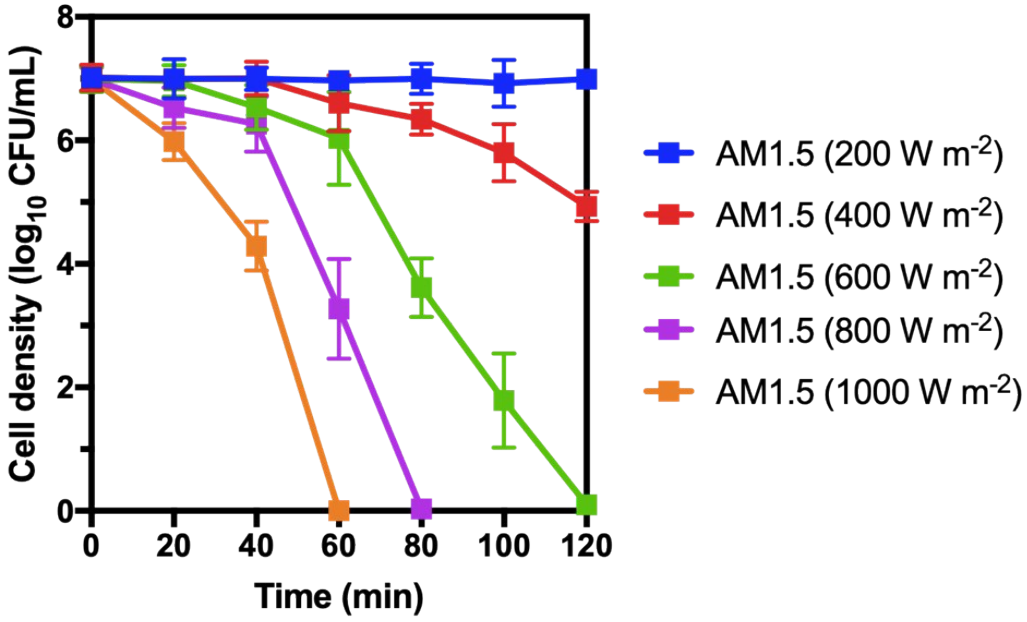

Figure S14. Control experiment of simulated solar disinfection (AM1.5 filter) of *E. coli* K-12 without temperature control.

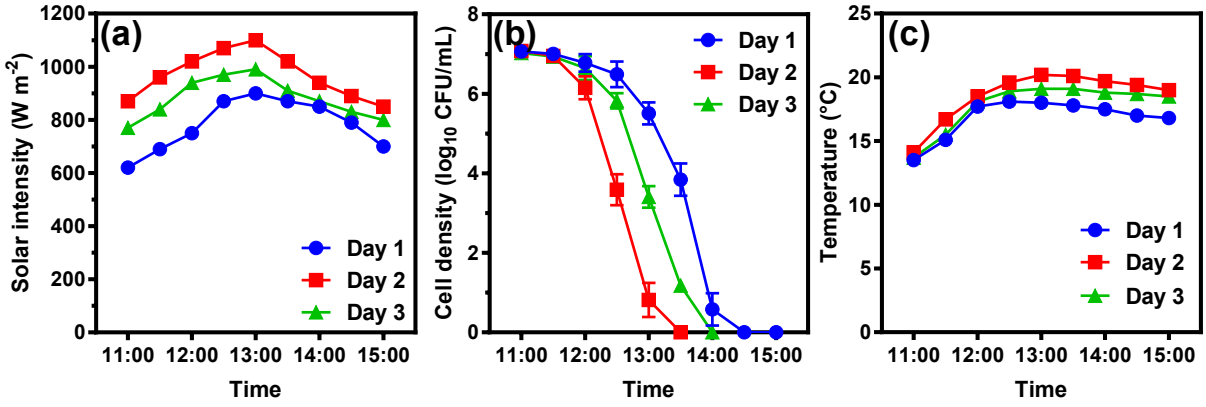

Figure S15. Photocatalytic disinfection of *E. coli* K-12 (1×10^7 CFU mL^{-1}) by the TRP (0.5 g/L) under real sunlight irradiation. (a) variation of solar intensity, (b) variation of living cell density, and (c) variation of the temperature.

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