Data Article

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

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ABSTRACT

The aim of this research is to degrade organic contaminants in aqueous solution via lead ferrite (PbFe$_2$O$_4$) as a catalyst to activate peroxymonosulfate (PMS). PbFe$_2$O$_4$ 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$_2$O$_4$ to other catalysts, PbO and Fe$_2$O$_3$, 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.

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Value of the data

- The data reveal that a new spinel material, PbFe₂O₄, 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 PbFe₂O₄/PMS system in thionine and tetracyclines antibiotics degradation.
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) | R²  |
|------------------|----------------------------------|-----|
| ① PbFe₂O₄        |                                  |     |
| 200              | 0.2002                           | 0.967 |
| 400              | 0.2048                           | 0.970 |
| 600              | 0.1477                           | 0.981 |
| 800              | 0.1347                           | 0.984 |
| ② Fe₂O₃         |                                  |     |
| 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 PbFe₂O₄/PMS system.

| Coexisting anions (mM) | k of first order kinetics (min⁻¹) | R²  |
|-----------------------|----------------------------------|-----|
| 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 NO₃⁻               |                                  |     |
| 0                     | 0.2048                           | 0.970 |
| 20                    | 0.1906                           | 0.975 |
| 50                    | 0.1991                           | 0.972 |
| ③ HCO₃⁻              |                                  |     |
| 0                     | 0.2048                           | 0.970 |
| 20                    | 0.2108                           | 0.965 |
| 50                    | 0.2016                           | 0.975 |
| ④ H₂PO₄⁻             |                                  |     |
| 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 |
|----------------------------|------------------|-----------------------|-----------|
| CuFe₂O₄/peroxymonosulfate  | Arsenic(III)     | SO₄⁻⁻ and 'OH        | [1]       |
| CuFe₂O₄/peroxymonosulfate  | Norfloxacin      | SO₄⁻⁻ and 'OH        | [2]       |
| CuFe₂O₄/kaolinite/peroxymonosulfate | Bisphenol A | SO₄⁻⁻ and 'OH      | [3]       |
| Benzoquinone/Peroxymonosulfate | sulfamethoxazole | ¹O₂                  | [4]       |
| CuO/CHFMs/Peroxymonosulfate  | Bisphenol A    | ¹O₂                  | [5]       |
| MWNTs/Peroxymonosulfate     | Methylene blue and phenol | charge transfer        | [6]       |
| α-MnO₃/Peroxymonosulfate     | Ciprofloxacin  | SO₄⁻⁻, 'OH and ¹O₂  | [7]       |
| Graphitized nanodiamonds/persulfates | Various organic compounds | charge transfer | [8]       |
| Cu/CuFe₂O₄//persulfate       | Tetracycline    | SO₄⁻⁻ and 'OH        | [9]       |
| Fe₃O₄/sepiolite/persulfate  | Atrazine        | SO₄⁻⁻ and SO₅⁻⁻     | [10]      |
| CuO/peroxydisulfate         | 2,4-dichlorophenol | charge transfer         | [11]     |
| PbFe₂O₄/peroxymonosulfate   | Thionine and tetracyclines | ¹O₂                  | This work |
Fig. 3. (a) Thionine removal efficiency in different systems, (b) thionine removal efficiency in catalytic PMS by PbFe$_2$O$_4$, Fe$_2$O$_3$ and PbO. General conditions: [PMS]$_0$=400μM, Catalyst dosage=400mg·L$^{-1}$, [Thionine]$_0$=10μM, pH=9.0, T=25°C.

Fig. 4. Thionine removal efficiency in using PbFe$_2$O$_4$/PMS system under different pH in 20min. Conditions: [Thionine]$_0$=10μM, [PMS]$_0$=400μM, Catalyst dosage=400mg·L$^{-1}$, T=25°C.

2. Experimental Design, Materials, and Methods

2.1. Experimental materials

The PbFe$_2$O$_4$ 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$_6$H$_8$O$_7$·H$_2$O (0.03M) was added to above solution with continuous stirring for 2h. The pH of solution was adjusted to 5 with concentrated NH$_3$·H$_2$O. 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.
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$_2$O$_4$ 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
room temperature (25 ± 2°C) with the rate 120 rpm under exposure to air and samples were withdrawn through 0.45 μm 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$_2$PO$_4^-$: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$_2$O$_4$/PMS, PbO/PMS, and Fe$_2$O$_3$/PMS system were fitted by pseudo-first order kinetics ([Eq. (1)], $R^2$>0.97).

$$\ln \left( \frac{C_t}{C_0} \right) = -kt \quad (1)$$

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.

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**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.

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