

*Supplementary Material*

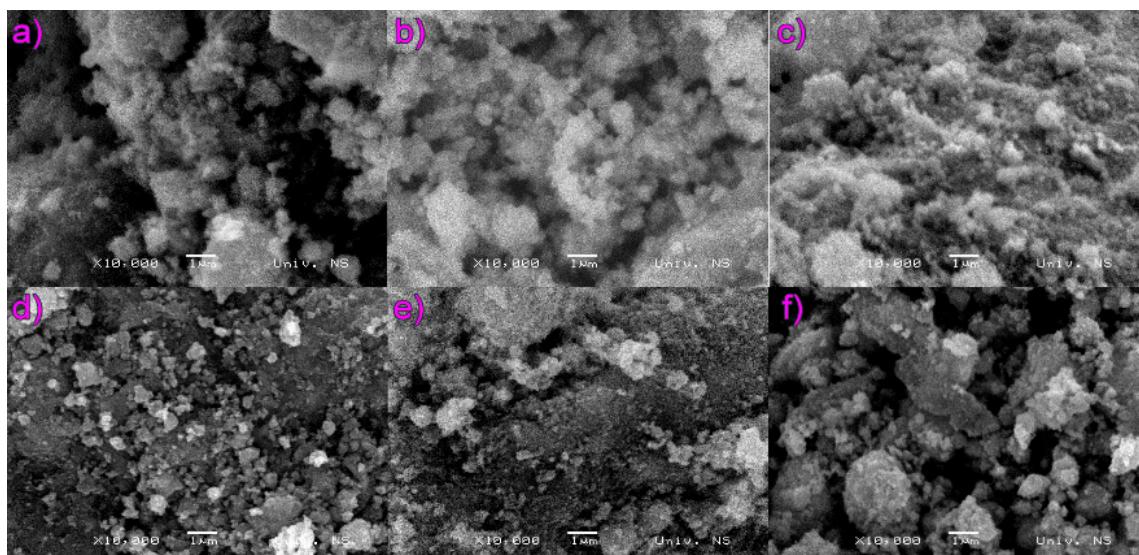
# Rapid Removal of Organic Pollutants from Aqueous Systems under Solar Irradiation Using $\text{ZrO}_2/\text{Fe}_3\text{O}_4$ Nanoparticles

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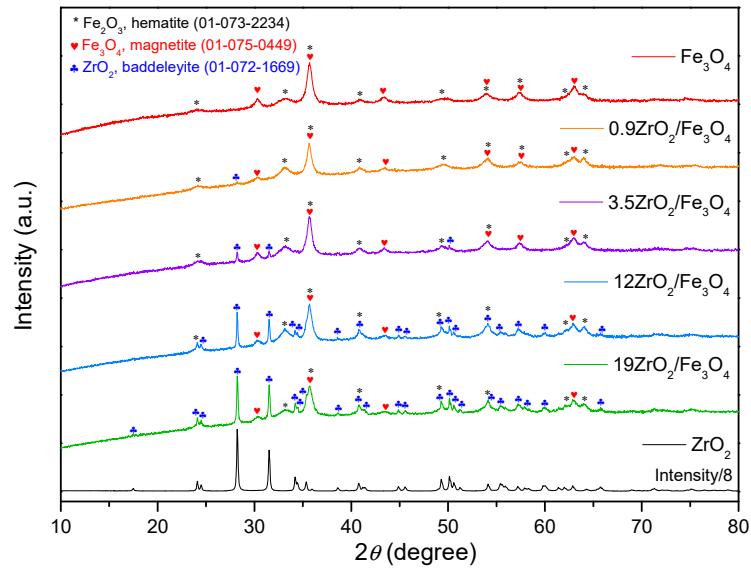
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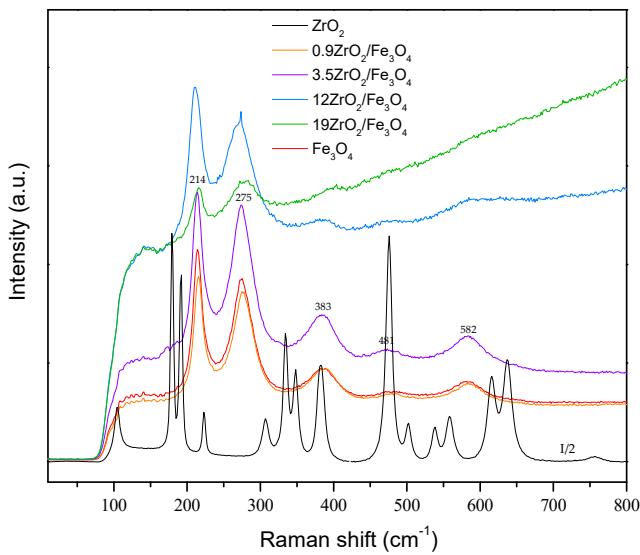
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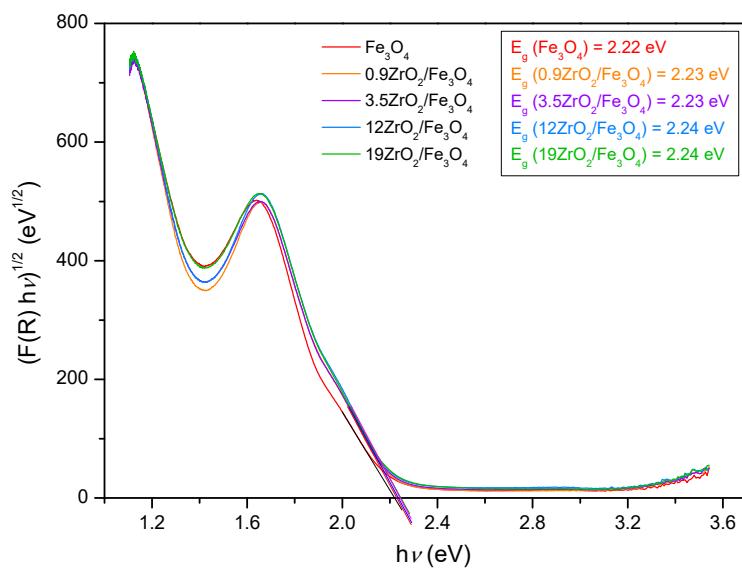
**Figure S1.** SEM images of particles: (a)  $\text{Fe}_3\text{O}_4$  and (b)  $\text{ZrO}_2$ , as well as synthesized nanopowders: (c)  $0.9\text{ZrO}_2/\text{Fe}_3\text{O}_4$ ; (d)  $3.5\text{ZrO}_2/\text{Fe}_3\text{O}_4$ ; (e)  $12\text{ZrO}_2/\text{Fe}_3\text{O}_4$  and (f)  $19\text{ZrO}_2/\text{Fe}_3\text{O}_4$ . Line bar  $1 \mu\text{m}$ .



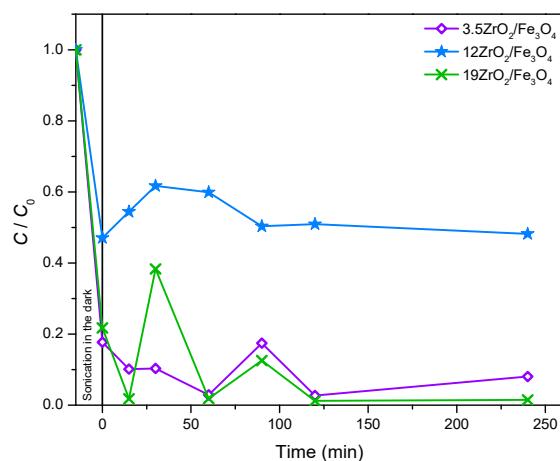
**Figure S2.** XRD patterns of particles:  $\text{Fe}_3\text{O}_4$  and  $\text{ZrO}_2$ , as well as synthesized nanopowders:  $0.9\text{ZrO}_2/\text{Fe}_3\text{O}_4$ ;  $3.5\text{ZrO}_2/\text{Fe}_3\text{O}_4$ ;  $12\text{ZrO}_2/\text{Fe}_3\text{O}_4$  and  $19\text{ZrO}_2/\text{Fe}_3\text{O}_4$ .



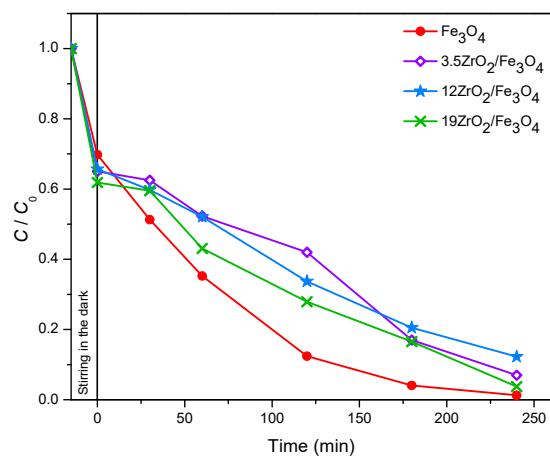
**Figure S3.** Raman spectra of particles:  $\text{Fe}_3\text{O}_4$  and  $\text{ZrO}_2$ , as well as synthesized nanopowders:  $0.9\text{ZrO}_2/\text{Fe}_3\text{O}_4$ ;  $3.5\text{ZrO}_2/\text{Fe}_3\text{O}_4$ ;  $12\text{ZrO}_2/\text{Fe}_3\text{O}_4$  and  $19\text{ZrO}_2/\text{Fe}_3\text{O}_4$ .



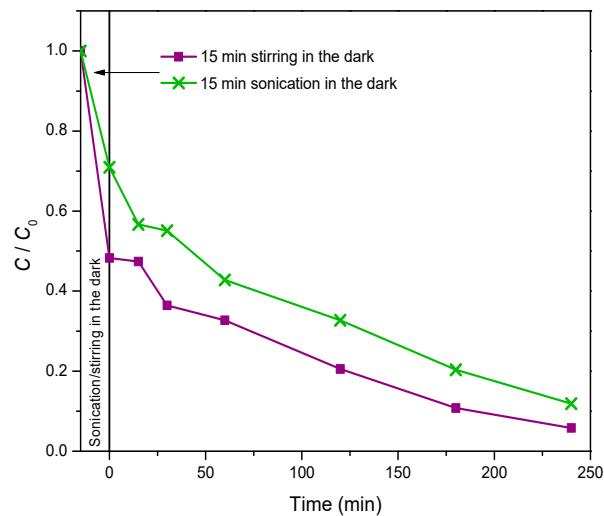
**Figure S4.** Estimation of particles  $\text{Fe}_3\text{O}_4$  and synthesized  $\text{ZrO}_2/\text{Fe}_3\text{O}_4$  catalysts optical band energy by  $[F(R)\cdot h\nu]^{1/2}$  vs. photon energy ( $h\nu$ ) plotting.



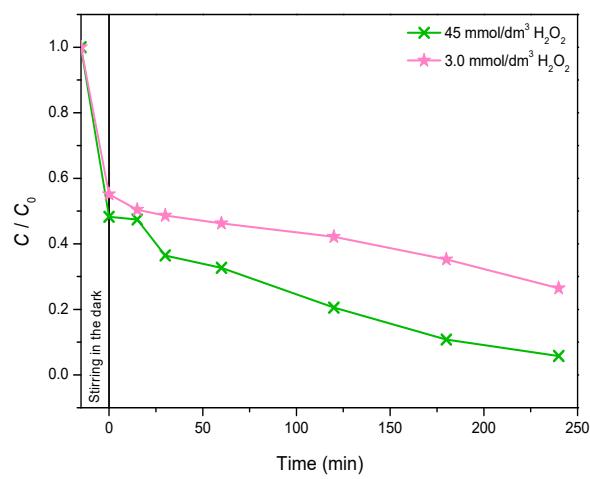
**Figure S5.** Kinetics of removal of sulcotriione ( $0.05 \text{ mmol}/\text{dm}^3$ ) at pH 2.8 in the presence of  $3.5\text{ZrO}_2/\text{Fe}_3\text{O}_4$ ,  $12\text{ZrO}_2/\text{Fe}_3\text{O}_4$ , and  $19\text{ZrO}_2/\text{Fe}_3\text{O}_4$  ( $1.0 \text{ mg}/\text{cm}^3$ ) with  $3.0 \text{ mmol}/\text{dm}^3 \text{H}_2\text{O}_2$ , under SSI.



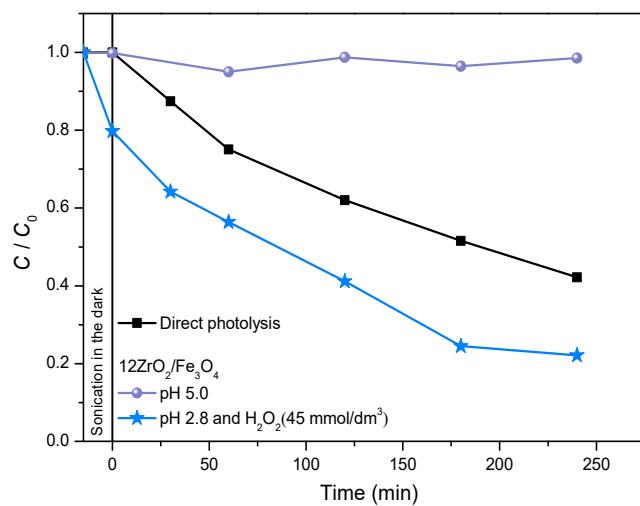
**Figure S6.** Influence of stirring prior to irradiation on the removal of sulcotrione ( $0.05 \text{ mmol}/\text{dm}^3$ ) with  $\text{Fe}_3\text{O}_4$  and various  $\text{ZrO}_2/\text{Fe}_3\text{O}_4$  nanopowders ( $1.0 \text{ mg}/\text{cm}^3$ ) in the presence of  $\text{H}_2\text{O}_2$  ( $3.0 \text{ mmol}/\text{dm}^3$ ) at pH 2.8, using SSI.



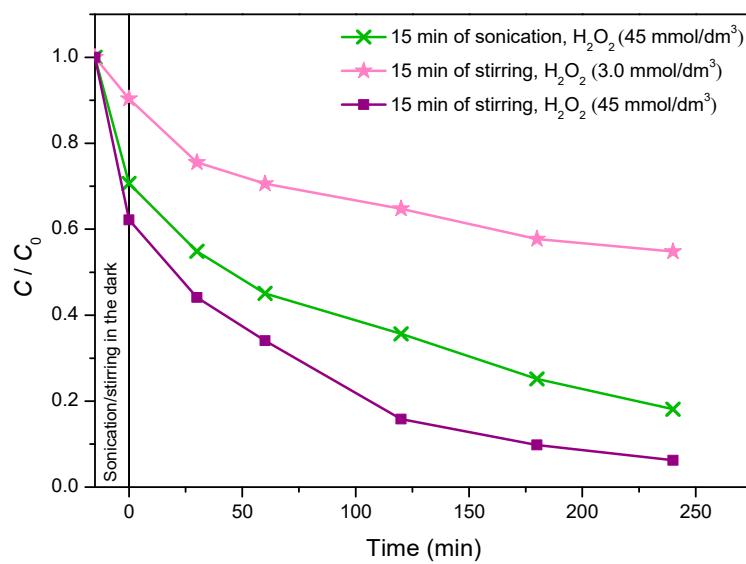
**Figure S7.** Effect of stirring/sonication on the removal efficiency of fluroxypyrr ( $0.05 \text{ mmol}/\text{dm}^3$ ) in the presence of  $45 \text{ mmol}/\text{dm}^3 \text{H}_2\text{O}_2$  and  $1.0 \text{ mg}/\text{cm}^3 19\text{ZrO}_2/\text{Fe}_3\text{O}_4$  at pH 2.8 using solar irradiation.



**Figure S8.** Effect of the initial concentration of  $H_2O_2$  on the removal efficiency of fluroxypyrr ( $0.05 \text{ mmol}/\text{dm}^3$ ) in the presence of  $1 \text{ mg}/\text{cm}^3 19ZrO_2/\text{Fe}_3\text{O}_4$  at pH 2.8 using solar irradiation.



**Figure S9.** Kinetics of photolytic and photocatalytic degradation of amitriptyline ( $0.05 \text{ mmol}/\text{dm}^3$ ) in the presence of  $12ZrO_2/\text{Fe}_3\text{O}_4$  as a photocatalyst ( $1.0 \text{ mg}/\text{cm}^3$ ) and using solar irradiation under different experimental conditions.



**Figure S10.** Kinetics of photocatalytic degradation of amitriptyline (0.05 mmol/dm<sup>3</sup>) in the presence of 19ZrO<sub>2</sub>/Fe<sub>3</sub>O<sub>4</sub> (1.0 mg/cm<sup>3</sup>) as a photocatalyst, H<sub>2</sub>O<sub>2</sub> (3.0 and 45 mmol/dm<sup>3</sup>), at pH 2.8 and using solar irradiation.

**Table S1.** The physicochemical properties of the analysed natural waters.

Parameter	Natural waters			
	Danube River	Underground	Ultrapure	Drinking
pH	7.70	7.62	6.56	7.30
Conductivity at 25 °C ( $\mu\text{S}/\text{cm}$ )	333	466	4.5	516
TOC ( $\text{mg}/\text{dm}^3$ )	2.30	0.78	<DL	1.80
Fluoride ( $\text{mg}/\text{dm}^3$ )	<DL	0.469	<DL	0.130
Chloride ( $\text{mg}/\text{dm}^3$ )	44.02	61.39	<DL	16.50
Bromide ( $\text{mg}/\text{dm}^3$ )	0.080	0.090	<DL	<0.005
Sulfate ( $\text{mg}/\text{dm}^3$ )	15.52	0.486	<DL	35.0
Nitrate ( $\text{mg}/\text{dm}^3$ )	3.86	0.099	<DL	1.87
Nitrite ( $\text{mg}/\text{dm}^3$ )	2.76	17.53	<DL	<0.01
Calcium ( $\text{mg}/\text{dm}^3$ )	0.136	<DL	<DL	70.49
Potassium ( $\text{mg}/\text{dm}^3$ )	0.030	<DL	<DL	3.75
Lithium ( $\text{mg}/\text{dm}^3$ )	<DL	0.024	<DL	<0.005
Phosphates ( $\text{mg}/\text{dm}^3$ )	0.202	0.052	<DL	<DL
Magnesium ( $\text{mg}/\text{dm}^3$ )	0.078	0.129	<DL	20.3
Sodium ( $\text{mg}/\text{dm}^3$ )	0.043	0.219	<DL	19.2
Ammonium ( $\text{mg}/\text{dm}^3$ )	<DL	15.76	<DL	<0.03