Characteristics of activated carbon remove sulfur particles against smog

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Abstract  Sulfur particles, which could cause diseases, were the main powder of smog. And activated carbon had the very adsorption characteristics. Therefore, five sulfur particles were adsorbed by activated carbon and were analyzed by FT-IR. The optimal adsorption time were 120 min of Na$_2$SO$_3$, 120 min of Na$_2$S$_2$O$_8$, 120 min of Na$_2$SO$_4$, 120 min of Fe$_2$(SO$_4$)$_3$ and 120 min of S. FT-IR spectra showed that activated carbon had the eight characteristic absorption of S, S–S stretch, H$_2$O stretch, O–H stretch, C=C stretch, conjugated C=O stretch or C=C stretch, CH$_2$ bend, C=O stretch and acetylenic C–H bend vibrations at 3850 cm$^{-1}$, 3740 cm$^{-1}$,3 4 3 0 c m$^{-1}$, 2920 cm$^{-1}$, 1630 cm$^{-1}$, 1390 cm$^{-1}$, 1110 cm$^{-1}$ and 600 cm$^{-1}$, respectively. For Na$_2$SO$_3$, the peaks at 2920 cm$^{-1}$, 1630 cm$^{-1}$, 1390 cm$^{-1}$ and 1110 cm$^{-1}$ achieved the maximum at 20 min. For Na$_2$S$_2$O$_8$, the peaks at 3850 cm$^{-1}$, 3740 cm$^{-1}$ and 2920 cm$^{-1}$ achieved the maximum at 60 min. The peaks at 1390 cm$^{-1}$, 1110 cm$^{-1}$ and 600 cm$^{-1}$ achieved the maximum at 40 min. For Na$_2$SO$_4$, the peaks at 3430 cm$^{-1}$, 2920 cm$^{-1}$, 1630 cm$^{-1}$, 1390 cm$^{-1}$, 1110 cm$^{-1}$ and 600 cm$^{-1}$ achieved the maximum at 60 min. For Fe$_2$(SO$_4$)$_3$, the peaks at 1390 cm$^{-1}$, 1110 cm$^{-1}$ and 600 cm$^{-1}$ achieved the maximum at 20 min. For S, the peaks at 1630 cm$^{-1}$, 1390 cm$^{-1}$ and 600 cm$^{-1}$ achieved the maximum at 120 min. It provided that activated carbon could remove sulfur particles from smog air to restrain many anaphylactic diseases.

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1. Introduction

Sulfur powder, is solid at room temperature, mainly from the exploitation of natural gas, oil and natural sulfur mine. Reactive sulfur in general, it can burn to sulfur dioxide, mixing with oxidants may explode, can react with the alkali metal (Zhang et al., 2010). An association between high levels of air pollutants and human disease has been known for more than half a century. Air pollution is composed of a heterogeneous mix-
ture of compounds including ozone (O₃), carbon monoxide (CO), sulfur dioxide (SO₂), nitrogen oxides (NOₓ), liquids, and particulate matter (PM). Substantial epidemiological evidence implicates air pollution, particularly sulfur dioxide (SO₂) and PM, as a major risk factor with serious consequences on human health (Ahmadpour and Do, 1996; Chandra et al., 2009; Jumasiah et al., 2005). Of particular interest in PM are the particles that are ≤10 μm in diameter (PM₁₀) because they are the PM that ultimately enters the lungs, which may make the person allergic and sick. Globally, the number of people receiving TB therapy grew to 5.4 million in 2013, from 1.0 million enrolled in the DOTS (directly observed treatment, short-course) program in 1995 (Yuan et al., 2004). Sulfur powder and sulfur dioxide (SO₂) often floated in air. If this was inhaled in vivo, it could cause diseases.

Activated carbon can use almost any type of carbon materials, such as wood (Zhang et al., 2010), sawdust, coal (Ding et al., 2002), shells (Yu et al., 2005), the stone of the fruit, bagasse, oil waste, waste plastics (Peng et al., 2014a), paper and leather scrap (Peng et al., 2013a), waste tires, urban waste, etc (Xiao et al., 2013). Activated carbon with highly developed porous structure and huge specific surface area (Peng et al., 2013b), good chemical stability and thermal stability, high mechanical strength and surface contains a variety of oxygen containing functional groups (Wang et al., 2013; Peng et al., 2013c). What’s more, activated carbon, which contained potassium, calcium and other minerals, could have adsorption and filtration of extractives, oil, sulfur-based compounds, other matters (Liu et al., 2008; Zhang et al., 2008; Ling et al., 1999; Bautista-Toledo et al., 1994). Therefore, activated carbon has a strong adsorption, and at the same time can make high dispersed catalyst load system, and as a reducing agent to participate in the reaction, reduces the reaction temperature (Wang et al., 2009). Activated carbon adsorption method is simple, no secondary pollution, can be very good for adsorption of sulfide in the air (Lin et al. 2015; Peng et al., 2014b, 2015; Sun et al., 2014; Wang et al., 2009). What’s more, activated carbon, which contained potassium, calcium and other minerals, could have adsorption and filtration of extractives, oil, sulfur-based compounds, other matters (Liu et al., 2008; Zhang et al., 2008; Ling et al., 1999; Bautista-Toledo et al., 1994). Therefore, activated carbon has a strong adsorption, and at the same time can make high dispersed catalyst load system, and as a reducing agent to participate in the reaction, reduces the reaction temperature (Wang et al., 2009). Activated carbon adsorption method is simple, no secondary pollution, can be very good for adsorption of sulfide in the air (Lin et al. 2015; Peng et al., 2014b, 2015; Sun et al., 2014; Wang et al., 2009). Activated carbon, Na₂SO₃, Na₂S₂O₈, Na₂SO₄, Fe₂(SO₄)₃, and S were purchased from the market.

2. Materials and methods

2.1. Materials

Activated carbon, Na₂SO₃, Na₂S₂O₈, Na₂SO₄, Fe₂(SO₄)₃ and S were purchased from the market.

2.2. Methods

Five kinds of pharmaceutical powders were weighed to 25 g, respectively. These powder and 4 g activated carbon were put into the closed vessel, respectively. It was left in closed vessel for 20 min, 40 min, 60 min, 80 min, 100 min and 120 min, respectively. Each activated carbon was removed, dried, weighed, respectively.

FT-IR spectra: FT-IR spectra of the above samples were obtained using a Thermo Scientific Nicolet iN10 FT-IR micro-

3. Result and analysis

Based on the above test, the result of adsorption was obtained and is listed in Table 1.

3.1. SC effect

Based on Table 1, Na₂SO₃’s adsorption capacity was 5.01 g/100 g, 9.23 g/100 g, 9.68 g/100 g, 11.9 g/100 g, 11.9 g/100 g, 16.3 g/100 g; Na₂S₂O₈’s adsorption capacity was 5.94 g/100 g, 6.93 g/100 g, 12.4 g/100 g, 17 g/100 g, 15.3 g/100 g, 17.7 g/100 g; Na₂SO₄’s adsorption capacity was 5.99 g/100 g, 4.24 g/100 g, 5.99 g/100 g, 6.48 g/100 g, 7.54 g/100 g, 15 g/100 g; Fe₂(SO₄)₃’s adsorption capacity was 7.21 g/100 g, 6.27 g/100 g, 8.93 g/100 g, 12.1 g/100 g, 13.3 g/100 g, 16.8 g/100 g; S’s adsorption capacity was 9.5 g/100 g, 10.2 g/100 g, 11.6 g/100 g, 13.6 g/100 g, 16.8 g/100 g, 19.5 g/100 g for adsorption time of 20 min, 40 min, 60 min, 80 min, 100 min and 120 min, respectively. It showed that adsorption capacity changed at regularity difference. It might be because rapid stirring led to a small amount of five kinds of pharmaceutical powders on the surface of the activated carbon. The optimal adsorption times were 120 min of Na₂SO₃, 120 min of Na₂S₂O₈, 120 min of Na₂SO₄, 120 min of Fe₂(SO₄)₃ and 120 min of S (Table 2).

3.2. FT-IR analysis

FT-IR spectra were recorded to investigate the functional groups of activated carbon during adsorption of Na₂SO₃, Na₂S₂O₈, Na₂SO₄, Fe₂(SO₄)₃ and S. Spectra of the samples were shown in Figs. 1–5. In the spectrum of adsorption, the S=O stretch, H₂O stretch, O–H stretch, =C–H stretch, conjugated C==O stretch or C=C stretch, CH₂ bend, C–O stretch and acetylenic C–H bend vibrations were observed at 3850 cm⁻¹, 3740 cm⁻¹, 3430 cm⁻¹, 2920 cm⁻¹, 1630 cm⁻¹, 1390 cm⁻¹, 1110 cm⁻¹ and 600 cm⁻¹, respectively. For FT-IR spectra of Na₂SO₃, the transmissivity of the peaks at 3850 cm⁻¹ and 3740 cm⁻¹ achieved the maximum for 120 min, the transmissivity of the peaks at 3430 cm⁻¹ and 600 cm⁻¹ achieved the maximum for 40 min, the transmissivity of the peaks at 2920 cm⁻¹, 1630 cm⁻¹, 1390 cm⁻¹ and 1110 cm⁻¹ achieved the maximum for 20 min.

For FT-IR spectra of Na₂S₂O₈, the transmissivity of the peaks at 3850 cm⁻¹, 3740 cm⁻¹ and 2920 cm⁻¹ achieved the maximum for 60 min, the transmissivity of the peaks at 3430 cm⁻¹ achieved the maximum for 100 min, the transmissivity of the peaks at 1630 cm⁻¹ achieved the maximum for 80 min, the transmissivity of the peaks at 1390 cm⁻¹, 1110 cm⁻¹ and 600 cm⁻¹ achieved the maximum for 40 min. For FT-IR spectra of Na₂SO₄, the transmissivity of the peaks at 3850 cm⁻¹ and 3740 cm⁻¹ achieved the maximum for 40 min, the transmissivity of the peaks at 3430 cm⁻¹, 2920 cm⁻¹, 1630 cm⁻¹, 1390 cm⁻¹, 1110 cm⁻¹ and 600 cm⁻¹ achieved the maximum for 60 min.

For FT-IR spectra of Fe₂(SO₄)₃, the transmissivity of the peaks at 3850 cm⁻¹ and 3740 cm⁻¹ achieved the maximum for 120 min, the transmissivity of the peaks at 3430 cm⁻¹ and
1630 cm\(^{-1}\) achieved the maximum for 60 min, the transmissivity of the peaks at 2920 cm\(^{-1}\) achieved the maximum for 80 min, the transmissivity of the peaks at 1390 cm\(^{-1}\), 1110 cm\(^{-1}\) and 600 cm\(^{-1}\) achieved the maximum for 20 min.
For FT-IR spectra of S, the transmissivity of the peaks at 3850 cm\(^{-1}\), 3740 cm\(^{-1}\) and 2920 cm\(^{-1}\) achieved the maximum for 80 min, the transmissivity of the peaks at 3430 cm\(^{-1}\) achieved the maximum for 40 min, the transmissivity of the peaks at 1630 cm\(^{-1}\), 1390 cm\(^{-1}\) and 600 cm\(^{-1}\) achieved the maximum for 120 min, the transmissivity of the peaks at 1110 cm\(^{-1}\) achieved the maximum for 20 min.

4. Conclusion

Na\(_2\)SO\(_3\)'s, Na\(_2\)S\(_2\)O\(_8\)'s, Na\(_2\)SO\(_4\)'s, Fe\(_2\)(SO\(_4\))\(_3\)'s and S's adsorption capacities were different for adsorption times of 20 min, 40 min, 60 min, 80 min, 100 min and 120 min, respectively. The optimal adsorption times were 120 min of Na\(_2\)SO\(_3\), 120 min of Na\(_2\)S\(_2\)O\(_8\), 120 min of Na\(_2\)SO\(_4\), 120 min of Fe\(_2\)(SO\(_4\))\(_3\) and 120 min of S.

FT-IR spectra of Na\(_2\)SO\(_3\)'s, Na\(_2\)S\(_2\)O\(_8\)'s, Na\(_2\)SO\(_4\)'s, Fe\(_2\)(SO\(_4\))\(_3\)'s and S's adsorption capacities showed that activated carbon had the eight characteristic absorption bands. And the S–S stretch, H\(_2\)O stretch, O–H stretch, \(\equiv\)C–H stretch, conjugated C–O stretch or C–C stretch, CH\(_2\) bend, C–O stretch and acetylenic C–H bend vibrations were observed at 3850 cm\(^{-1}\), 3740 cm\(^{-1}\), 3430 cm\(^{-1}\), 2920 cm\(^{-1}\), 1630 cm\(^{-1}\), 1390 cm\(^{-1}\), 1110 cm\(^{-1}\), and 600 cm\(^{-1}\), respectively. For FT-IR spectra of Na\(_2\)SO\(_3\) the transmissivity of the peaks at 2920 cm\(^{-1}\), 1630 cm\(^{-1}\), 1390 cm\(^{-1}\) and 1110 cm\(^{-1}\) achieved the maximum for 20 min. For FT-IR spectra of Na\(_2\)S\(_2\)O\(_8\), the transmissivity of the peaks at 3850 cm\(^{-1}\), 3740 cm\(^{-1}\), 2920 cm\(^{-1}\), 1630 cm\(^{-1}\), 1390 cm\(^{-1}\), 1110 cm\(^{-1}\), and 600 cm\(^{-1}\) achieved the maximum for 40 min. For FT-IR spectra of Na\(_2\)SO\(_4\), the transmissivity of the peaks at 3430 cm\(^{-1}\), 2920 cm\(^{-1}\), 1630 cm\(^{-1}\), 1390 cm\(^{-1}\), 1110 cm\(^{-1}\) and 600 cm\(^{-1}\) achieved the maximum for 60 min.
For FT-IR spectra of Fe₂(SO₄)₃, the transmissivity of the peaks at 1390 cm⁻¹, 1110 cm⁻¹ and 600 cm⁻¹ achieved the maximum for 20 min. For FT-IR spectra of S, the transmissivity of the peaks at 1630 cm⁻¹, 1390 cm⁻¹ and 600 cm⁻¹ achieved the maximum for 120 min. In these states, the number of the transmissivity of the maximum peaks is the largest.

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Figure 5 FT-IR spectra of activated carbon during adsorption of S.