Saudi Journal of Biological Sciences (2017) 24, 103–107

King Saud University

Saudi Journal of Biological Sciences

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ORIGINAL ARTICLE

Adsorption characteristics of sulfur powder by bamboo charcoal to restrain sulfur allergies

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Received 19 May 2016; revised 31 August 2016; accepted 31 August 2016
Available online 20 September 2016

KEYWORDS

Bamboo charcoal;
Desulfuration;
Na_2SO_3;
$Na_2S_2O_8$;
Na_2SO_4;
$Fe_2(SO_4)_3$;
S

Abstract Exposures to particulate matter with a diameter of 2.5 μm or less (PM2.5) may influence the risk of birth defects and make you allergic, which causes serious harm to human health. Bamboo charcoal can adsorb harmful substances,that was of benefitto people's health. In order to figure out the optimal adsorbtion condition and the intrinsic change of bamboo charcoal, five chemicals were adsorbed by bamboo charcoal and were analyzed by FT-IR. The optimal blast time was 80 min of Na_2SO_3, 100 min of $Na_2S_2O_8$, 20 min of Na_2SO_4, 120 min of $Fe_2(SO_4)_3$ and 60 min or 100 min of S. FT-IR spectra showed that bamboo charcoal had five characteristic peaks of S—S stretch, H_2O stretch, O—H stretch, C═O stretch or C═C stretch, and NO_2 stretch at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1}, respectively. For Na_2SO_3, the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum at 20 min. For $Na_2S_2O_8$, the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1} and 1530 cm^{-1} achieved the maximum at 40 min. For Na_2SO_4, the peaks at 3850 cm^{-1}, 3740 cm^{-1} and 1530 cm^{-1} achieved the maximum at 40 min. For $Fe_2(SO_4)_3$, the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum at 120 min. For S, the peaks at 3850 cm^{-1} and 3740 cm^{-1} achieved the maximum at 40 min, the peaks at 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum at 40 min. It proved that bamboo charcoal could remove sulfur powder from air to restrain sulfur allergies.

1. Introduction

With the rapid development of global economy, the development and utilization of coal have brought serious pollution to the environment, especially as the coal-fired power plant boiler emits large amounts of sulfur dioxide and nitrogen oxides (accounts for about 35%∼40% of the total SO2 and NOx emissions) to further aggravate the deterioration of the environment. For example, Shanghai and Beijing are two of the largest cities in China. Both cities have populations of over

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.sjbs.2016.08.013
1319-562X

Table 1 Adsorption results.

Blast time [min]	20	40	60	80	100	120
Na_2SO_3	1.48	0.25	0.5	1.52	1.24	1.5
$Na_2S_2O_8$	1.75	0.75	0.74	2	2.02	1.73
Na_2SO_4	2.25	2.02	2.02	0.74	1.49	0.5
$Fe_2(SO_4)_3$	1.49	0.49	1.01	1.26	1.24	1.74
S	2.76	3.25	4.47	2.24	4.47	2.98

Table 2 Groups of bamboo charcoal during adsorption of Na_2SO_3, $Na_2S_2O_8$, Na_2SO_4, $Fe_2(SO_4)_3$ and S (%).

Kind	Peak (cm^{-1})	Adsorption time (min)						Groups
		20	40	60	80	100	120	
Na_2SO_3	1530	87.7	56.9	51.3	44.3	56.9	52.2	NO_2
	1630	87.0	59.3	54.3	43.0	60.7	52.8	C═O or C═C
	3430	81.7	55.1	47.2	37.4	55.9	47.2	O─H stretch
	3740	88.7	57.9	48.5	43.7	57.8	52.1	H_2O
	3850	89.1	59.4	49.6	43.7	59.5	52.7	S─S stretch
$Na_2S_2O_8$	1530	84.7	87.3	82.5	88.5	82.9	83.7	NO_2
	1630	86.9	86.9	86.8	87.2	87.4	88.1	C═O or C═C
	3430	80.5	83.0	82.6	78.5	78.0	80.7	O─H stretch
	3740	81.3	88.7	81.8	87.1	81.5	82.0	H_2O
	3850	84.4	89.0	84.0	88.1	83.0	84.0	S─S stretch
Na_2SO_4	1530	85.5	88.3	85.6	83.4	82.0	82.5	NO_2
	1630	87.4	87.9	88.1	86.0	84.8	86.4	C═O or C═C
	3430	79.0	79.2	80.5	78.8	77.1	80.0	O─H stretch
	3740	83.2	86.5	82.6	82.3	81.4	81.1	H_2O
	3850	85.0	87.5	84.6	84.0	83.4	83.0	S─S stretch
$Fe_2(SO_4)_3$	1530	81.2	82.0	89.1	82.0	84.2	90.4	NO_2
	1630	86.0	87.3	86.5	87.3	86.6	88.3	C═O or C═C
	3430	78.5	81.2	78.4	81.2	82.8	78.8	O─H stretch
	3740	79.3	81.2	88.1	81.2	84.3	88.9	H_2O
	3850	81.5	83.4	88.8	83.4	85.8	89.2	S─S stretch
S	1530	90.5	90.1	79.2	85.1	85.2	80.3	NO_2
	1630	88.8	88.3	84.0	86.4	88.1	83.7	C═O or C═C
	3430	78.2	80.4	76.1	78.3	83.4	73.8	O─H stretch
	3740	88.4	89.2	78.9	84.3	83.5	79.5	H_2O
	3850	88.7	89.4	81.3	85.5	85.2	81.7	S─S stretch

10 million. These two urban areas have experienced a rapid increase in the use of vehicles, concurrent with large increases in energy consumption. Particulate pollution has become a major problem (Yao et al., 2002). NOx and hydrocarbon with photochemical smog formation, cause serious harm to human health. In hazy weather during sports the human respiratory system changes direction, damaging the human respiratory system seriously (Li, 2014). Exposures to particulate matter with a diameter of 2.5um or less (PM2.5) may influence the risk of birth defects and make you allergic (Girguis et al., 2015).

Bamboo planting in China is very large, it is a kind of short growth cycle and timber fast biomass resource. Therefore, bamboo charcoal is a natural, renewable environmental protection material and functional material. Bamboo charcoal was created by heating bamboo at temperatures of 600–900 °C and then the charcoal itself was processed and mixed in with fabrics as part of the growing field of nanotechnology (Girguis et al., 2015; Yang et al., 2005; Ignatova et al., 2003; Abe et al., 2001; Kawashita et al., 2003; Mizuta et al., 1994; Wang et al., 2006; Xue et al., 2014; Cui et al., 2014; Le et al., 2015; Peng et al., 2014a,b,c; Peng et al., 2012a). Bamboo charcoal had many positive qualities (Girguis et al., 2015; Yang et al., 2005; Ignatova et al., 2003; Abe et al., 2001). The fabric inhibited bacterial metabolism causing fewer allergic skin reactions than other fibers sterilized with antimicrobial agents. Because the trait was due to the highly porous structure of the bamboo fabric, it could absorb sulfur-based compounds, nitrogen-based compounds and so on (Ignatova et al., 2003; Abe et al., 2001; Kawashita et al., 2003; Mizuta et al., 1994; Wang et al., 2006; Xue et al., 2014; Cui et al., 2014). What's more, bamboo charcoal, which contained potassium, calcium and other minerals, could cause adsorption and filtration of extractives, oil, and other substances (Peng et al., 2013a; Xiao et al., 2013; Peng et al., 2013b; Wang et al., 2013; Peng et al., 2013c; Peng et al., 2012b; Peng and Le, 2012; Peng

et al., 2011; Zhang et al., 2008; Qi et al., 2012), that was beneficial for people's health. But so far, the bamboo charcoal in coal-fired flue gas pollution (sulfide, etc.) control in the field of study is less reported. In order to figure out the optimal adsorbtion condition and the intrinsic change of the bamboo charcoal, five chemicals were adsorbed by bamboo charcoal and were analyzed by FT-IR.

2. Materials and methods

2.1. Materials

Bamboo charcoal, Na_2SO_3, $Na_2S_2O_8$, Na_2SO_4, $Fe_2(SO_4)_3$ and S were purchased from the market.

2.2. Methods

Five kinds of pharmaceutical powder were weighed in amounts of 25 g. These powders and 4 g bamboo charcoal were put into the closed vessel. It was blasted in a closed vessel for 20 min, 40 min, 60 min, 80 min, 100 min and 120 min. Each bamboo charcoal was removed, dried, and weighed.

FT-IR spectra. FT-IR spectra of the above samples were obtained using a Thermo Scientific Nicolet iN10 FT-IR microscope as previously (Lin et al., 2015; Peng et al., 2014a,b,c; Sun et al., 2014).

3. Result and analysis

Based on the above test, the results of adsorption were obtained and listed in Table 1.

3.1. SC Effect

Based on Table 1, Na_2SO_3's adsorption capacity was 1.48 g/100 g, 0.25 g/100 g, 0.5 g/100 g, 1.52 g/100 g, 1.24 g/100 g, 1.5 g/100 g; $Na_2S_2O_8$'s adsorption capacity was 1.75 g/100 g, 0.75 g/100 g, 0.74 g/100 g, 2 g/100 g, 2.02 g/100 g, 1.73 g/100 g; Na_2SO_4's adsorption capacity was 2.25 g/100 g, 2.02 g/100 g, 2.02 g/100 g, 0.74 g/100 g, 1.49 g/100 g, 0.5 g/100 g; $Fe_2(SO_4)_3$'s adsorption capacity was 1.49 g/100 g, 0.49 g/100 g, 1.01 g/100 g, 1.26 g/100 g, 1.24 g/100 g, 1.74 g/100 g; S's adsorption capacity was 2.76 g/100 g, 3.25 g/100 g, 4.47 g/100 g, 2.24 g/100 g, 4.47 g/100 g, 2.98 g/100 g for a blast time of 20 min, 40 min, 60 min, 80 min, 100 min and 120 min, respectively. It showed that adsorption capacity changed the regularity difference. It might be because rapid stirring lead to a small amount of five kinds of pharmaceutical powders on the surface of bamboo charcoal. The optimal blast time was 80 min of Na_2SO_3,

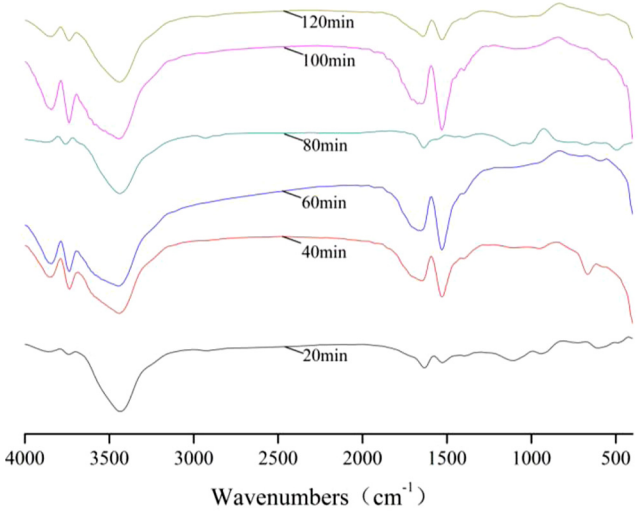

Figure 1 FT-IR spectra of bamboo charcoal during adsorption of Na_2SO_3.

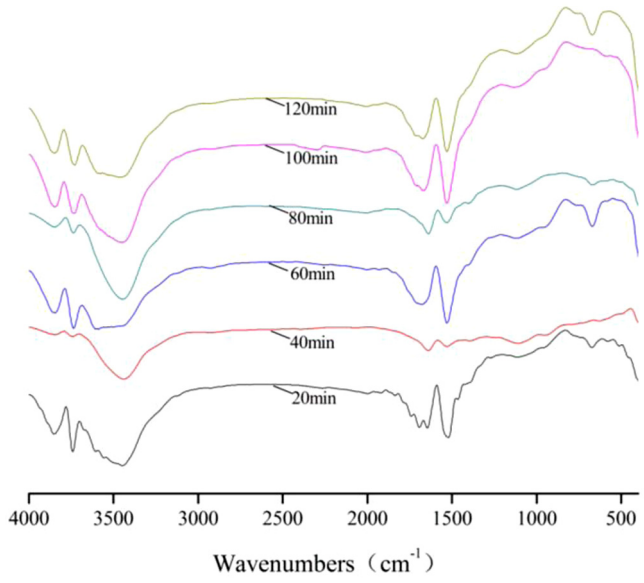

Figure 2 FT-IR spectra of bamboo charcoal during adsorption of $Na_2S_2O_8$.

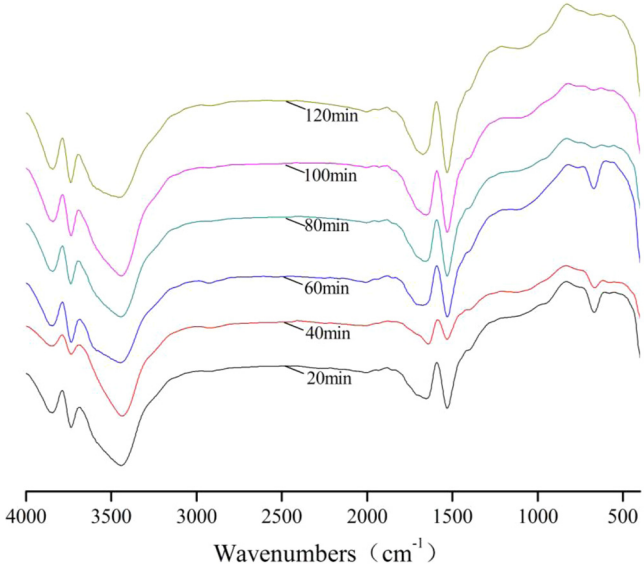

Figure 3 FT-IR spectra of bamboo charcoal during adsorption of Na_2SO_4.

100 min of $Na_2S_2O_8$, 20 min of Na_2SO_4, 120 min of $Fe_2(SO_4)_3$ and 60 min or 100 min of S (see Table 2).

3.2. FT-IR analysis

FT-IR spectra were recorded to investigate the functional groups of bamboo charcoal during adsorption of Na_2SO_3, $Na_2S_2O_8$, Na_2SO_4, $Fe_2(SO_4)_3$ and S. Spectra of the samples were shown in supporting information Figs. 1–5. In the spectrum of adsorption, the S—S stretch, H_2O stretch, O—H stretch, C═O stretch or C═C stretch, NO_2 stretch were observed at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1}, respectively [28–32].

For FT-IR spectra of Na_2SO_3, the transmissivity of the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum for 20 min.

For FT-IR spectra of $Na_2S_2O_8$, the transmissivity of the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1} and 1530 cm^{-1} achieved the maximum for 40 min, the transmissivity of the peaks at 1630 cm^{-1} achieved the maximum for 120 min.

For FT-IR spectra of Na_2SO_4, the transmissivity of the peaks at 3850 cm^{-1}, 3740 cm^{-1} and 1530 cm^{-1} achieved the maximum for 40 min, the transmissivity of the peaks at 3430 cm^{-1} and 1630 cm^{-1} achieved the maximum for 60 min.

For FT-IR spectra of $Fe_2(SO_4)_3$, the transmissivity of the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum for 120 min, the transmissivity of the peaks at 3430 cm^{-1} achieved the maximum for 100 min.

For FT-IR spectra of S, 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} achieved the maximum for 100 min, the transmissivity of the peaks at 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum for 40 min.

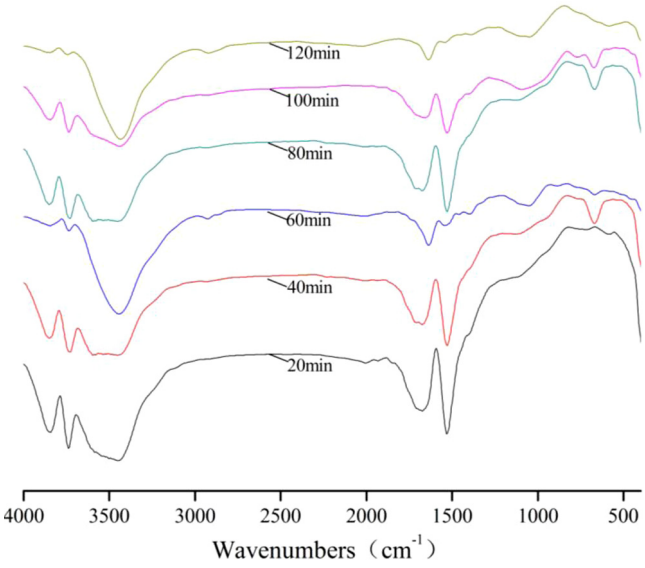

Figure 4 FT-IR spectra of bamboo charcoal during adsorption of $Fe_2(SO_4)_3$.

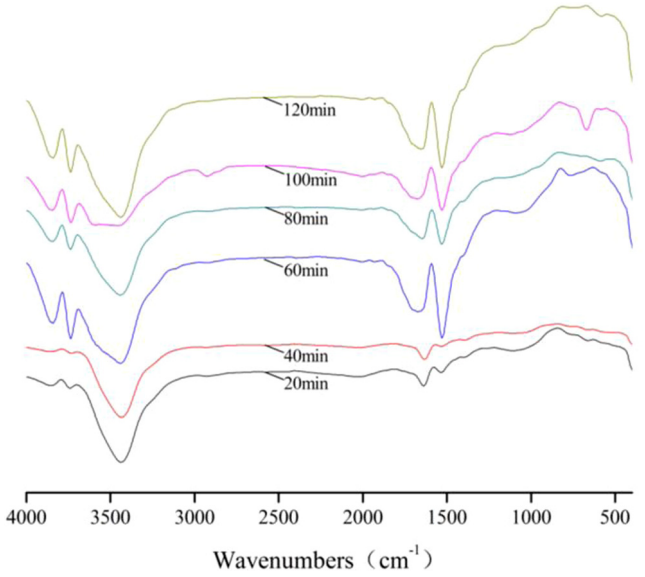

Figure 5 FT-IR spectra of bamboo charcoal during adsorption of S.

4. Conclusion

Na_2SO_3's, $Na_2S_2O_8$'s, Na_2SO_4's, $Fe_2(SO_4)_3$'s and S's adsorption capacity were different for blast times of 20 min, 40 min, 60 min, 80 min, 100 min and 120 min, respectively. The optimal blast time was 80 min of Na_2SO_3, 100 min of $Na_2S_2O_8$, 20 min of Na_2SO_4, 120 min of $Fe_2(SO_4)_3$ and 60 min or 100 min of S.

FT-IR spectra showed that bamboo charcoal had the eight characteristic absorption band. And the S—S stretch, H_2O stretch, O—H stretch, C═O stretch or C═C stretch, NO_2 stretch were observed at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1}, respectively. For FT-IR spectra of Na_2SO_3, the transmissivity of the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum for 20 min. For FT-IR spectra of $Na_2S_2O_8$, the transmissivity of the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 3430 cm^{-1} and 1530 cm^{-1} achieved the maximum for 40 min. For FT-IR spectra of Na_2SO_4, the transmissivity of the peaks at 3850 cm^{-1}, 3740 cm^{-1} and 1530 cm^{-1} achieved the maximum for 40 min. For FT-IR spectra of $Fe_2(SO_4)_3$, the transmissivity of the peaks at 3850 cm^{-1}, 3740 cm^{-1}, 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum for 120 min. For FT-IR spectra of S, 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 1630 cm^{-1} and 1530 cm^{-1} achieved the maximum for 40 min. In these states, the number of the transmissivity of the maximum peaks is the largest.

Acknowledgment

This work was financially supported by the National 948 Plan (2014-4-38).

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