Fenton-like catalytic oxidation of o-cresol wastewater by H₂O₂ over Fe₂O₃/AC catalysts

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Abstract
A series of high specific surface Fe₂O₃/AC catalysts for the Fenton-like catalytic oxidation of o-cresol wastewater was designed. The catalytic performance due to the characteristics of high specific surface area, large pore volume, high chemical stability and dispersive activity center. Under the suitable reaction conditions, the Fe₂O₃/AC with 3 wt.% Fe₂O₃ loading catalyst can run efficiently and continuously for 500 h without being deactivated, meanwhile the removal efficiency of COD can still be maintained above 59%, even the activity of the catalyst can remain above 79%. As a result, this kind of high specific surface Fe₂O₃/AC catalysts used in the heterogeneous Fenton-like catalytic oxidation of o-cresol wastewater has a great potential for industrial application.

1. Introduction
As an important organic chemical material, o-cresol is widely derived from production and discharge in the chemical fields, such as pesticides, medicine, printing and dyeing, materials, etc [1, 2]. O-Cresol is a prototypical poison, which is harmful for humanity’s ecological life due to the difficulty to be removed under natural conditions. O-Cresol wastewater has such characteristics as difficulty in treatment, extensive source, large pollution, strong toxicity, etc [1, 2].

Thus, how to efficiently treat the o-cresol wastewater is meaningful for the current research of water pollution control. A large number of literatures have been reported for the o-cresol industrial wastewater treatment, generally including physical method, biological method, chemical method, etc [3, 4]. At present, the advanced oxidation process (AOPs) for the pollution control of o-cresol wastewater has been major concerned as its large-scale, efficient, systematic application in the chemical industry. The advanced oxidation process usually refers to the catalytic oxidation, such as catalytic ozone oxidation, catalytic H₂O₂ Fenton oxidation, electrocatalytic oxidation, photocatalytic oxidation, etc [5–7].

The principle of catalytic H₂O₂ Fenton oxidation technology is that a large number of oxygen-containing radicals, such as ·HO₂, ·HO₃, ·O₂⁻, and ·OH, produced from catalytic decomposition of H₂O₂ in the presence of Fe²⁺ oxidize and degrade organic matters [8, 9]. However, catalytic H₂O₂ Fenton oxidation process has many defects, including large iron sludge output, wastewater color reversion, harsh conditions and serious corrosion, etc. Heterogeneous catalyst is used in catalytic Fenton oxidation method. To enhance the ability of catalytic H₂O₂ Fenton oxidation reaction to control the organic wastewater and eliminate the technical barrier of homogeneous catalytic Fenton oxidation [10–13], it is of great significance to select heterogeneous Fenton catalytic oxidation process and enhance the catalytic performance, the key step is the heterogeneous catalyst and its catalytic carriers [10–13]. Zeolite was used as catalytic carriers, but the enhancement of efficiency of degrading o-cresol is limited, the removal rate only reached 50% after 120 min [14]. In order to obtain higher degradation efficiency, it is necessary to find more effective load materials.

Activated carbon (AC) is a kind of advanced porous carbon material and it has a wide application prospect especially in catalysis, separation, biology and nano-materials. Currently, AC as catalytic carriers have been used in new research fields of catalytic reaction and water pollution control. This kind of porous material has the
characteristics as high chemical and physical stability, high specific surface area and pore volume, complicated and variable pore structure, easy to control, etc \[15\text{–}19\]. The unique and new findings is that Fe$_2$O$_3$/AC catalysts for the Fenton-like catalytic oxidation of o-cresol wastewater for the AOPs process, however the application of such high-performance material to treat o-cresol wastewater by catalytic H$_2$O$_2$ Fenton oxidation has not been reported yet, no literature have reported the new AOPs process.

Because of AC material has the excellent catalytic performance in the field of catalysis, in our work a series of heterogeneous Fenton-like Fe$_2$O$_3$/AC materials with high specific surface area, large pore volume, high chemical stability and dispersive activity center were prepared by impregnation method. Fenton-like catalytic process has been selected in our work for the preparation of a new type of Fe$_2$O$_3$/AC catalysts for the control of o-cresol wastewater. With characterization of FTIR, XRD, BET, XPS, SEM, TEM, as well as NH$_3$/CO$_2$-TPD on the catalytic performance, this kind of high specific surface Fe$_2$O$_3$/AC catalysts used in the heterogeneous Fenton-like catalytic oxidation of o-cresol wastewater has a great potential for the industrial application.

2. Material and experiment

2.1. Material and characterization

O-Cresol C$_7$H$_8$O (analytically pure) and iron(III) nitrate nonahydrate Fe(NO$_3$)$_3$ · 9H$_2$O (analytically pure) were produced in Chemical Reagent Co., Ltd. of Sinopharm Group; AC (Activated carbon) with high specific surface ($S_{\text{BET}}$ 1511 m$^2$ g$^{-1}$, $V_{\text{total}}$ 0.78 cm$^3$ g$^{-1}$) was home-made in laboratory. The crystal structure was observed by an X-ray diffractometer (XRD Rigaku D/Max-1200) at the scanning range of 5°–80° and the scanning speed of 10° min$^{-1}$. The valence state was analyzed by X-ray photoelectron spectroscopy (XPS Thermo Fisher Scientific) and performed on a KAlpha 1063 system with an Al Ka radiation. The catalyst was tested on its specific surface area and pore volume by ASAP 2400 specific surface area and micropore analyzer made by Micromeritics Company after pretreated at 350°C in vacuum for 3 h by using N$_2$ as adsorbate. The morphology of the samples was observed by a scanning electron microscopy (SEM, SUPRA55). The transmission electron microscopy (TEM) images were obtained using FEI Tecnai G2 F20. Acid-base properties (NH$_3$/CO$_2$-TPD) of catalysts were determined by ChemBET-3000 chemical adsorption analyzer.

2.2. Catalyst preparation

The mesophase carbon microspheres and the activator KOH were proportionally mixed in a solution, a small amount of C$_2$H$_5$OH was added as dispersant, and then they were dried at 130°C. The activated carbon semi-finished product was heated to the activation temperature and kept at this temperature for a period of time in a corundum crucible protected by N$_2$ and displaced by steam at 120°C for 10 h; different weights of Fe(NO$_3$)$_3$ · 9H$_2$O were dissolved in ultrapure water, immersed in an equal volume of solution for 24 h, and dried at 80°C for 12 h; and the dried catalyst was roasted at 350°C in nitrogen tube furnace for 5 h to obtain light yellow solid, which was pressed to form the Fe$_2$O$_3$/AC catalysts with different Fe$_2$O$_3$ loadings. These Fe$_2$O$_3$/AC catalysts were used to prepare the Fe$_2$O$_3$/AC samples with the Fe$_2$O$_3$
content of 1, 3, 5, 7 and 10 wt.%, which were numbered as Fe$_2$O$_3$(1)/AC, Fe$_2$O$_3$(3)/AC, Fe$_2$O$_3$(5)/AC, Fe$_2$O$_3$(7)/AC, and Fe$_2$O$_3$(10)/AC, respectively.

2.3. Catalyst evaluation

For the equipment of Fenton-like catalytic oxidation of o-cresol wastewater catalyzed by Fe$_2$O$_3$/AC materials, in the figure 1. H$_2$O$_2$ was used as the oxygen source. The H$_2$O$_2$ concentration and o-cresol wastewater flow was controlled by throttle valves. The organic glass (acrylic glass) reactor has the volume of $\phi 65 \text{ cm} \times 35 \text{ cm}$. The o-cresol wastewater was sampled at the inlet and outlet and tested on its o-cresol concentration and COD. For the single reaction, see figure 1. At the room temperature of 20 °C, 10g of Fe$_2$O$_3$/AC was added, and the water inlet and outlet valves were opened. After saturated and stable catalyst adsorption (excluding the impact of physical adsorption), the o-cresol concentration of the simulated o-cresol containing wastewater inlet was adjusted to 60 mg l$^{-1}$ (COD, 173 mg l$^{-1}$). 300 ml of wastewater was injected to the catalyst bed before the inlet and outlet valves were closed. The H$_2$O$_2$ flow rate was adjusted to 5 mg min$^{-1}$. Fe$_2$O$_3$/AC catalyzed H$_2$O$_2$ oxidation of o-cresol containing wastewater. The wastewater was sampled and tested every 10 min. For the continuous reaction, see figure 1. At the room temperature at 20 °C, 30g of Fe$_2$O$_3$/AC was added, and the water inlet and outlet valves were opened. After saturated and stable catalyst adsorption (excluding the impact of physical adsorption), the COD at the simulated o-cresol containing wastewater inlet was adjusted to 238 mg l$^{-1}$. Fe$_2$O$_3$/AC continuously catalyzed H$_2$O$_2$ oxidation of o-cresol containing wastewater at the wastewater flow rate was of 0.81 h$^{-1}$, H$_2$O$_2$ flow rate of 5 mg min$^{-1}$, and HRT of 5 min. After stable reaction, the effluent at the outlet was sampled once every 20 h. Chemical oxygen demand (COD) is the oxygen concentration corresponding to the consumed potassium dichromate calculated according to the organic matters in wastewater oxidized by potassium dichromate. A known amount of potassium dichromate solution was added to a strongly acidic medium. The chloride ions in the solution were shielded by mercury sulfate. The organic matters in the wastewater were catalytically oxidized by silver sulfate as catalyst. The wastewater was tested on its COD by spectrophotometry and on its o-cresol concentration by 4-aminoantipyrine method [20].

3. Result and discussion

3.1. Catalyst characterization

Figure 2 shows the XRD and FT-IR spectra of Fe$_2$O$_3$/AC Fenton catalyst. It can be seen from the wide angle spectrum (10° ~ 65°) of XRD in figure 2(a) that all Fe$_2$O$_3$/AC Fenton catalysts have the characteristic peak of activated carbon, in which 26.7° is the typical peak of activated carbon [21]. Compared with the unmodified activated carbon, Fe$_2$O$_3$/AC Fenton catalyst has not only the characteristic peak of carbon, but also characteristic peaks of iron oxide at 35.6° (JCPDS 33-0664) [21]. With increasing Fe$_2$O$_3$ content in the catalyst, the characteristic peaks of iron oxide become more obvious, but the peak intensity of iron oxide is weak and no main phase is clearly shown due to the decrease of Fe$_2$O$_3$ content, further suggesting that the iron oxide has been loaded into the surface of activated carbon, consistent with the electron microscopy results. It can be seen from the FT-IR spectrum of Fe$_2$O$_3$/AC Fenton catalyst in figure 2(b) that Fe$_2$O$_3$/AC Fenton catalyst has the characteristic peaks of active carbon, in which at 2922–2855 cm$^{-1}$ is the stretching vibration peaks of C–H, at 1385 cm$^{-1}$ is the deformation vibration peak of H–C–H, at 1110 cm$^{-1}$ is the stretching vibration peak of C–O, at 3462–3432 cm$^{-1}$ is the stretching vibration peak of O–H [22, 23]. Compared with AC, the Fe$_2$O$_3$/AC Fenton
Figure 3. SEM and TEM images of Fe$\text{}_2\text{O}_3$/AC Fenton-like catalysts.

Figure 4. Scan and Fe 2p XPS spectras of Fe$\text{}_2\text{O}_3$/AC Fenton-like catalysts.
catalyst not only has the FT-IR characteristic peak of AC, in which the peak value at 3462–3432 cm\(^{-1}\) increases because of stretching vibration addition of O–H on the surface of iron oxide, but also FT-IR characteristic peak of Fe\(_2\)O\(_3\), in which at 1634 cm\(^{-1}\) is the characteristic peak of Fe–OH, and at 740 cm\(^{-1}\) is the characteristic peak of Fe–O in FeOOH [22, 23].

As shown in figure 3(a), SEM image shows that the catalysts has complicated surface morphology, a typical complicated amorphous porous structures of activated carbon, which provide a large specific surface and pore volume and a large number of catalytic active sites for the catalyst; and the low magnification images of TEM (figures 2(b), (c)) show that some Fe\(_2\)O\(_3\) active sites uniformly disperse and others agglomerate on the AC surface due to the porous irregularity of AC surface [24]. In addition, the lattice fringes with a d-spacing of 0.27 nm can be assigned to the (110) lattice plane of Fe\(_2\)O\(_3\) (figure 3(c)).

Figure 4 shows the full spectra of Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst and Fe 2p spectra. From the full spectra of Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst that the characteristic peaks of Fe 2p, O 1s and C 1s can be seen at roughly 710 eV, 530 eV, and 285 eV, respectively, as shown in figure 4(a), suggesting that Fe\(_2\)O\(_3\)(3)/AC Fenton fresh catalyst contains Fe, O and C, etc., and Fe element covers the catalyst surface [25, 26]. In addition, it can be seen from the Fe 2p spectra of Fe\(_2\)O\(_3\)(3)/AC fresh Fenton catalyst and the spent catalyst from 500 h reaction in figure 4(b) that for the fresh catalyst, main peak and satellite peak of Fe 2p\(_{1/2}\) are at 724.08 eV and 732.78 eV, respectively, and of Fe 2p\(_{3/2}\) are at 710.68 eV and 718.68 eV, respectively, indicating that the difference in binding energy between main peak of Fe 2p\(_{3/2}\) and the satellite peak of Fe 2p\(_{3/2}\) is about 8 eV and between main peaks of Fe 2p\(_{3/2}\) and Fe 2p\(_{1/2}\) is about 13.4 eV, which are the characteristics of the peaks of Fe 2p. The analysis of the main peak of Fe 2p\(_{3/2}\) shows that Fe\(^{3+}/Fe^{2+}\) is 96:4, indicating that Fe\(^{3+}\) valence structure of Fe\(_2\)O\(_3\) mainly exists in the fresh catalyst [25, 26]. For the spent catalyst from 500 h reaction, main peaks of Fe 2p\(_{1/2}\) and Fe 2p\(_{3/2}\) are at 723.08 eV and 709.58 eV, respectively, and the difference in the binding energy between the two main peaks is about 13.4 eV, which is a characteristic of the peak of Fe 2p. The analysis of the main peaks of Fe 2p\(_{3/2}\) shows that Fe\(^{3+}/Fe^{2+}\) is 55:45, indicating that Fe\(^{3+}\) and Fe\(^{2+}\) of Fe\(_2\)O\(_3\) mainly exist in the fresh catalyst, in 500 h reaction, some of Fe\(^{3+}\) is reduced to Fe\(^{2+}\), which is stable structure [25, 26].

Figure 5 shows the NH\(_3\)-TPD and CO\(_2\)-TPD tests of Fe\(_2\)O\(_3\)/AC Fenton-like catalysts. A mount of acid/base properties on Fe\(_2\)O\(_3\)/AC Fenton catalyst surface was analyzed [27]. It can be known from figure 5(a) that a large number of weak acid centers (at about 170 °C) and a large number of moderate/strong acid centers (at about 370 °C) are produced on the surface of Fe\(_2\)O\(_3\)/AC Fenton catalyst compared with the carrier AC; the spent Fe\(_2\)O\(_3\)/AC Fenton catalyst from 500 h reaction has fewer weak acid centers and moderate/strong acid centers on its surface than fresh Fe\(_2\)O\(_3\)/AC Fenton catalyst. It can be seen from figure 5(b) that a large number of weak base centers (at about 160 °C) and a small number of moderate/strong base centers (at about 340 °C) are produced on the surface of Fe\(_2\)O\(_3\)/AC Fenton catalyst compared with the carrier AC, and the spent Fe\(_2\)O\(_3\)/AC Fenton catalyst from 500 h reaction has fewer weak base centers and moderate/strong base centers on its surface than fresh Fe\(_2\)O\(_3\)/AC Fenton catalyst. Based on the catalyst performance evaluation, it shows that the activity of the catalyst is closely related to the content of acid/base centers on the surface of the catalyst, and the main active sites of the modified Fenton catalyst are Fe\(_2\)O\(_3\) and Fe\(_2\)O\(_4\), which effectively catalyze the H\(_2\)O\(_2\) oxidation of o-cresol containing wastewater.
3.2 Catalyst performance evaluation

Table 1 shows the structure and catalytic performance parameters of Fe2O3/AC Fenton catalysts, which are used for H2O2 oxidation of o-cresol containing wastewater, including blank, Fe2O3/AC Fenton catalyst with different Fe2O3 loadings, and Fe2O3(3)/AC Fenton catalyst from 500 h reaction. With increasing Fe2O3 loading from 0wt. % to 10wt. %, the specific surface area of the catalyst decreases from 1511 m2 g−1 to 785 m2 g−1 and the pore volume decreases from 0.78 cm3 g−1 to 0.49 cm3 g−1 because Fe2O3 occupies the porous surface of the AC as the catalytic active sites [28].

After 60 min H2O2 oxidation of 300 ml × 60 mg l−1 o-cresol solution at the catalyst consumption of 10g and H2O2 flow rate of 5 mg min−1, the o-cresol removal and COD removal are only 8.9% and only 3.5% respectively in the absence of catalyst. With the increasement of Fe2O3 loading, the performance of Fe2O3/AC Fenton catalyst in the H2O2 oxidation of o-cresol containing wastewater increases first and then decreases, and the Fe2O3(3)/AC Fenton catalyst maintain better o-cresol removal (40.3%–99.3%) and COD removal (27.8%–77.6%). Table 1 shows that the AC carrier also has an obvious effect on H2O2 catalytic oxidation of o-cresol, indicating that the complicated porous structure on the surface of AC can promote the catalytic decomposition of H2O2. From the perspective of Fenton catalysis principle, the active sites, Fe2O3 and Fe3O4, can provide Fe2+ and Fe3+ heterogeneous adsorption sites, which decompose H2O2 into a large number of oxygen-containing radicals, which efficiently catalyze the oxidation of the adsorbed o-cresol [29].

It can be seen from table 1 that Fe2O3/AC Fenton catalyst have higher catalytic performance than AC. The synergistic effect of AC and Fe2O3 as a catalytic active site further enhances the catalytic performance of H2O2 oxidation of o-cresol containing wastewater. The removal of o-cresol and COD are 99.3% and 77.6%, respectively, after 60 min. H2O2 oxidation of 300 ml × 60 mg l−1 o-cresol solution at the catalyst consumption of 10g and H2O2 flow rate of 5 mg min−1. The Fe2O3(3)/AC Fenton catalyst from 500 h continuous reaction was re-evaluated, with the o-cresol and COD removal of 77.2% and 59.4%, respectively, under the same conditions, indicating that Fe2O3(3)/AC Fenton catalyst exhibits very good initial catalytic performance and stability during H2O2 oxidation of o-cresol containing wastewater.

Figure 6 shows the performance (o-cresol and COD removal) of Fe2O3/AC Fenton catalyst for 1 h H2O2 oxidation of o-cresol containing wastewater. The AC carrier provides higher catalytic performance of H2O2 oxidation of o-cresol containing wastewater and much better catalytic effect in the initial reaction time of 60 min than the Fe2O3/AC Fenton catalyst for 10 min. H2O2 oxidation of 300 ml × 60 mg l−1 o-cresol solution at the

![Figure 6. Effect of reaction time on catalytic performance over Fe2O3(3)/AC Fenton catalysts.](image)

### Table 1. Catalytic oxidation performance of o-cresol wastewater by H2O2 over Fe2O3/AC.

| Samples          | BET surface area /m² g⁻¹ | Pore volume/cm³ g⁻¹ | o-cresol removal rate/% | COD removal rate/% |
|------------------|--------------------------|---------------------|-------------------------|-------------------|
| non catalyst     | \                        | \                   | 8.9                     | 3.5               |
| AC + H2O2        | 1511                     | 0.78                | 40.3                    | 27.8              |
| Fe2O3(1)/AC      | 1332                     | 0.67                | 67.2                    | 51.7              |
| Fe2O3(3)/AC      | 1108                     | 0.65                | 99.3                    | 77.6              |
| Fe2O3(5)/AC      | 976                      | 0.56                | 90.4                    | 69.5              |
| Fe2O3(7)/AC      | 842                      | 0.53                | 94.2                    | 49.2              |
| Fe2O3(10)/AC     | 785                      | 0.49                | 43.2                    | 33.2              |
| 500 h spent      | 954                      | 0.47                | 77.2                    | 59.4              |
catalyst consumption of 10 g and H2O2 flow rate of 5 mg min\(^{-1}\). With increasing Fe\(_2\)O\(_3\) loading, the catalytic oxidation effect of Fe\(_2\)O\(_3\)/AC Fenton catalyst increases first and then decreases in the initial reaction time of 60 min, but the Fe\(_2\)O\(_3\)/AC Fenton catalyst has better total catalytic performance than AC carrier, indicating that Fe\(_2\)O\(_3\) loading further improves the catalytic oxidation performance of the catalyst. The catalyst from 500 h continuous reaction was evaluated on its 60 min catalysis performance. The evaluation results show that the catalyst maintains outstanding degradation rate and performance. After 40 min reaction catalyzed by Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst, the COD removal and o-cresol removal tend to a balance and reach about 71% and 94%, respectively, suggesting that Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst has the best performance. Thus, Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst is selected for continuous reaction evaluation and continuous flow stability test.

Figure 7 shows the 500 h H2O2 oxidation of o-cresol containing wastewater in a continuous flow reaction catalyzed by 30 g of Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst and AC, respectively, at the initial COD of 238 mg/l in the o-cresol solution, H2O2 consumption of 5 mg min\(^{-1}\), the wastewater HRT of 5 min and the wastewater flow rate of 0.8 l h\(^{-1}\). It can be seen from figure 7 that the Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst has much better activity and stability than AC; after continuous catalytic oxidation reaction, the COD at the AC outlet is 180–214 mg l\(^{-1}\) and the COD removal is 24%–10%, and the catalyst significantly deactivates because the catalyst activity reduces by 58% to only 42% of the initial activity. Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst has better catalytic activity and stability. After 500 h continuous catalytic oxidation reaction catalyzed by Fe\(_2\)O\(_3\)(3)/AC Fenton catalyst, the COD at the outlet is 53–97 mg l\(^{-1}\) and the COD removal is about 78%–59%, and the catalytic activity reduces only by 24% to
76% of the initial activity. The Fe₂O₃(3)/AC Fenton catalyst had industrial application value due to its outstanding performance in continuous flow test in a laboratory.

### 3.3. Catalytic mechanism

According to the principle of H₂O₂ oxidation catalyzed by Fenton Fe²⁺, a series of Fe₂O₃(3)/AC Fenton catalysts were prepared by impregnation method and structurally characterized. The active sites were Fe₂O₃ and Fe₃O₄ at a stable equilibrium. The Catalytic oxidation mechanism as displayed in figure 8 shows, oxygen-deficient α-Fe₂O₃ catalysts not only provided dual reaction sites (Fe²⁺ and oxygen vacancy) for H₂O₂ activation promoting H₂O₂ to decompose the *in situ*-generated ·OH, but also afforded rich oxygen vacancy sites for organic pollutant adsorption and the generated ·OH to rapid react with adjacent adsorbed pollutant, thus showing excellent Fenton-like catalytic performance [30–34]. Our findings show that the surface electronic-state modulation could obviate the need for modification of many transition metal oxides with other materials, addressing poor reactivity issues.

### 4. Conclusion

Initial activity of Fe₂O₃/AC Fenton catalyst was evaluated. The Fe₂O₃/AC Fenton catalyst has the best performance, o-cresol removal and COD removal of 99.3% and 77.6%, respectively, after 60 min H₂O₂ oxidation of 300 ml x 60 mg l⁻¹ o⁻¹-cresol solution at the catalyst consumption of 10 g and H₂O₂ flow rate of 5 mg min⁻¹. In the 500 h H₂O₂ oxidation of o-cresol-containing wastewater in a continuous flow reaction catalyzed by 30 g of Fe₂O₃(3)/AC Fenton catalyst at the initial COD of 238 mg/l in the o-cresol solution, H₂O₂ consumption of 5 mg min⁻¹, the wastewater HRT of 5 min and the wastewater flow rate of 0.81 l h⁻¹, the Fe₂O₃(3)/AC Fenton catalyst operates efficiently and stably for 500 h, seldom deactivates, and maintains the COD removal of over 78% and the catalytic activity of over 59%. The Fe₂O₃/AC Fenton catalysts, especially Fe₂O₃(3)/AC catalyst, had been stably and efficiently used in industrial water treatment for the field of o-cresol containing wastewater.

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### Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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