Waste tailing Particle Electrode enables enhance electrochemical degradation for sulfamethoxazole

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Text S1. The Analytical Methodologies

The physical morphology and element composition of the plate surface was analyzed by (SEM; MIRA 3 LMU; Czech Republic), (EDS; Oxford X-Max20; Czech Republic), and Zeta potential (NanoPlus). X-ray polycrystalline powder diffractometer (XRD; Ultima IV; Japan) and X-ray photoelectron spectroscopy (XPS; ESCALAB250Xi; America) were used to analyze the crystal structure and valence composition of the metal on the surface of the electrode. The electrochemical workstation (EW; CHI660E; Shanghai, China) was used to analyze various electrocatalytic activities and chlorine evolution performance of the electrode. electron paramagnetic resonance (EPR) was used to confirm the generation of free radicals. UV spectrophotometer (UV-Vis, Cary 8454 UV-Vis, Shanghai, China), Total organic

carbon analyzer (TOC, TOC-L, Shimadzu Corporation), and High-performance liquid chromatography (HPLC, LC-20A, Japan) were used to analyze the removal efficiency of SMZ. The degradation mechanism was analyzed by Triple quadrupole liquid chromatography-mass spectrometry (LC-MS, 1260-6460, Agilent). Toxicity Estimation Software Tool software was used to analyze the toxicology of water quality before and after degradation.

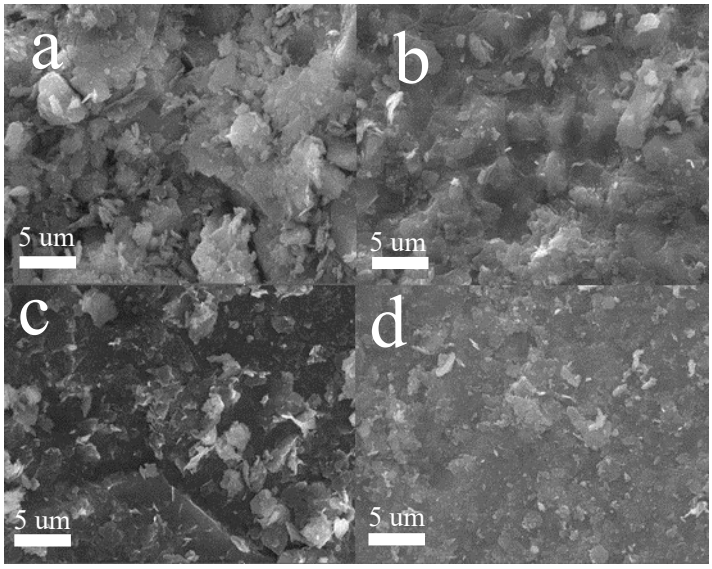

Fig. S1. SEM images of LZT-SO calcined at 350 ℃ (a), 450 ℃ (b), 550 ℃ (c), and 650 ℃ (d), respectively.

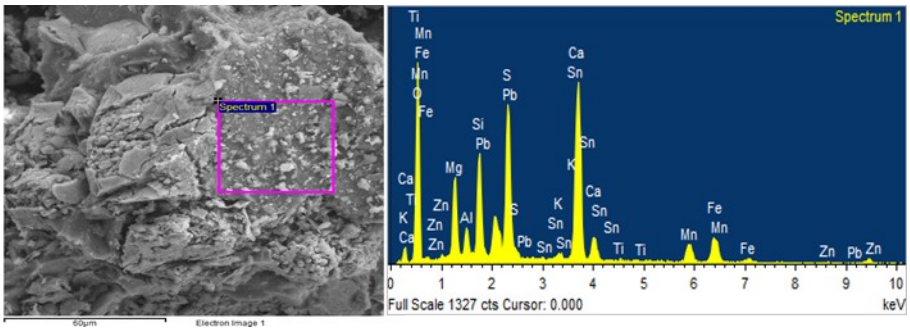

Fig. S2. The SEM and EDS of LZT.

Table S1. The element proportion of LZT.

Element	Weight%	Atomic%
O K	50.34	69.62
Mg K	5.27	4.79
Al K	1.57	1.29
Si K	5.52	4.35
S K	9.61	6.63

K K	0.57	0.32
Ca K	15.86	8.76
Ti K	0.06	0.03
Mn K	3.92	1.58
Fe K	6.21	2.46
Zn K	0.09	0.03
Sn L	0.36	0.07
Pb M	0.62	0.07
Totals	100.00	100.00

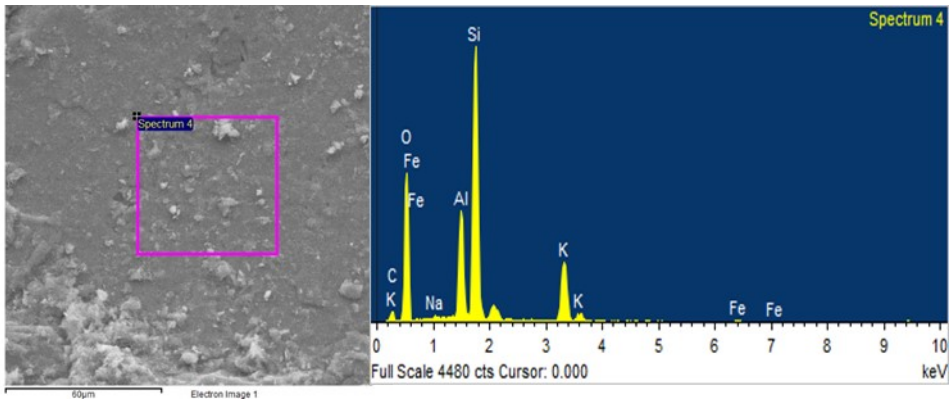

Fig. S3. The SEM and EDS of SO.

Table S2. The element proportion of SO.

Element	Weight%	Atomic%
C K	7.44	11.83
O K	51.92	61.99
Na K	0.33	0.28
Al K	7.81	5.53
Si K	23.84	16.22
K K	8.19	4.00
Fe K	0.47	0.16
Totals	100.00	100.00

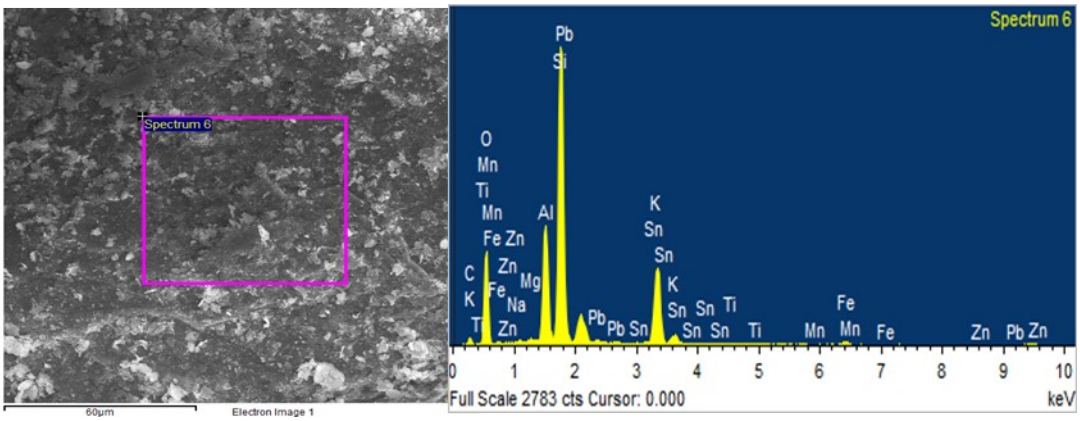

Fig. S4. The SEM and EDS of LZT-SO.

Table S3. The element proportion of LZT-SO.

Element	Weight%	Atomic%
C K	6.32	10.85
O K	53.54	63.35
Na K	0.37	0.31
Mg K	0.60	0.34
Al K	6.02	4.24
Si K	27.83	18.81
Sn K	0.17	0.11
K K	1.02	0.50
Ca K	0.14	0.07
Ti K	0.21	0.08
Mn K	0.59	0.22
Fe K	2.82	1.02
Zn K	0.12	0.05
Pb M	0.21	0.09
Totals	100.00	100.00

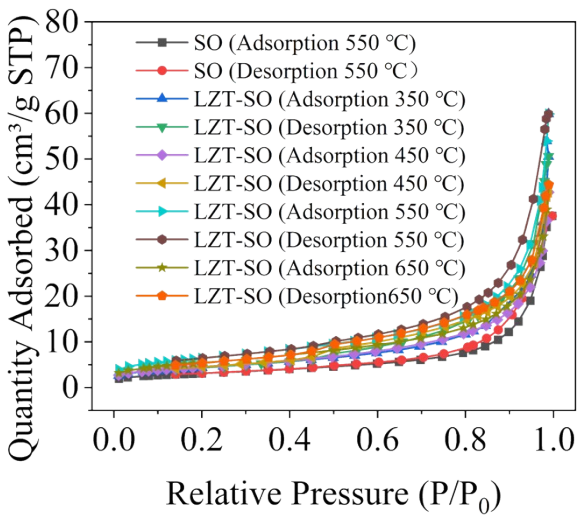

Fig. S5. Nitrogen adsorption and desorption isotherms of LZT-SO and SO calcined at no temperature.

Table S4 Pore structure parameters of LZT-SO and SO.

Samples	Surface Area (m^2/g)	Pore Volume (cm^3/g)	Average Pore Size (nm)
SO	11.1604	0.05741	20.5749
LZT-SO	23.1724	0.09258	15.9817

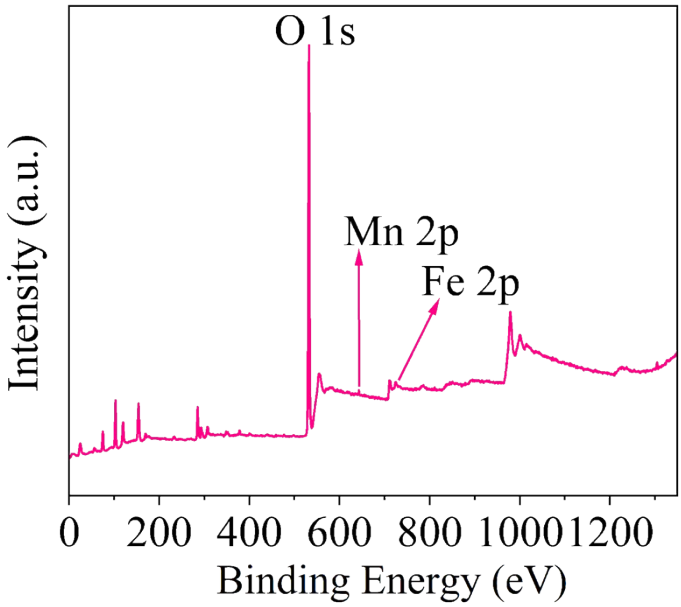

Fig. S6. The XPS total spectrum of LZT-SO.

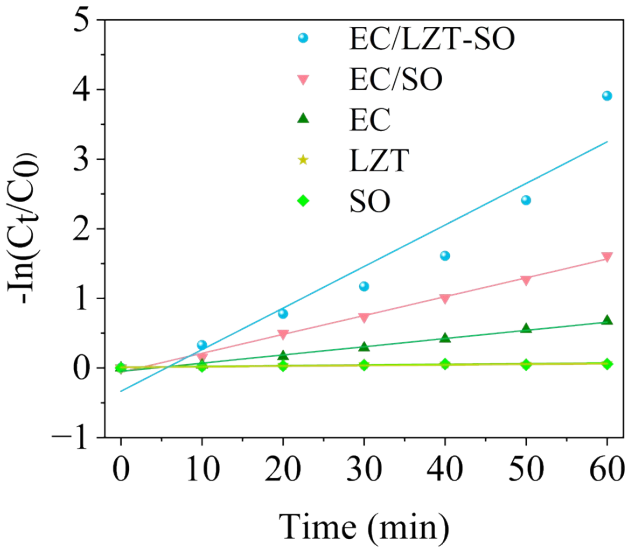

Fig. S7. Linear fittings of the pseudo-first-order model.

Text S4. The specific operating parameters of the electrochemical workstation

The ITO electrode was ultrasonically cleaned in acetone, 1 mol L^{-1} sodium hydroxide solution, and deionized water for 15 min, dried with nitrogen, and then dried at 120 °C for 2 h. Weigh 8 mg of particle electrode (LZT-SO) material, disperse it in 4 mL of ultrapure water, ultrasonic for 30 min, evenly drop 30 uL suspension on ITO electrode in a fixed area, and dry it at room temperature. Then, start the test.

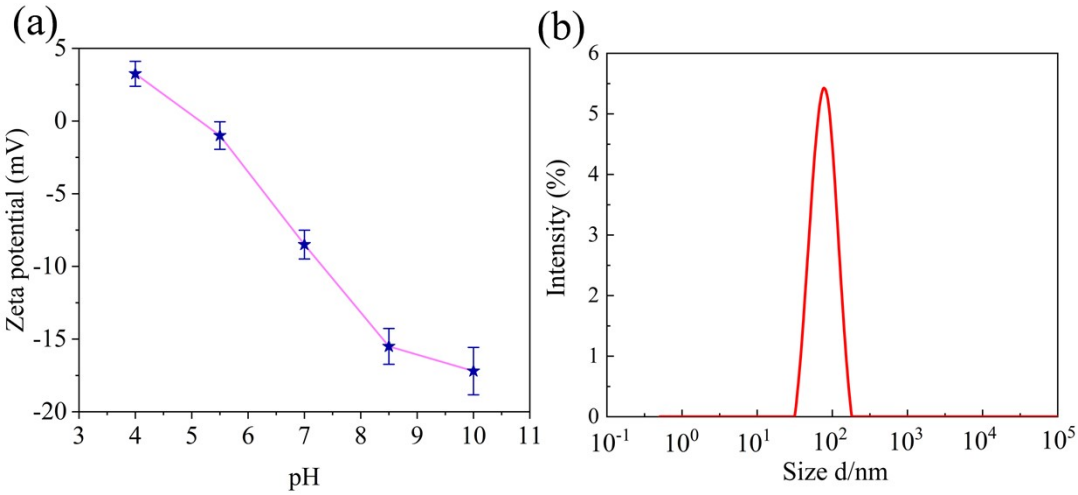

Fig. S8. The zeta potentiometer (a) and nanoparticle size (b) of LZT-SO.

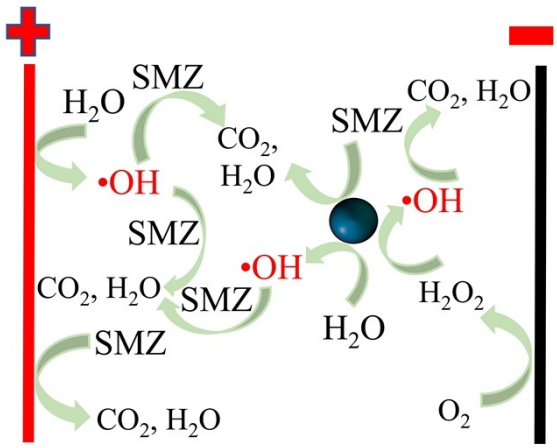

Fig. S9. The possible degradation mechanism of SMZ.

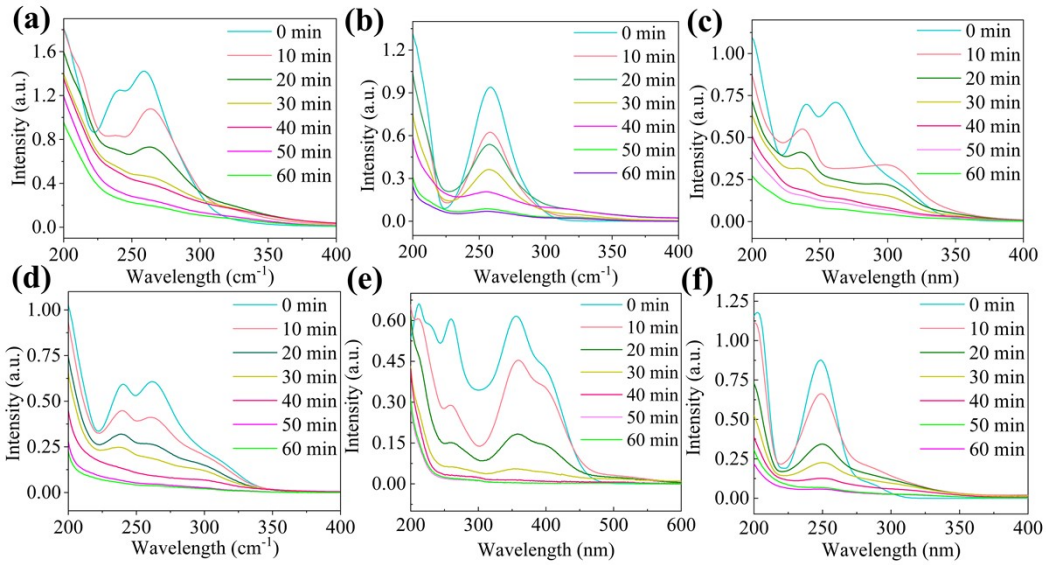

Fig. S10. UV absorption spectra of SMZ (a), SA (b), SAZ (c), SMA (d), 2,4-dinitrophenol (e), and 4-aminobenzenesulfonic acid (f) before and after degradation (pH=6.02, pate spacing=4 cm, aeration flow rate=12 L/h, voltage=10 V, Na_2SO_4 dose=0.050 mmol, the dose of LZT-SO=35.02 g, $[SMZ]_0$=10.02 mg/L, the degradation time=70 min).

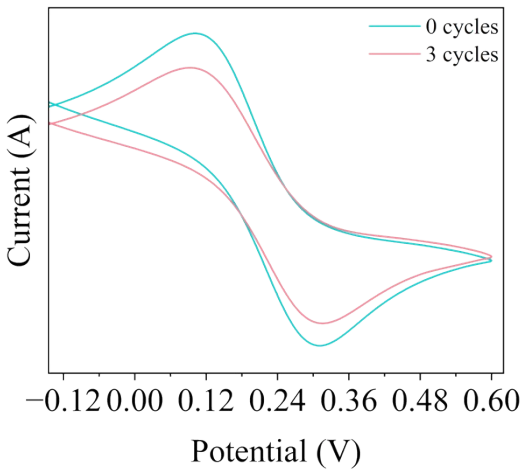

Fig. S11. Cyclic voltammetry curve of 0 cycle and 3 cycles.

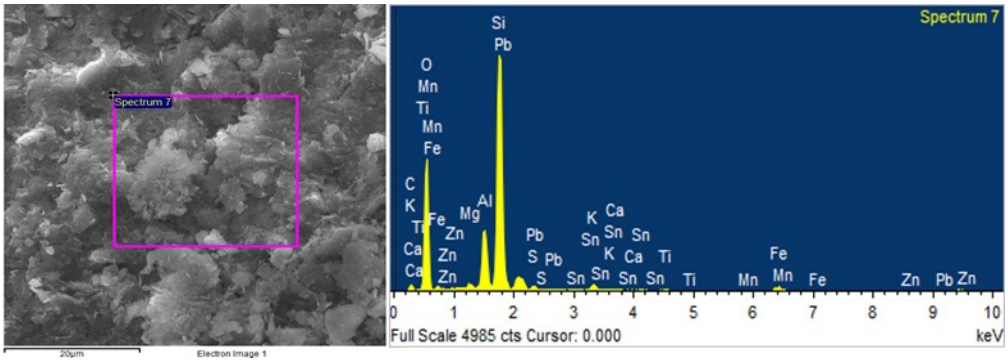

Fig. S12. The SEM and EDS of LZT-SO after three cycles.

Table S5. The element proportion of waste coal cinder after three cycles

Element	Weight%	Atomic%
C K	6.51	10.93
O K	53.87	63.43
Na K	0.39	0.32
Mg K	0.58	0.33
Al K	6.06	4.26
Si K	27.84	18.8
Sn K	0.15	0.1
K K	1.01	0.5
Ca K	0.15	0.07
Ti K	0.18	0.06
Mn K	0.5	0.17
Fe K	2.52	0.92
Zn K	0.09	0.04
Pb M	0.15	0.07
Totals	100.00	100.00

Table S6. The mass loss of LZT-SO after three cycles

Cycles	Mass loss (%)
0	0
1	1.56
2	3.21
3	5.46

Table S7 Comparison of different methods for removal antibacterial.

Method	Contaminants	Concentration	Time (h)	Removal efficiency (%)	pH	Ref
Adsorption	Sulfanilamide	10 mg/L	4	86.77	6	(Sun et al., 2022)
Photocatalytic	Sulfamethoxazole	20 mg/L	2/3	89.02	7.5	(Paragas et

						al., 2018)
Sonocatalytic	Sulfamethoxazole	10 μM /L	1	95	7	(Al-Hamadani et al., 2016)
Ozone Oxidative	Sulfamethoxazole	1000 μg/L	0.5	96-98	3.5	(Garoma et al., 2010)
Fenton Oxidative	Sulfamethoxazole	20 mg/L	2/3	87.8	6.5	(Liu et al., 2021)
Peroxide activation	Sulfamethoxazole	10 mg/Kg	36	95.8	6	(Amina et al., 2022)
Biological oxidation	Sulfamethoxazole	52 μg/L	168	47.86 ± 2.35	8.4	(Rodrigues et al., 2020)
Three-dimensional electrocatalytic oxidation	Sulfamethoxazole	10 mg/L	1	100.00	6.02	This work

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and potassium co-doped graphitic carbon nitride photocatalysts. Chemosphere. 210, 1099-1107. https://doi.org/10.1016/j.chemosphere.2018.07.109.

Table S8 Degradation process parameters and cost.

Factor	Parameter	SMZ removal efficiency (%)	Power consumption (kW·h)
pH	4.01	90.11	1.70
	6.02	100.00	1.51
	7.02	96.02	1.55
	7.99	98.01	1.61
	9.98	84.02	1.74
Na_2SO_4 dosage (mmol)	0.00	9.23	0.11
	0.25	89.11	0.84
	0.40	93.52	1.28
	0.50	100.00	1.51
	0.60	100.00	1.68
	0.70	100.00	1.82
Voltage (V)	6	94.01	0.96
	8	98.01	1.39
	10	100.00	1.51
	12	100.00	1.70
	14	100.00	1.86
Aeration flow rate (L/h)	0	83.91	1.61
	8	95.71	1.58
	10	97.71	1.59
	12	100.00	1.51
	14	92.40	1.42
Groove spacing (cm)	4	100.00	1.51
	5	95.02	1.22
	6	91.12	0.81

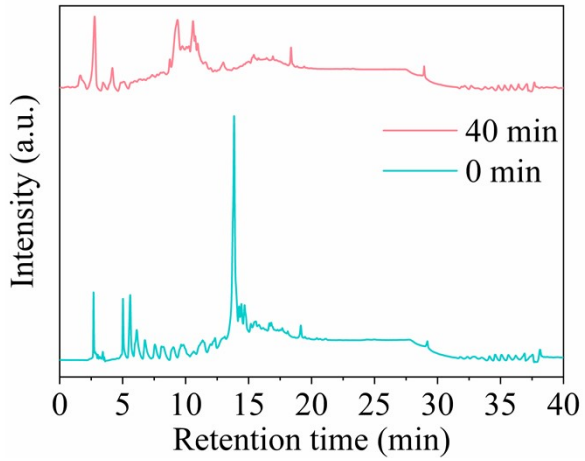


Fig. S13. The total ion chromatography spectra of SMZ before and after degradation.

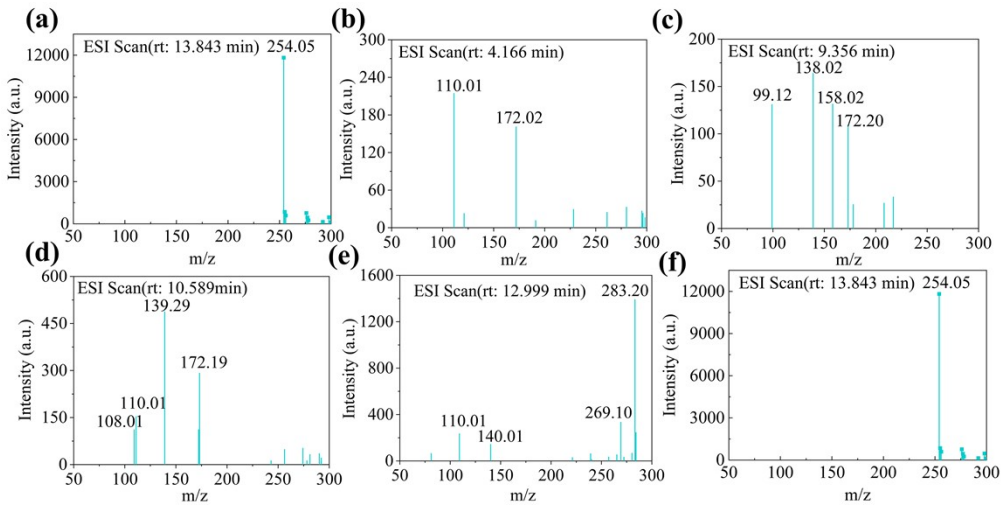


Fig. S14. The mass spectra of SMZ before (a) and after degradation (b-f).

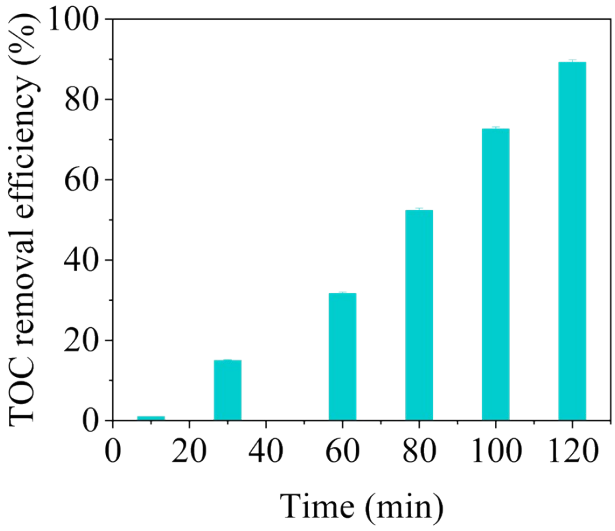
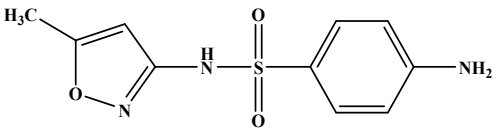
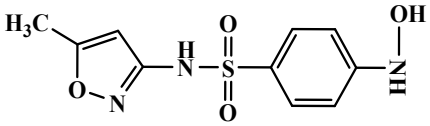
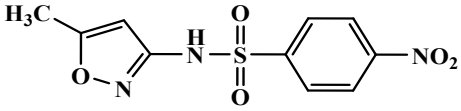
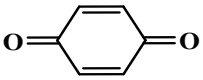
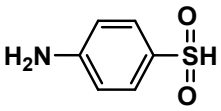
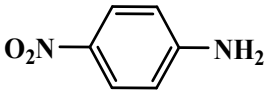
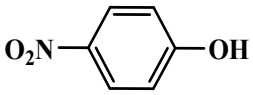
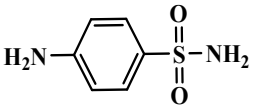
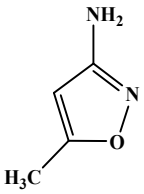
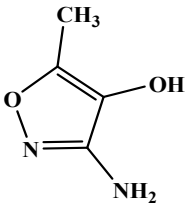


Fig. S15. The TOC removal efficiency of SMZ before and after degradation (pH=6.02, pate spacing=4 cm, aeration flow rate=12 L/h, voltage=10 V, Na_2SO_4 dose=0.050 mmol, the dose of LZT-SO=35.02 g, $[SMZ]_0$ =10.02 mg/L).

Table S9. The structural information of the possible intermediate products.

Compound	Molecular structure	Mass/charge ratio (m/z)
SMZ		254.05

P1		269.1
P2		283.2
P3		110.1
P4		108.1
P5		158.02
P6		138.1
P7		139.29
P8		172.2
P9		99.12
P10		140.01