

Supplementary materials

Piezoelectric-enhanced photocatalytic purification of wastewater containing tetracycline via MoS₂/ZnO heterojunction

1 Materials

TC (99.5%), ammonium oxalate (AO, 99.9%), tert-butyl alcohol (TBA, 99.5%), 1,4-Benzoquinone (BQ, 99%), zinc acetate dihydrate, methanol solution, sodium hydroxide solution, 1-butyl-3-methylimidazolium chloride (BMIM[Cl], 97%) and sodium molybdate dihydrate (Na₂MoO₄·2H₂O, 98%) were obtained from Aladdin. Thiourea (CH₄N₂S, 99%) was obtained from Shanghai Zhanyun Chemical Co., Ltd. hydrochloric acid (HCl, 36%–38%) was obtained from Sinopharm Chemical Reagent Co.,Ltd. All reagents were of analytical grade.

2 Experimental

2.1 Synthesis of ZnO

Zinc acetate dihydrate (0.2195 g) was dissolved in 10 mL of methanol. Separately, NaOH (0.400 g) was dissolved in 20 mL of methanol. The two solutions were combined and magnetically stirred until a homogeneous suspension formed. The mixture was transferred to a 50 mL Teflon-lined stainless-steel autoclave and subjected to solvothermal treatment at 150 °C for 24 h. After natural cooling to room temperature, the precipitate was collected by centrifugation, thoroughly washed with

deionized water and ethanol, and dried at 60 °C, yielding ZnO nanocrystals.

2.2 Synthesis of MoS₂

Sodium molybdate dihydrate (90 mg) and thiourea (180 mg) were dispersed in 60 mL of deionized water and magnetically stirred for 10 min. The solution was transferred to a Teflon-lined autoclave and heated at 200 °C for 24 h. After cooling, the black precipitate was separated by centrifugation, rinsed repeatedly with deionized water and ethanol, and dried at 60 °C to obtain MoS₂ nanosheets.

2.3 Synthesis of MoS₂/ZnO core–shell composites

To prepare MoS₂/ZnO composites with different mass ratios, Na₂MoO₄·2H₂O (90 mg) and thiourea (180 mg) were first dissolved in 60 mL of deionized water and stirred for 10 min. Predetermined amounts of ZnO (0.60 g, 0.30 g, or 0.15 g, corresponding to MoS₂:ZnO mass ratios of 1:10, 1:5, and 1:2.5, respectively) were then dispersed into the solution via 10 min of ultrasonication, followed by 30 min of magnetic stirring to ensure uniform mixing. The suspension was transferred to an autoclave and heated at 200 °C for 24 h. After cooling to room temperature, the products were collected by centrifugation, washed several times with deionized water and ethanol, and dried at 60 °C.

3 Characterization

Various characterizations of the prepared samples were carried out to study the

morphological, structural and optical properties. Morphological and structural characterization using scanning electron microscopy (SEM), transmission electron microscopy (TEM) and powder X-ray diffraction (XRD, Bruker D8ADVANCE). Compositional analysis and concentration of elements realized by energy spectroscopy (EDS). The surface chemical state and chemical composition were analyzed by X-ray photoelectron spectroscopy (XPS, Thermo Science). The absorbance of the contaminants at the maximum absorption wavelength was measured using a UV-vis spectrophotometer (SHIMADZU, UV-2550).

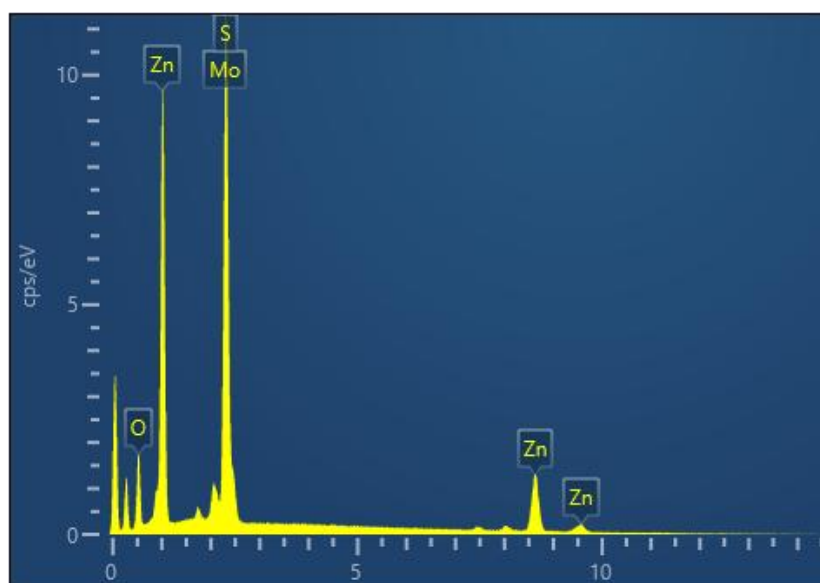


Figure S1 Spectrogram of the total number of distribution maps

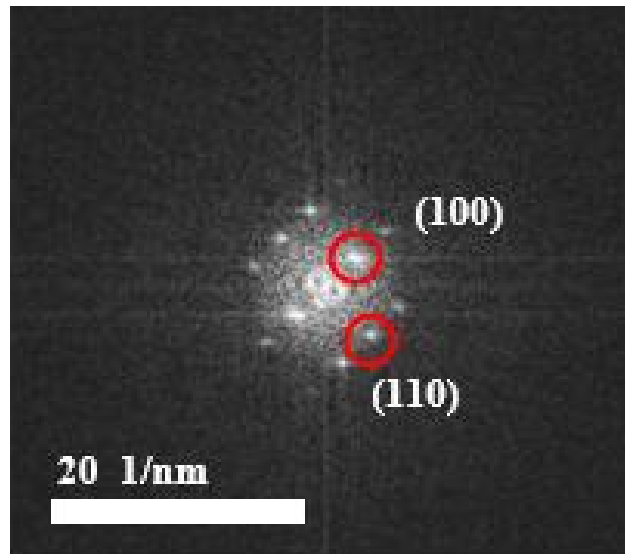


Figure S2 High-magnification TEM image

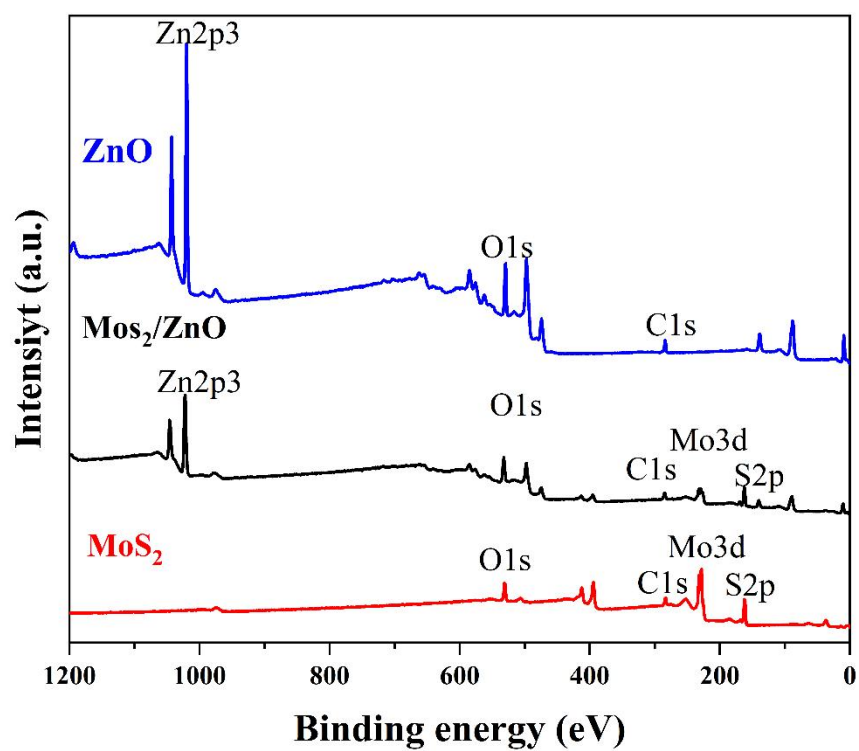


Figure S3 XPS survey spectra of MoS₂, ZnO, MoS₂/ZnO

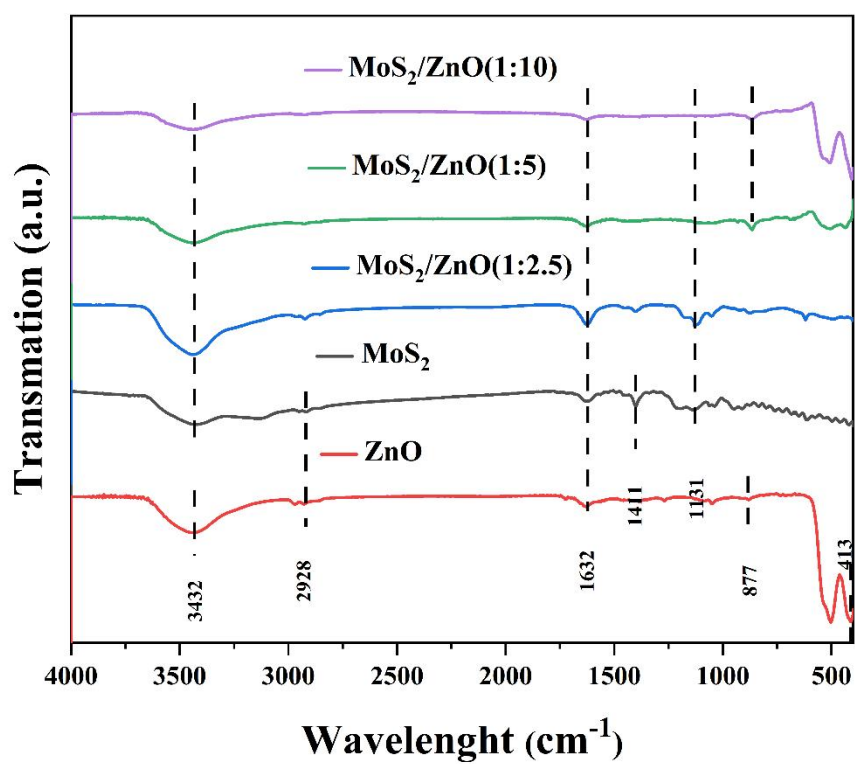


Figure S4 FTIR spectra of MoS₂, ZnO, MoS₂/ZnO (1:2.5), MoS₂/ZnO (1:5), MoS₂/ZnO (1:10)

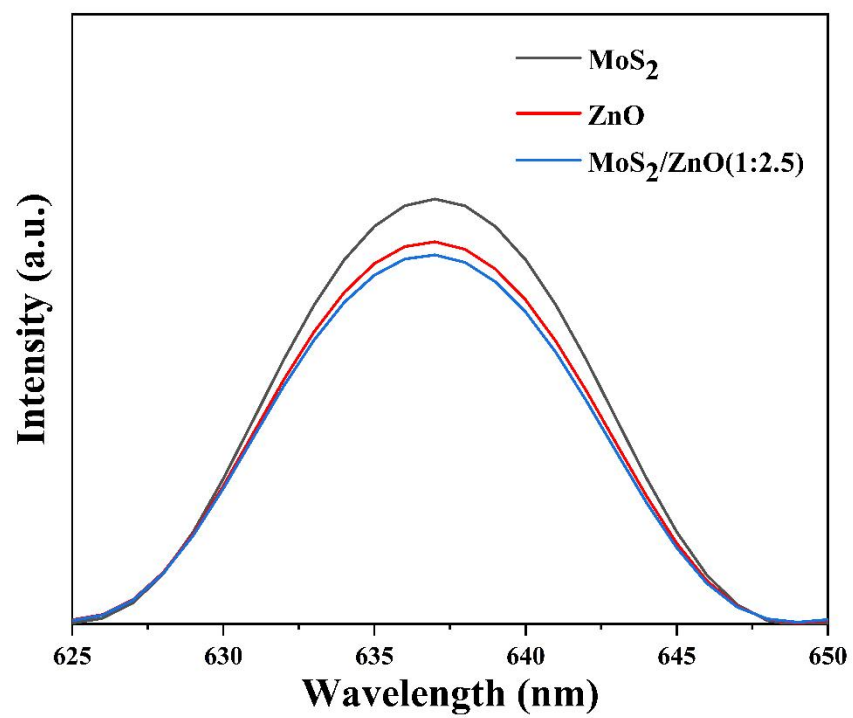


Figure S5 PL emission spectra of MoS₂, ZnO, MoS₂/ZnO (1:2.5)

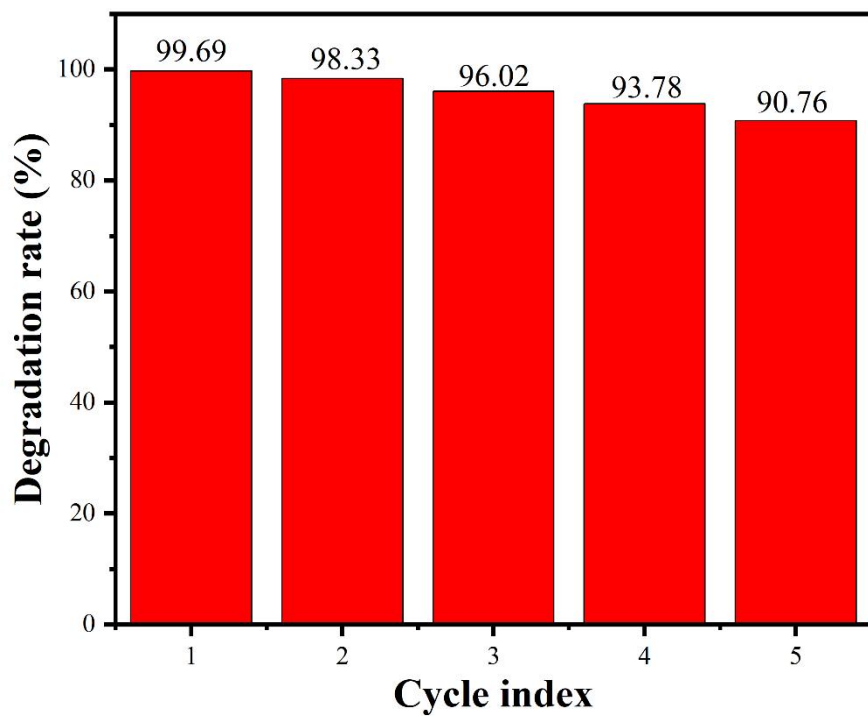


Figure S6 Effect of multiple cycles on degradation rate

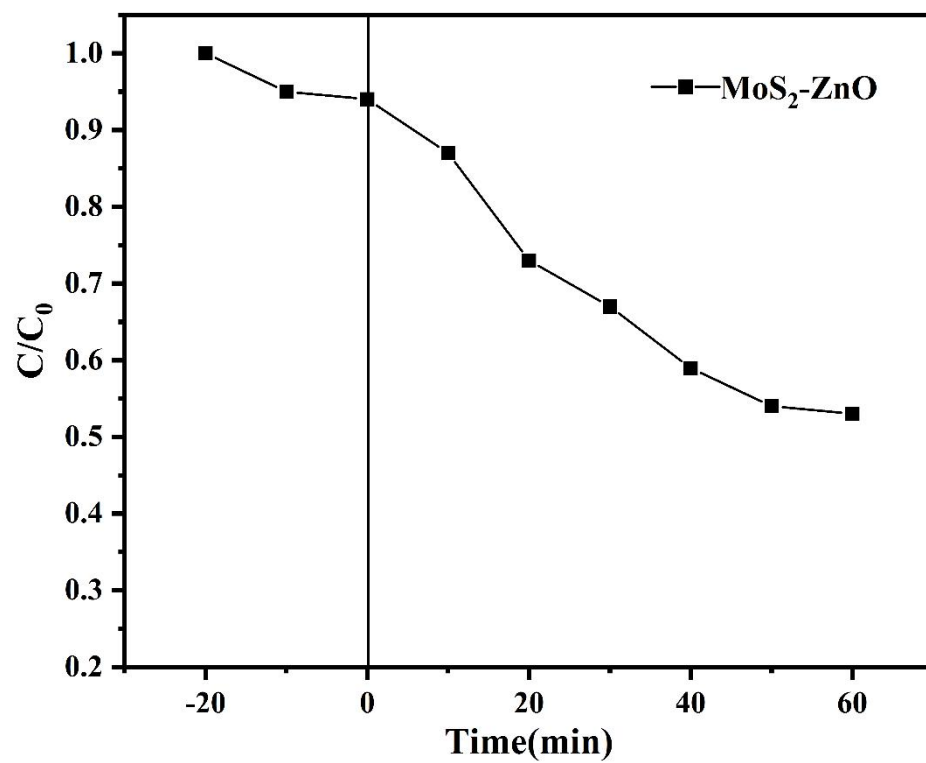


Figure S7 The degradation efficiency of tetracycline after physical mixing of $\text{MoS}_2\text{-ZnO}$

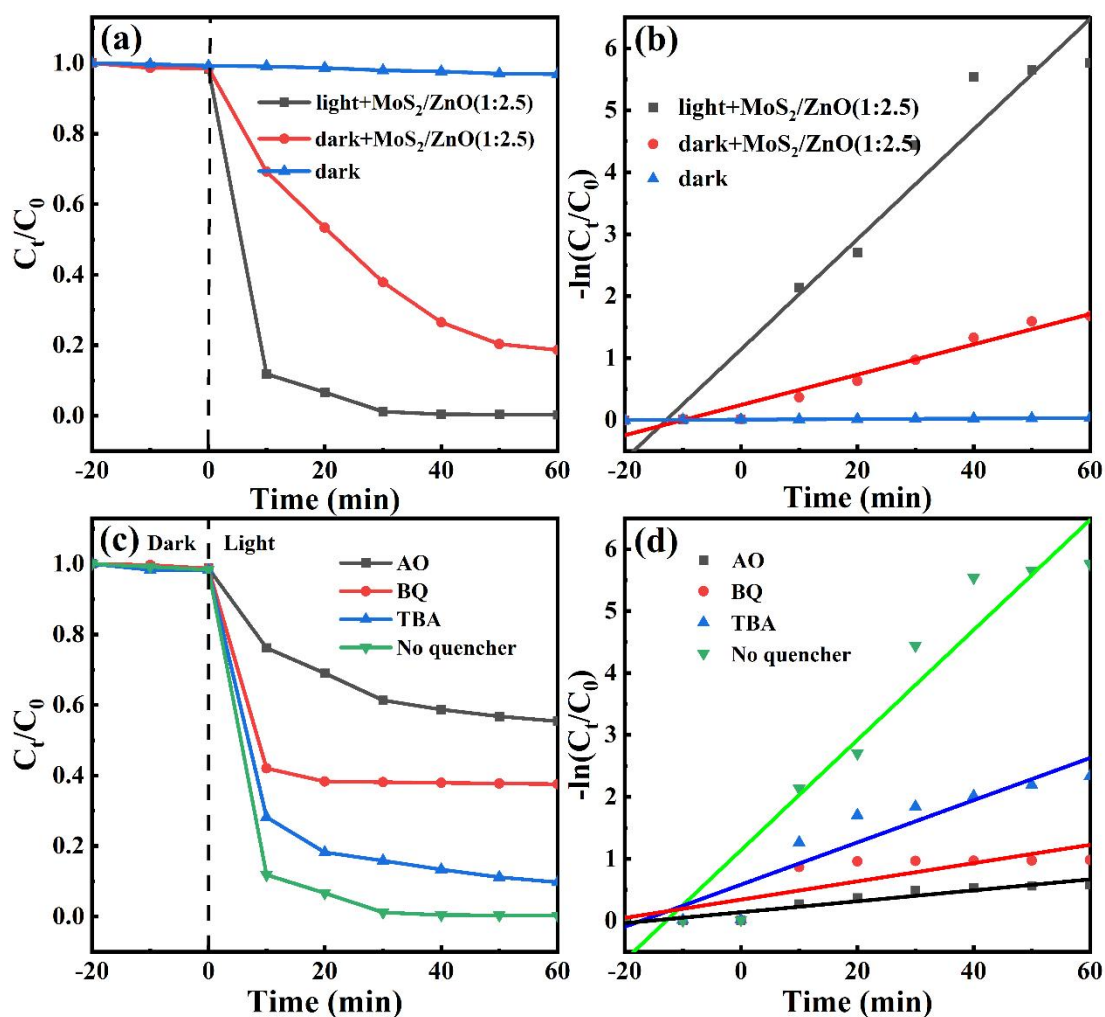


Figure S8 (a) Effect of different reaction conditions on TC degradation rate; (b) Pseudo-first-order reaction kinetics modeling; (c) The effect of trapping agent on TC degradation rate; (d) Pseudo-first-order reaction kinetic model

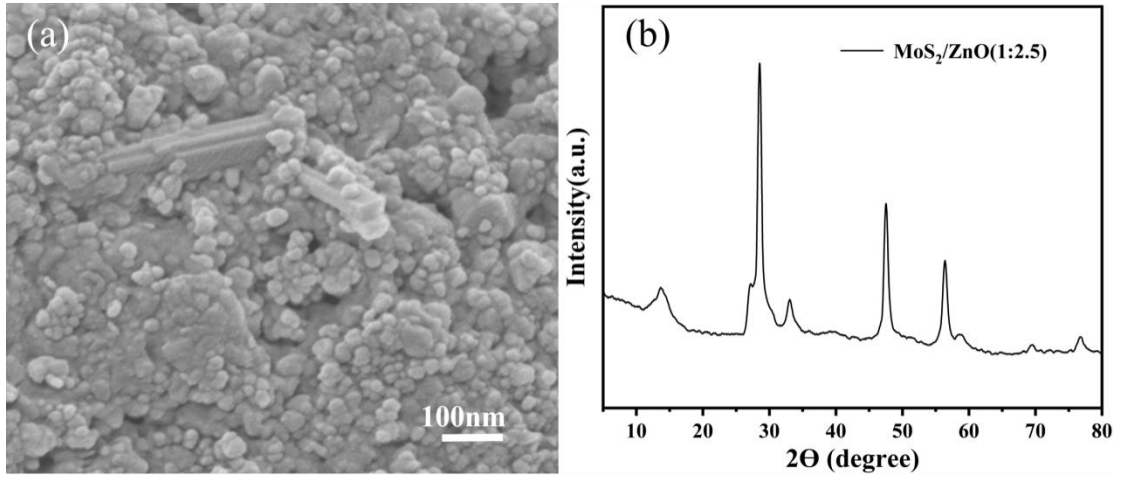


Figure S9 (a)SEM, (b)XRD of MoS₂/ZnO after five cycles

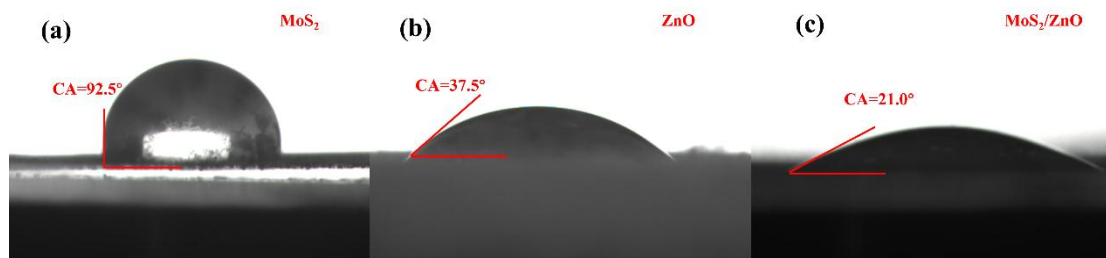


Figure S10 Static water contact angles of (a) MoS_2 , (b) ZnO and (c) MoS_2/ZnO

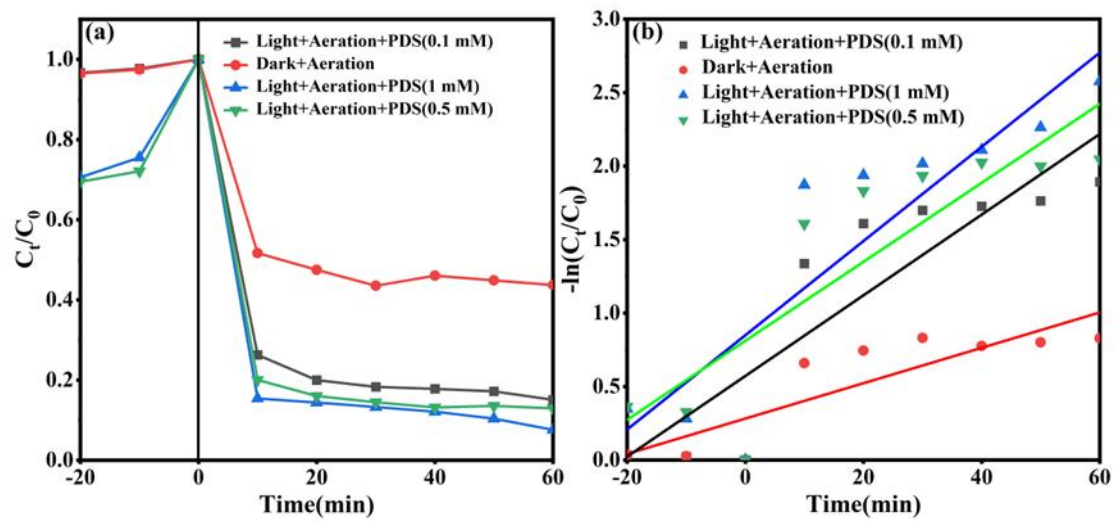


Figure S11 (a) Effect of PDS concentration on TC degradation rate; **(b)** Pseudo-first-order reaction kinetics modeling

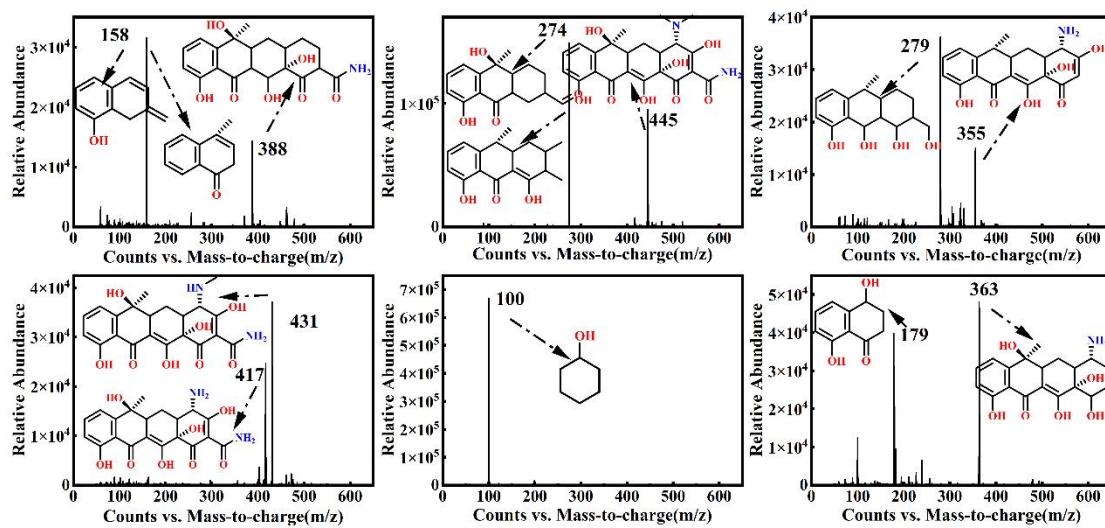


Figure S12 The HPLC-MS spectra of tetracycline removal