ORIGINAL ARTICLE

Adsorption characteristics of sulfur solution by acticarbon against drinking-water toxicosis

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Abstract Sulfur and ammonia nitrogen are rich nutrient pollutants, after entering water can cause algal blooms, cause eutrophication of water body, the spread of them will not only pollute the environment, destroy the ecological balance, but also harm human health through food chain channels, especially drinking-water toxicosis. Acticarbon can adsorb harmful substances, it was beneficial for people’s health. In order to figure out the optimal adsorption condition and the intrinsic change of acticarbon, five chemicals were adsorbed by acticarbon and analyzed by FT-IR. The optimal adsorption condition of Fe2(SO4)3, Na2SO4, Na2S2O8, S and Na2SO3 was 9 g/1000 g at 80 min, 21 g/1000 g at 20 min, 15 g/1000 g at 20 min, 21 g/1000 g at 60 min and 21 g/1000 g at 100 min, respectively. FT-IR spectra showed that acticarbon had eight characteristic peaks, such as S-S stretch, H2O stretch, O-H stretch, C=O or C=C stretch, CH2 bend, C-H were at 3850 cm⁻¹, 3740 cm⁻¹, 3435 cm⁻¹, 2925 cm⁻¹, 1630 cm⁻¹, 1390 cm⁻¹, 1115 cm⁻¹, 600 cm⁻¹, respectively. For FT-IR spectra of Fe2(SO4)3, the peaks at 3850 cm⁻¹, 3740 cm⁻¹, 2925 cm⁻¹ achieved the maximum with 9 g/1000 g at 20 min. For Na2SO4, the peaks at 2925 cm⁻¹, 1630 cm⁻¹, 1390 cm⁻¹, 1115 cm⁻¹, 600 cm⁻¹ achieved the maximum with 21 g/1000 g at 120 min. For ones of Na2S2O8, the peaks at 3850 cm⁻¹, 3740 cm⁻¹, 1390 cm⁻¹, 1115 cm⁻¹, 600 cm⁻¹ achieved the maximum with 2 g/1000 g at 80 min. For ones of S, the peaks at 3850 cm⁻¹, 3740 cm⁻¹, 2925 cm⁻¹ achieved the maximum with 19 g/1000 g at 100 min, the peaks at 1390 cm⁻¹, 1115 cm⁻¹, 600 cm⁻¹ achieved the maximum with 19 g/1000 g at 20 min. For FT-IR spectra of Na2SO3, the peaks at 1630 cm⁻¹, 1390 cm⁻¹, 1115 cm⁻¹, 600 cm⁻¹ achieved the maximum with 2 g/1000 g at 100 min. It provided that acticarbon could adsorb and desulphurize from sulfur solution against drinking-water toxicosis.

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1. Introduction

Sulfur and ammonia nitrogen mainly come from chemical fertilizers, processed meat, leather and other industry emissions of industrial waste water, and city life sewage and farmland irrigation and drainage (He et al., 2008; Mao et al., 2000; Chai et al., 2010). Sulfur and ammonia nitrogen are rich nutrient pollutants, after entering water can cause algal blooms, cause eutrophication of water body, the spread of them will not only pollute the environment, destroy the ecological balance, but also harm human health through food chain channels, such as drinking-water toxicosis. Ecological effects of acid precipitation can be determined from the timing of changes in lake chemistry or acid-sensitive micro fossils and metallic pollutants in sediments. This is thought to be a result of a few factors: increased construction of large power plants and smelters with tall smokestacks coupled with a decrease in use of coal for home heating, converting the local air pollution problem into along-range, transboundary one; emissions of NOx and other pollutants that aid in the oxidation of sulfur and nitrogen oxide have increased; and it took years for lakes, streams and their catchments to lose their buffering capabilities, so that lower pH levels were not recognized until sometime after the precipitation became acidic. Anthropogenic emissions are comparable to natural emissions on the global level, but regionally over 90% of sulfur deposited from the atmosphere is anthropogenic (Schindler, 1988).

Acticarbon can use almost any type of carbon materials, such as wood (Wang et al., 2009a), sawdust (Zhang et al., 2010), coal (Ahmadpour and Do, 1996), shells (Chandra et al., 2009), the stone of the fruit (Jumasiah et al., 2005), bagasse, oil waste, waste plastics (Zhou et al., 2007), paper and leather scrap (Yuan et al., 2004), waste tires and urban waste (Wang, 2004). Acticarbon with highly developed porous structure and huge specific surface area (Ding et al., 2002), good chemical stability and thermal stability, high mechanical strength and surface contains a variety of oxygen containing functional groups (Yu et al., 2005 and Pu and Jiang, 2005). What’s more, acticarbon, which contained potassium, calcium and other minerals, could have adsorption and filtration of extractives, oil, other matters (Peng et al., 2013a,b,c, 2014a, 2012, 2011; Xiao et al., 2013; Wang et al., 2013; Peng and Le, 2012; Liu et al., 2008; Zhang et al., 2008; Qi et al., 2012). 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 (Milena et al., 2003; Ikuo et al., 2001; Masakazu et al., 2003; Kei et al., 1994; Wang et al., 2006; Xue et al., 2014; Cui et al., 2014). In order to figure out the optimal adsorption condition and the intrinsic change of the acticarbon, five chemicals were adsorbed by acticarbon and were analyzed by FT-IR.

2. Materials and methods

2.1. Materials

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

2.2. Methods

The Fe2(SO4)3 powder was weighed in quantities of 5 g, 9 g, and 21 g. These powder and 4 g over dry acticarbon were put into beaker which equipped with 1000 ml water, respectively. It was stirred in a beaker for 20 min, 80 min and 120 min. The Na2SO4 powder was weighed in quantities of 11 g, 19 g, and 21 g. These powder and 4 g over dry acticarbon were put into beaker which equipped with 1000 ml water, respectively. It was stirred in a beaker for 20 min, 60 min and 120 min, respectively. The Na2S2O8 powder was weighed

| SC (%) | Stir time (min) | SC (%) | Stir time (min) | SC (%) | Stir time (min) | SC (%) | Stir time (min) | SC (%) | Stir time (min) | SC (%) | Stir time (min) |
|--------|----------------|--------|----------------|--------|----------------|--------|----------------|--------|----------------|--------|----------------|
| Fe2(SO4)3 | 20 | 80 | 120 | 20 | 60 | 120 | 20 | 80 | 100 | 20 | 80 | 100 | 20 | 40 | 100 |
| 0.5 | 3.76 | 2.49 | 1 | 1.1 | 1.25 | 0.75 | 2.51 | 0.2 | 0.5 | 1.79 | 1.03 | 0.2 | 7.75 | 4.52 | 4.73 | 0.2 | 0 | 2.74 | 1.75 |
| 0.9 | 1.75 | 23.7 | 0.5 | 1.9 | 3.52 | 1.99 | 2.26 | 1.1 | 8.25 | 3.23 | 2.23 | 1.9 | 37.3 | 38.6 | 11.5 | 1.1 | 2.74 | 2.74 |
| 2.1 | 17.5 | 18.5 | 2.75 | 2.1 | 8.21 | 1.75 | 2.99 | 1.5 | 20.1 | 12.7 | 2.19 | 2.1 | 37.7 | 80.3 | 32.8 | 2.1 | 1.25 | 2.26 |

Note: SC – Concentration of sulfur solution.
in quantities of 2 g, 11 g, and 15 g. These powder and 4 g over dry acticarbon were put into beaker which equipped with 1000 ml water, respectively. It was stirred in a beaker for 20 min, 80 min and 100 min. The S powder was weighed in quantities of 2 g, 19 g, 21 g. These powder and 4 g over dry acticarbon were put into beaker which equipped with 1000 ml water, respectively. It was stirred in a beaker for 20 min, 60 min and 100 min. The Na2SO3 powder was weighed in quantities of 2 g, 11 g, 21 g. These powders and 4 g over dry acticarbon were put into a beaker which contained 1000 ml water. It was stirred in a beaker for 20 min, 40 min and 100 min. Each acticarbon 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., 2014b, 2015; Sun et al., 2014; Wang et al., 2009b; Parag and Bhanu, 2013).

3. Results 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, when the concentrations of Fe2(SO4)3 were 5 g/1000 g, 9 g/1000 g, 21 g/1000 g, Fe2(SO4)3’s adsorption

Figure 2 FT-IR spectra of acticarbon during adsorption of Na2SO4 solution.

Figure 3 FT-IR spectra of acticarbon during adsorption of Na2S2O8 solution.

Figure 4 FT-IR spectra of acticarbon during adsorption of S solution.

Figure 5 FT-IR spectra of acticarbon during adsorption of Na2SO3 solution.
capacities were 0.5 g/100 g, 8.25 g/100 g, 20.1 g/100 g, 1.99 g/100 g, 2.51 g/100 g, 2.26 g/100 g, 2.99 g/100 g for the stir time of 20 min, 80 min, 120 min, respectively. When the concentrations of Na2SO4 were 11 g/1000 g, 15 g/1000 g, Na2SO4’s adsorption capacities were 0.5 g/100 g, 8.25 g/100 g, 20.1 g/100 g, 1.79 g/100 g, 3.23 g/100 g, 12.7 g/1000 g, 1.03 g/100 g, 2.23 g/100 g, 2.19 g/100 g for the stir time of 20 min, 80 min, 100 min, respectively. When the concentrations of S were 2 g/1000 g, 19 g/1000 g, 21 g/1000 g, S’s adsorption capacities were 7.75 g/100 g, 37.3 g/100 g, 37.7 g/100 g, 4.52 g/100 g, 58.6 g/100 g, 80.3 g/100 g, 4.73 g/100 g, 11.5 g/100 g, 32.8 g/100 g for the stir time of 20 min, 60 min, 100 min, respectively. When the concentrations of Na2SO3 were 2 g/1000 g, 11 g/1000 g, 21 g/1000 g, Na2SO3’s adsorption capacities were 0 g/100 g, 2.74 g/100 g, 1.25 g/100 g, 2.74 g/100 g, 2.26 g/100 g, 1.75 g/100 g, 2.26 g/100 g, 4.26 g/100 g for the stir time of 20 min, 40 min, 100 min, respectively. It showed that adsorption capacity

| Table 2 | Groups of acticarbon during adsorption of Fe2(SO4)3, Na2SO4, Na2SO3, S and Na2SO3 (%) |
|---------|--------------------------------------------------------------------------------------|
| Kind    | Peak (cm⁻¹) | Adsorption time (min)/concentration (%) | Group |
|---------|-------------|----------------------------------------|-------|
| Fe2(SO4)3 | 600        | 20/0.5                                | C=H   |
|         | 1115       | 20/0.9                                | C=O stretch |
|         | 1390       | 20/0.5                                | CH3 bend |
|         | 1630       | 20/0.5                                | C=O or C=C |
|         | 2925       | 20/0.5                                | C=H stretch |
|         | 3435       | 20/0.5                                | O=H stretch |
|         | 3740       | 20/0.5                                | H2O    |
|         | 3850       | 20/0.5                                | S=S stretch |
| Na2SO4  | Peak (cm⁻¹) | 20/0.1/1                               | Group |
|         | 600        | 20/0.1/1                               | C=H   |
|         | 1115       | 20/0.1/1                               | C=O stretch |
|         | 1390       | 20/0.1/1                               | CH3 bend |
|         | 1630       | 20/0.1/1                               | C=O or C=C |
|         | 2925       | 20/0.1/1                               | C=H stretch |
|         | 3435       | 20/0.1/1                               | O=H stretch |
|         | 3740       | 20/0.1/1                               | H2O    |
|         | 3850       | 20/0.1/1                               | S=S stretch |
| Na2SO3  | Peak (cm⁻¹) | 20/0.2/2                               | Group |
|         | 600        | 20/0.2/2                               | C=H   |
|         | 1115       | 20/0.2/2                               | C=O stretch |
|         | 1390       | 20/0.2/2                               | CH3 bend |
|         | 1630       | 20/0.2/2                               | C=O or C=C |
|         | 2925       | 20/0.2/2                               | C=H stretch |
|         | 3435       | 20/0.2/2                               | O=H stretch |
|         | 3740       | 20/0.2/2                               | H2O    |
|         | 3850       | 20/0.2/2                               | S=S stretch |
| S       | Peak (cm⁻¹) | 20/0.2/1.9                             | Group |
|         | 600        | 20/0.2/1.9                             | C=H   |
|         | 1115       | 20/0.2/1.9                             | C=O stretch |
|         | 1390       | 20/0.2/1.9                             | CH3 bend |
|         | 1630       | 20/0.2/1.9                             | C=O or C=C |
|         | 2925       | 20/0.2/1.9                             | C=H stretch |
|         | 3435       | 20/0.2/1.9                             | O=H stretch |
|         | 3740       | 20/0.2/1.9                             | H2O    |
|         | 3850       | 20/0.2/1.9                             | S=S stretch |
| Na2SO3  | Peak (cm⁻¹) | 20/0.2/1.1                             | Group |
|         | 600        | 20/0.2/1.1                             | C=H   |
|         | 1115       | 20/0.2/1.1                             | C=O stretch |
|         | 1390       | 20/0.2/1.1                             | CH3 bend |
|         | 1630       | 20/0.2/1.1                             | C=O or C=C |
|         | 2925       | 20/0.2/1.1                             | C=H stretch |
|         | 3435       | 20/0.2/1.1                             | O=H stretch |
|         | 3740       | 20/0.2/1.1                             | H2O    |
|         | 3850       | 20/0.2/1.1                             | S=S stretch |
changed at regularity difference. It might be because rapid stirring lead to a small amount of chemical medicine that was adsorbed by the acticarbon. The Fe$_2$(SO$_4$)$_3$’s optimal adsorption condition were the concentration was 9 g/1000 g and stir 80 min, the Na$_2$SO$_4$’s optimal adsorption condition was the concentration of 21 g/1000 g and stir time of 20 min, the Na$_2$S$_2$O$_8$’s optimal adsorption condition was the concentration of 15 g/1000 g and stir time of 20 min, the S’s optimal adsorption condition was the concentration of 21 g/1000 g and stir time of 60 min and the Na$_2$SO$_3$’s optimal adsorption condition was the concentration of 21 g/1000 g and stir time of 100 min.

3.2. FT-IR analysis

For FT-IR spectra of Na$_2$SO$_4$, the transmissivity of the peaks at 3850 cm$^{-1}$, 3740 cm$^{-1}$ achieved the maximum for 100 min and the concentration was 11 g/1000 g, the transmissivity of the peaks at 3435 cm$^{-1}$ achieved the maximum for 40 min and the concentration was 2 g/1000 g, the transmissivity of the peaks at 2925 cm$^{-1}$ achieved the maximum for 100 min and the concentration was 21 g/1000 g, the transmissivity of the peaks at 1390 cm$^{-1}$, 1115 cm$^{-1}$, 600 cm$^{-1}$ achieved the maximum for 100 min and the concentration was 2 g/1000 g.

As we can see from the above methods, Fe$_2$(SO$_4$)$_3$’s, Na$_2$SO$_4$’s, Na$_2$S$_2$O$_8$’s, S’s, and Na$_2$SO$_3$’s adsorption capacity were different for several stir times and several concentrations, respectively. The Fe$_2$(SO$_4$)$_3$’s optimal adsorption condition was the concentration was 9 g/1000 g and stir time of 80 min, the Na$_2$SO$_4$’s optimal adsorption condition was the concentration was 21 g/1000 g and stir 20 min, the Na$_2$S$_2$O$_8$’s optimal adsorption condition was the concentration of 15 g/1000 g and stir time of 20 min, the S’s optimal adsorption condition was the concentration was 21 g/1000 g and stir time of 60 min and the Na$_2$SO$_3$’s optimal adsorption condition were the concentration of 21 g/1000 g and stir time of 100 min.

FT-IR spectra showed that acticarbon had the eight characteristic adsorption band. And the S-S stretch, H$_2$O stretch, O-H stretch, C=C-H stretch, C=O or C=C stretch, CH$_2$ bend, C-H, were observed at 3850 cm$^{-1}$, 3740 cm$^{-1}$, 3435 cm$^{-1}$, 2925 cm$^{-1}$, 1630 cm$^{-1}$, 1390 cm$^{-1}$, 1115 cm$^{-1}$, 600 cm$^{-1}$, respectively (listed in Table 2). For FT-IR spectra of Fe$_2$(SO$_4$)$_3$, the transmissivity of the peaks at 3850 cm$^{-1}$, 3740 cm$^{-1}$ achieved the maximum for 20 min and the concentration was 9 g/1000 g, the transmissivity of the peaks at 3435 cm$^{-1}$, 600 cm$^{-1}$ achieved the maximum for 120 min and the concentration was 5 g/1000 g, the transmissivity of the peaks at 1630 cm$^{-1}$ achieved the maximum for 120 min and the concentration was 21 g/1000 g, the transmissivity of the peaks at 1390 cm$^{-1}$, 1115 cm$^{-1}$ achieved the maximum for 120 min and the concentration was 9 g/1000 g.

For FT-IR spectra of Na$_2$SO$_4$, the transmissivity of the peaks at 3850 cm$^{-1}$, 3740 cm$^{-1}$, achieved the maximum for 60 min and the concentration was 11 g/1000 g, the transmissivity of the peaks at 3435 cm$^{-1}$ achieved the maximum for 120 min and the concentration was 11 g/1000 g, the transmissivity of the peaks at 2925 cm$^{-1}$, 1630 cm$^{-1}$, 1390 cm$^{-1}$, 1115 cm$^{-1}$, 600 cm$^{-1}$ achieved the maximum for 120 min and the concentration was 21 g/1000 g.

For FT-IR spectra of Na$_2$S$_2$O$_8$, the transmissivity of the peaks at 3850 cm$^{-1}$, 3740 cm$^{-1}$, 1390 cm$^{-1}$, 1115 cm$^{-1}$, 600 cm$^{-1}$, achieved the maximum for 80 min and the concentration was 2 g/1000 g, the transmissivity of the peaks at 3435 cm$^{-1}$ achieved the maximum for 80 min and the concentration was 15 g/1000 g, the transmissivity of the peaks at 2925 cm$^{-1}$ achieved the maximum for 20 min and the concentration was 15 g/1000 g, the transmissivity of the peaks at 1630 cm$^{-1}$ achieved the maximum for 20 min and the concentration was 2 g/1000 g.

For FT-IR spectra of S, the transmissivity of the peaks at 3850 cm$^{-1}$, 3740 cm$^{-1}$, 2925 cm$^{-1}$ achieved the maximum for 100 min and the concentration was 19 g/1000 g, the transmissivity of the peaks at 3435 cm$^{-1}$ achieved the maximum for 100 min and the concentration was 19 g/1000 g, the transmissivity of the peaks at 1630 cm$^{-1}$ achieved the maximum for 60 min and the concentration was 2 g/1000 g, the transmissivity of the peaks at 1390 cm$^{-1}$, 1115 cm$^{-1}$, 600 cm$^{-1}$ achieved the maximum for 20 min and the concentration was 19 g/1000 g.

4. Conclusion

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