Data Article

Data for a new spinel catalyst to activate peroxymonosulfate for highly efficient degrading organic contaminants in water based on non-radical process

Fu Liu, Wenwen Li, Dechang Wu, Tong Tian, Jian-Feng Wu, Zong-Mu Dong, Guang-Chao Zhao*

College of Environmental Science and Engineering, Anhui Normal University, Wuhu 241000, P. R. China

ARTICLE INFO

ABSTRACT

The aim of this research is to degrade organic contaminants in aqueous solution via lead ferrite ($PbFe_2O_4$) as a catalyst to activate peroxymonosulfate (PMS). $PbFe_2O_4$ was synthesized by a citrate combustion method and analyzed by SEM, TEM and XRD. A simulated solution including thionine were used, with different conditions tested to optimize the degradation process, including comparing $PbFe_2O_4$ to other catalysts, PbO and Fe_2O_3, and tracking active oxygen species. The concentrations of thionine and PMS were tracked with a UV-Vis spectrophotometer in the treatment process. The data are presented as graphs and tables. A detailed analyses of this report can be found in the article "New insight into the mechanism of peroxymonosulfate activation by nanoscaled lead-based spinel for organic matters degradation: a singlet oxygen-dominated oxidation process" published in *Journal of colloid and interface science*.

---

* Corresponding author: Guang-Chao Zhao.
  E-mail address: gczhao@mail.ahnu.edu.cn (G.-C. Zhao).

Specifications Table

Subject	Environmental engineering
Specific subject area	Advanced oxidation process
Type of data	Table
	Figure
How data were acquired	Field emission scanning electron microscope (FESEM, Hitachi SU-8010, 5kV, Japan), field emission transmission electron microscope (FETEM, Hitachi HT-7700, 120kV, Japan), X-ray diffraction (XRD, Bruker D8 Advance, Germany), Electron paramagnetic resonance spectrometer (EPR, Bruker Biospin GmbH E500-9.5/12, Germany), Atomic Absorption Spectrophotometer (AAS, TAS-990, China), UV-Vis spectrophotometer (TU-1901, China), and high-performance liquid chromatography (HPLC, Shimadzu LC-20AT, Japan)
Data format	Raw and analyzed data
Parameters for data collection	The effect of initial thionine concentration, solution pH, catalysts and peroxymonosulfate dosages was evaluated during the experiments of organic degradation. Experiments were done in triplicates in separate reactors and room temperature (25 ± 2°C) was maintained throughout the reactions.
Description of data collection	HPLC coupled with UV detector was used to track tetracyclines antibiotics concentrations throughout the degradation reaction, and the thionine concentration of different time intervals were detected by UV-Vis spectrophotometer.
Data source location	Anhui Normal University
	Wuhu
	China
Data accessibility	With the article
Related research article	Author's name
	Fu Liu, Wenwen Li, Dechang Wu, Tong Tian, Jian-Feng Wu, Zong-Mu Dong, Guang-Chao Zhao *
	* Corresponding author: E-mail: gczhao@mail.ahnu.edu.cn
	Title
	New insight into the mechanism of peroxymonosulfate activation by nanoscaled lead-based spinel for organic matters degradation: a singlet oxygen-dominated oxidation process
	Journal
	Journal of Colloid and Interface Science
	DOI/In Press
	https://doi.org/10.1016/j.jcis.2020.03.116

Value of the data

- The data reveal that a new spinel material, $PbFe_2O_4$, can be used as catalyst to activate PMS generating active oxygen species for organic contaminants degradation in aqueous with a non-radical process.
- Researchers involved in advanced oxidation processes (AOPs) and treatment of organic contaminants in water can benefit from the data.
- The data can be used as a comparison for other researchers interested in developing new catalysts to activate peroxymonosulfate for organic contaminants degradation in aqueous. It also helps the researchers to understand the corresponding catalytic mechanism in degradation process.
- The data can also be utilized to develop a real treatment system for organic (dye and pharmaceutical) effluents by improving and perfecting the various parameters design. Additionally, effect of chlorides (Cl^-) and phosphates in real effluents can provide useful information in this process.

1. Data Description

Data presented in this paper described the microstructure and morphology of the synthesized catalysts and effectiveness of $PbFe_2O_4$/PMS system in thionine and tetracyclines antibiotics degradation.
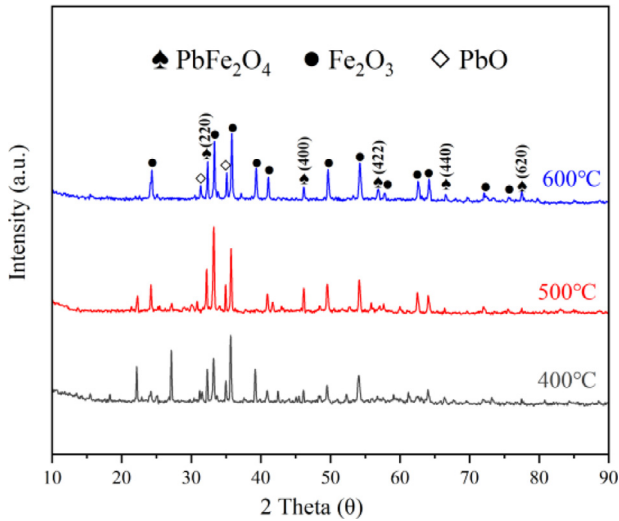
Fig. 1. XRD spectra of virgin PbFe$_2$O$_4$ prepared with different calcination temperature (400-600°C)
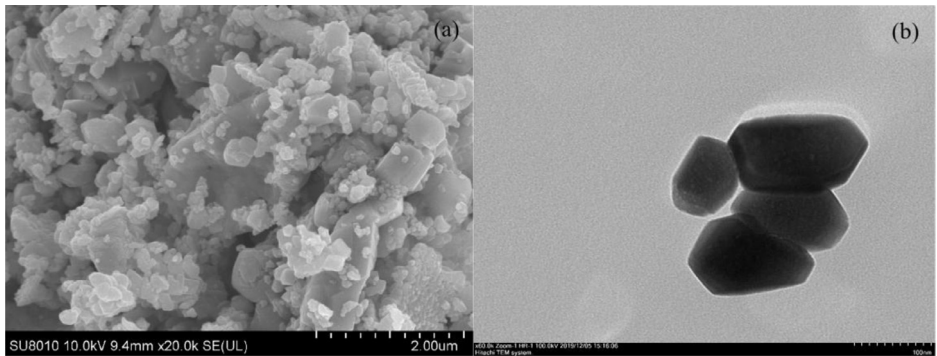

Fig. 2. SEM (a), TEM (b) images of the used PbFe$_2$O$_4$.

The virgin and used catalysts were analyzed by SEM, TEM, and XRD, and depicted in Figs. 1 and 2. The thionine removal by PbFe$_2$O$_4$, PMS, or PbFe$_2$O$_4$/PMS systems, and thionine removal efficiency in catalytic PMS by PbFe$_2$O$_4$, Fe$_2$O$_3$ and PbO are depicted in Fig. 3. The effect of pH on the removal efficiency of thionine in PbFe$_2$O$_4$/PMS system is presented in Fig. 4. The concentrations of lead and ferric ions leached from PbFe$_2$O$_4$/PMS system after every cycle use of PbFe$_2$O$_4$ are shown in Fig. 5. The observed rate constants (k), obtained for pseudo-first order fitting, for degradation of thionine with different catalyst dosages in PMS oxidation system are presented in Table 1, and the variation of k with the joining of coexisting anions are presented in Table 2. A simple review on the different reactive species responsible for removing contaminants by advanced oxidation processes based on persulfates catalytic oxidation are presented in Table 3.

EPR spectra, used with DMPO and TMP as a spin trap agent, are shown in Fig. 6. Moreover, the Fig. 7 presents the degradation of tetracyclines antibiotics by PbFe$_2$O$_4$/PMS system in different water samples. The raw data of all degradation experiments are shared as supplementary material.

Table 1
Variation of the pseudo-first order rate constant of thionine degradation with catalyst dosages in PMS oxidation system.

Oxide dose (mg/L)	k of first order kinetics (min^{-1})	R^2
① $PbFe_2O_4$	–	–
200	0.2002	0.967
400	0.2048	0.970
600	0.1477	0.981
800	0.1347	0.984
② Fe_2O_3	–	–
200	0.1172	0.983
400	0.1235	0.996
600	0.0716	0.992
800	0.0526	0.960
③ PbO	–	–
200	0.1027	0.989
400	0.1068	0.985
600	0.0332	0.913
800	0.0234	0.922

Table 2
Variation of the pseudo-first order rate constant of thionine degradation with coexisting anions concentration in $PbFe_2O_4$/PMS system.

Coexisting anions (mM)	k of first order kinetics (min^{-1})	R^2
① Cl^-	–	–
0	0.2048	0.970
5	0.2133	0.955
20	0.2724	0.950
50	0.4231	0.987
100	0.5970	0.981
② NO_3^-	–	–
0	0.2048	0.970
20	0.1906	0.975
50	0.1991	0.972
③ HCO_3^-	–	–
0	0.2048	0.970
20	0.2108	0.965
50	0.2016	0.975
④ $H_2PO_4^-$	–	–
0	0.2048	0.970
20	0.2176	0.977
50	0.2445	0.994

Table 3
Contaminants removal by advanced oxidation processes based on different catalyst/persulfates catalytic oxidation system.

| Advanced oxidation process	Target pollutant	Main reactive species	Reference
$CuFe_2O_4$/peroxymonosulfate	Arsenic(III)	$SO_4^{\cdot-}$ and $^{\cdot}OH$	[1]
$CuFe_2O_4$/peroxymonosulfate	Norfloxacin	$SO_4^{\cdot-}$ and $^{\cdot}OH$	[2]
$CuFe_2O_4$/kaolinite/peroxymonosulfate	Bisphenol A	$SO_4^{\cdot-}$ and $^{\cdot}OH$	[3]
Benzoquinone/Peroxymonosulfate	sulfamethoxazole	$^1O_2$	[4]
CuO@CHFMs/Peroxymonosulfate	Bisphenol A	$^1O_2$	[5]
MWCNTS/peroxymonosulfate	Methylene blue and phenol	charge transfer	[6]
α-MnO_2/Peroxymonosulfate	ciprofloxacin	$SO_4^{\cdot-}$, $^{\cdot}OH$ and $^1O_2$	[7]
Graphitized nanodiamonds/persulfates	Various organic compounds	charge transfer	[8]
$Cu/CuFe_2O_4$//persulfate	Tetracycline	$SO_4^{\cdot-}$ and $^{\cdot}OH$	[9]
Fe_3O_4/sepiolite/persulfate	Atrazine	$SO_4^{\cdot-}$ and $SO_5^{\cdot-}$	[10]
CuO/peroxydisulfate	2,4-dichlorophenol	charge transfer	[11]
$PbFe_2O_4$/peroxymonosulfate	Thionine and tetracyclines	$^1O_2$	This work
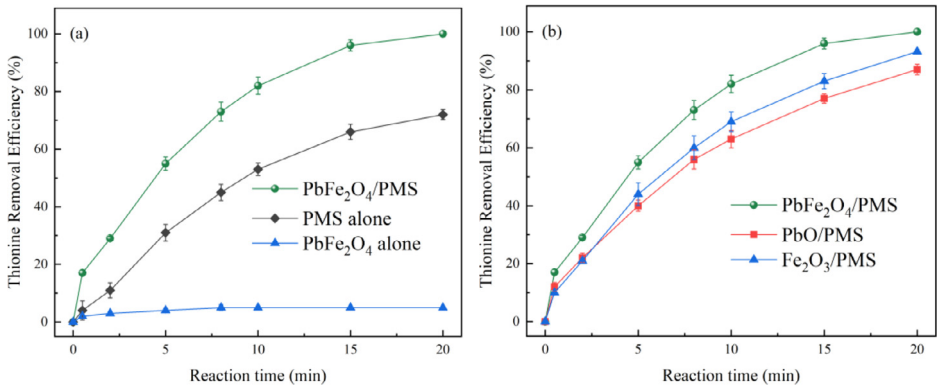
Fig. 3. (a) Thionine removal efficiency in different systems, (b) thionine removal efficiency in catalytic PMS by $PbFe_2O_4$, Fe_2O_3 and PbO. General conditions: $[PMS]_0 = 400\mu M$, Catalyst dosage=400mg·L^{-1}, $[Thionine]_0 = 10\mu M$, pH=9.0, T=25°C.
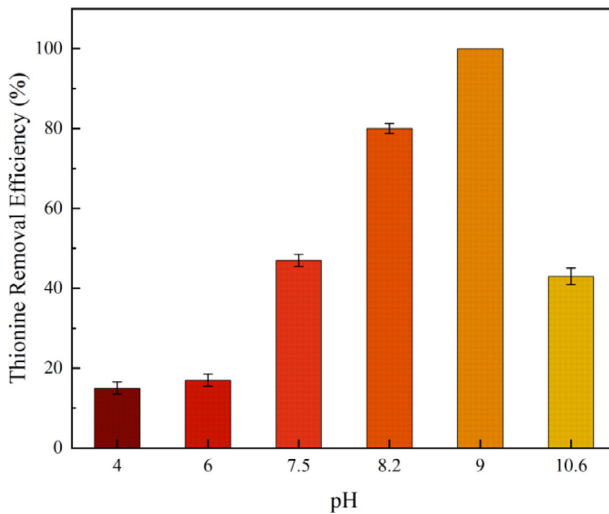

Fig. 4. Thionine removal efficiency in using $PbFe_2O_4$/PMS system under different pH in 20min. Conditions: $[Thionine]_0 = 10\mu M$, $[PMS]_0 = 400\mu M$, Catalyst dosage=400mg·L^{-1}, T=25°C.

2. Experimental Design, Materials, and Methods

2.1. Experimental materials

The $PbFe_2O_4$ catalyst was synthesized by a citrate combustion method according to the modified previous reports [12]. Briefly, the stoichiometric ratio 1:2 of $Pb(NO_3)_2$ (0.01M) and $Fe(NO_3)_2$ (0.02M) were dissolved in 100 mL of ultrapure water under magnetic stirring to form a mixed solution. After that, the specific amount of $C_6H_8O_7 \cdot H_2O$ (0.03M) was added to above solution with continuous stirring for 2h. The pH of solution was adjusted to 5 with concentrated $NH_3 \cdot H_2O$. The obtained homogeneous solution was constant stirred at 90°C until the formation of sticky gel, and then calcined at 600°C for 2h. Finally, the resulted brown products were ground, washed three times with ultrapure water and dried at 80°C for 24h.
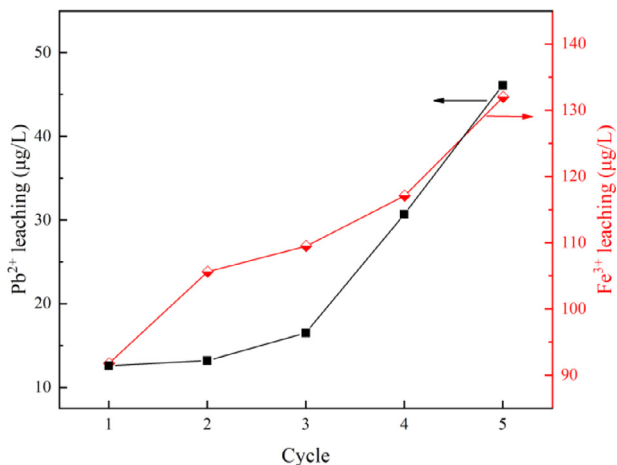
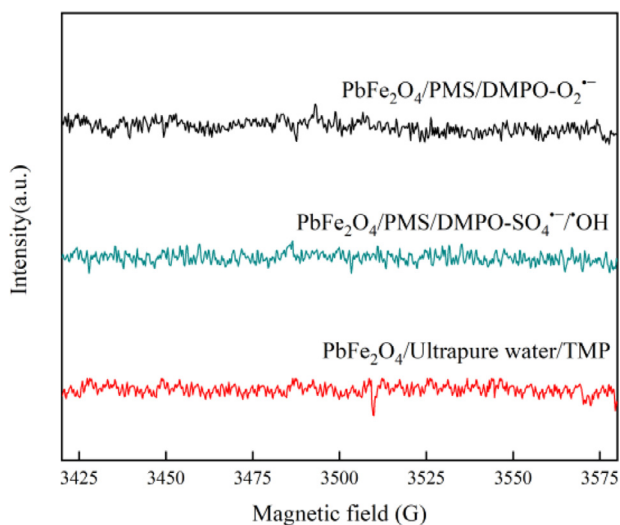**Fig. 5.** Concentrations of lead and ferric ions leached from $PbFe_2O_4$/PMS system after every cycle use of $PbFe_2O_4$.

Fig. 6. EPR spectra of $TMP-{}^1O_2$ and $DMPO-SO_4^{\cdot-}/^{\cdot}OH/O_2^{\cdot-}$.
Conditions: $[PMS]_0=1mM$, $[PbFe_2O_4]=400mg\cdot L^{-1}$, pH=9.0, T=25°C, 3min, $[TMP]_0=25mM$, $[DMPO]_0=25mM$.

Pure PbO and Fe_2O_3 catalysts were used as a comparison in this work and were prepared according to the aforementioned methods used for $PbFe_2O_4$, but without $Pb(NO_3)_2$ and $Fe(NO_3)_2$, respectively.

2.2. Experimental procedure

A common stock solution of each reactant was prepared and aliquots of the stock solutions were combined to achieve the initial experimental conditions. Batch experiments were carried out in 100mL brown glass vials. Specific amounts of $PbFe_2O_4$ were initially dispersed into 80mL organic contaminants solution (thionine or tetracyclines antibiotics). After mixing for 1min, a certain dosage of PMS solution was added to start the reaction. The suspension was stirring at
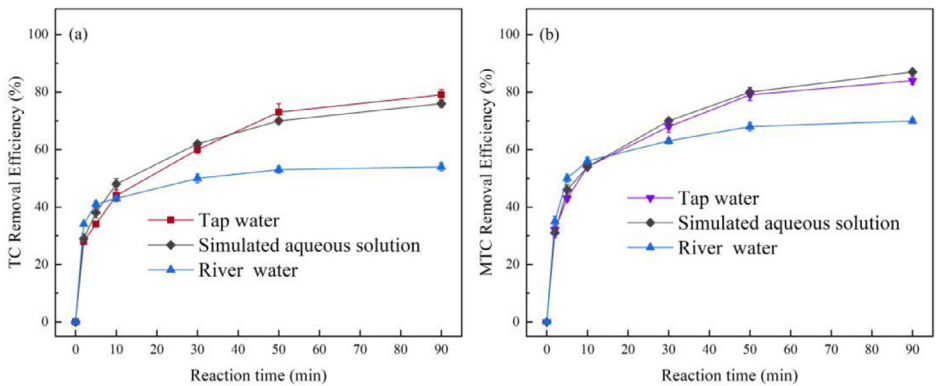
Fig. 7. Remvoal efficiency of Tetracycline (a) and Metacycline (b) by $PbFe_2O_4$/PMS system in different water samples. General conditions: [Tetracyclines]$_0$=5mg•L^{-1}, [PMS]$_0$=400μM, Catalyst dosage=400mg•L^{-1}, pH=9.0, T=25°C.

room temperature (25 ± 2°C) with the rate 120 rpm under exposure to air and samples were withdrawn through 0.45μm filters at different time intervals.

To accurately analyze the concentration of organic compounds, excess sodium nitrite was immediately introduced into the filtrate to quench residual PMS. The residual concentration of thionine in the solution was measured by a UV–vis spectrophotometer (TU-1901, China) at maximum absorbance wavelength of 602 nm, and the tetracyclines antibiotics concentration were determined using a high-performance liquid chromatography (HPLC, Shimadzu LC-20AT, Japan) equipped with Agilent ZORBAX extend 80A C-18 column (4.6 mm × 250 mm with i.d. 5 μm) and a UV detector at a wavelength of 272 nm. The degradation of tetracyclines antibiotics in practical water samples were conducted. Water samples were prepared through adding tetracyclines antibiotics to tap water, river water and self-made water in lab (containing HCO_3^-:10 mM; $H_2PO_4^-$:10 mM; SO_4^{2-}:10 mM and NO_3^-:10 mM) to form a simulated waste water sample for degradation experiments. After finished the thionine degradation experiment, the dissolved metal ions in solution was determined by Atomic Absorption Spectrophotometer (AAS, TAS-990, China).

All of the degradation experiments were performed in triplicate, with error bars in figures representing one standard deviation. Thionine degradation data in $PbFe_2O_4$/PMS, PbO/PMS, and Fe_2O_3/PMS system were fitted by pseudo-first order kinetics (Eq. (1), R^2>0.97).

$$1n \ (C_t/C_0) = -kt \tag{1}$$

where C_0 and C_t represent the initial thionine concentration and the concentration at time t (min) respectively, k (min^{-1}) is the first order reaction rate constant.

Acknowledgments

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2020.105626.

References

[1] Y. Wei, H. Liu, C. Liu, S. Luo, Y. Liu, X. Yu, J. Ma, K. Yin, H. Feng, Fast and efficient removal of As(III) from water by CuFe2O4 with peroxymonosulfate: Effects of oxidation and adsorption, Water Res 150 (2019) 182–190.

[2] Y. Wang, D. Tian, W. Chu, M. Li, X. Lu, Nanoscaled magnetic $CuFe_2O_4$ as an activator of peroxymonosulfate for the degradation of antibiotics norfloxacin, Separation and Purification Technology 212 (2019) 536–544.

[3] X. Dong, B. Ren, Z. Sun, C. Li, X. Zhang, M. Kong, S. Zheng, D.D. Dionysiou, Monodispersed CuFe2O4 nanoparticles anchored on natural kaolinite as highly efficient peroxymonosulfate catalyst for bisphenol A degradation, Applied Catalysis B: Environmental 253 (2019) 206–217.

[4] Y. Zhou, J. Jiang, Y. Gao, J. Ma, S.-Y. Pang, J. Li, X.-T. Lu, L.-P. Yuan, Activation of Peroxymonosulfate by Benzoquinone: A Novel Nonradical Oxidation Process, Environmental Science & Technology 49 (2015) 12941–12950.

[5] J. Deng, Y. Ge, C. Tan, H. Wang, Q. Li, S. Zhou, K. Zhang, Degradation of ciprofloxacin using α-MnO2 activated peroxymonosulfate process: Effect of water constituents, degradation intermediates and toxicity evaluation, Chemical Engineering Journal 330 (2017) 1390–1400.

[6] X. Duan, Z. Ao, L. Zhou, H. Sun, G. Wang, S. Wang, Occurrence of radical and nonradical pathways from carbocatalysts for aqueous and nonaqueous catalytic oxidation, Applied Catalysis B: Environmental 188 (2016) 98–105.

[7] S. Wang, J. Tian, Q. Wang, F. Xiao, S. Gao, W. Shi, F. Cui, Development of CuO coated ceramic hollow fiber membrane for peroxymonosulfate activation: a highly efficient singlet oxygen-dominated oxidation process for bisphenol a degradation, Applied Catalysis B: Environmental 256 (2019).

[8] H. Lee, H.I. Kim, S. Weon, W. Choi, Y.S. Hwang, J. Seo, C. Lee, J.H. Kim, Activation of Persulfates by Graphitized Nanodiamonds for Removal of Organic Compounds, Environ Sci Technol 50 (2016) 10134–10142.

[9] Z. Li, C. Guo, J. Lyu, Z. Hu, M. Ge, Tetracycline degradation by persulfate activated with magnetic Cu/CuFe2O4 composite: Efficiency, stability, mechanism and degradation pathway, J Hazard Mater 373 (2019) 85–96.

[10] X. Xu, W. Chen, S. Zong, X. Ren, D. Liu, Atrazine degradation using Fe3O4-sepiolite catalyzed persulfate: Reactivity, mechanism and stability, J Hazard Mater 377 (2019) 62–69.

[11] T. Zhang, Y. Chen, Y. Wang, J. Le Roux, Y. Yang, J.-P. Croué, Efficient Peroxydisulfate Activation Process Not Relying on Sulfate Radical Generation for Water Pollutant Degradation, Environmental Science & Technology 48 (2014) 5868–5875.

[12] P. Smitha, P.K. Pandey, S. Kurian, N.S. Gajbhiye, Mössbauer studies and magnetic properties of spinel lead ferrite, Hyperfine Interactions 184 (2008) 129–134.