

THE POTENTIAL APPLICATIONS OF USING COMPOST CHARS FOR REMOVING ENVIRONMENTAL POLLUTANTS FROM SOLUTION

Lo Tsui, Mingchi University of Technology, Taipei, Taiwan 24301

William R. Roy, Illinois State Geological Survey, Champaign, IL 61820

Abstract

Municipal compost sample was pyrolyzed to produce compost char as a sorbent for removing the herbicide atrazine from solution. The compost-based char was compared with an activated carbon derived from corn stillage. When compost was pyrolyzed, the char yield was greater than 45% when heated under air, and 52% when heated under N₂. In contrast, when the corn stillage was pyrolyzed under N₂, the yield was only 22%. The corn stillage char was activated by steam vapor, and yielded a N₂-BET surface area of 439 m²/g, which was much greater than the maximum compost char surface area of 72 m²/g. However, the sorption affinity of the compost char for dissolved atrazine was comparable to that of corn stillage activated carbon. This similarity could have resulted from the initial organic materials being subjected to a relatively long period of thermal processes during composting, and thus, the compost was more thermally stable when compared with the raw materials. In addition, the microorganisms endemic to compost might have increased the microporosity of the compost, which would not have been measured by the N₂-BET method. Overall, the experimental results suggested that the compost sample in current study was a relatively stable material thermally for producing a char, and that it has the potential as a feed stock for making high-quality activated carbon.

Introduction

It has been suggested that any material with high carbon-content could be used as the precursor for producing activated carbon. Therefore, different types of agricultural waste have been tested for such a purpose. However, the carbon yields from agricultural wastes have generally been less than 40%. Composting is a biological process that converts organic substances into stable humus materials. During thermophilic composting, the temperature in the compost pile can increase to up to 90°C, resulting from the microbial transformation of organic substances. Hence, compost could be more thermally stable than its parent compounds, and thus, could serve as a better source material for producing activated carbon.

The production of activated carbon involves two processes: carbonization and activation. Although the carbonization and activation processes can be applied simultaneously, it has been shown that activated carbon produced from a two-stage process, i.e. carbonization followed by activation, could have a surface area

three times greater when compared with the one-stage process (Diao et al., 2002). Because the two-stage process could produce a better quality activated carbon, it would be reasonable to examine the quality of first-stage char first.

The primary goal of this study was to examine the efficacy of creating chars from a commercial compost sample. The compost sample was pyrolyzed under air or nitrogen conditions, and the pyrolyzed chars were then examined for their ability to sorb atrazine (2-chloro-4-ethylamine-6-isopropylaminto-S-triazine) from solution as a typical hydrophobic contaminant in surface water. For comparison, an activated carbon produced from a corn-to-ethanol byproduct (corn stillage) was also tested for its sorption affinity for atrazine.

Materials and Methods

An atrazine stock solution was prepared by dissolving ^{14}C -labeled and nonlabeled atrazine in methanol, and then deionized water was added to prepare different concentration of atrazine solution. The highest atrazine concentration was set at 1.71 mg/L. The commercial compost sample was collected from a composting facility. Before conducting this study, the compost sample had been stored at room temperature for 3 years, and was relatively dry and carbon-rich (Table 1). The corn stillage activated carbon was kindly provided by the Illinois State Geological Survey (Desai, 1999). The corn stillage was first pyrolyzed in flowing N_2 , followed by physical activation in steam at 800°C .

Table 1. The Chemical Composition of the Compost Sample.

Parameter	Level
pH	8.0
Moisture	6%
Organic C	51.5%
N	3.5%
Ash content	7%

A mass of 50 g of the compost sample was heated in a 5-cm diameter horizontal quartz tube by a Lindberg type 59344 furnace. The samples were heated in flowing air (1 L/min) at temperatures ranging from 120°C to 420°C , and in flowing ultra-high purity N_2 from 220°C to 820°C for 1h. After heating, the samples were allowed to cool to room temperature under continuous flowing air or N_2 conditions, and the remaining sample mass was recorded. The yield of compost char was defined as the ratio of the weight of the pyrolyzed char to that of the original compost, with both weights on a dry basis. The surface area was

measured using N₂-BET method.

The adsorption study for atrazine was carried out using the batch methods developed by Roy et al. (1992). The ¹⁴C-labelled atrazine concentration was determined by using a Packard 2000CA TriCarb liquid scintillation counter, and the amount of adsorbed atrazine was calculated as the difference between the initial atrazine concentration in the original solution and the equilibrated solution. Sorption isotherms were used to describe the sorption behavior, and one activated carbon sample produced from corn stillage was used for comparisons of sorption performance for atrazine with pyrolyzed compost samples.

Results and Discussion

When a compost sample was pyrolyzed under air, the N₂-BET surface areas of the resulting chars increased with increasing temperature up to 22.19 m²/g at 370°C, but decreased to 2.31 m²/g when heated at 420°C (Table 2). The N₂-BET surface area of compost chars continued to increase with an increase in temperature up to 720°C when compost was pyrolyzed under N₂. When comparing, the compost chars under air and N₂ at the same temperature, the compost chars produced under air had a greater surface area than the corresponding chars under N₂ at temperature less than 420°C. The surface areas of the pyrolysis char and activated carbon produced from corn stillage are also shown in Table 2. The results suggested that the pyrolysis of compost at 620°C under N₂ would yield a larger N₂-BET surface area when compared with corn stillage chars pyrolyzed at 900°C, but the surface areas of all the compost chars were less when compared with corn stillage activated carbon.

Char yield decreased with increasing temperature when the compost samples were pyrolyzed under both air and N₂ conditions (Table 2). When the compost was heated under air at the maximum temperature (420°C), there was still 46% of the initial mass remaining in the residue, suggesting that the raw compost sample might have contained substantial mineral matter content. When the compost was heated under N₂ at 820°C, the chars yield was 52 %, which was at least twice greater yield when compared with the corn stillage char yield of 21.8%. The high-yield compost chars may have resulted from readily decomposed compounds in compost had been broken down during the active thermophilic composting process, such that the compost sample was a more thermostable raw material for pyrolysis than was the corn stillage sample.

The corn stillage activated carbon had a N₂-BET surface area of 439 m²/g, which was obviously larger than the compost chars with the maximum surface area of 72 m²/g (Table 2). However, the compost chars that were pyrolyzed at 620°C under N₂ had comparable sorption affinity for atrazine (Figure 1). If the sorption affinity was compared on the per-gram of precursor weight base, then all the compost samples pyrolyzed under N₂ had greater sorption affinity than did the corn stillage.

Table 2. Yield and Surface Area of Pyrolyzed Compost Chars and Corn Carbons

Sample Type	Temperature (°C)	Yield (%)	N ₂ - BET surface area (m ² /g)
Compost			
Untreated	25		2.93
Pyrolysis, air	120	92	3.13
	220	80	10.21
	320	60	17.72
	370	54	22.19
	420	46	2.31
	Pyrolysis, N ₂	220	88
320		72	10.38
420		66	16.27
520		64	22.39
620		60	51.21
720		56	72.39
820		52	71.63
Corn stillage			
Pyrolysis, N ₂	900	21.8	35
Activation, Stream	800	15.8	439

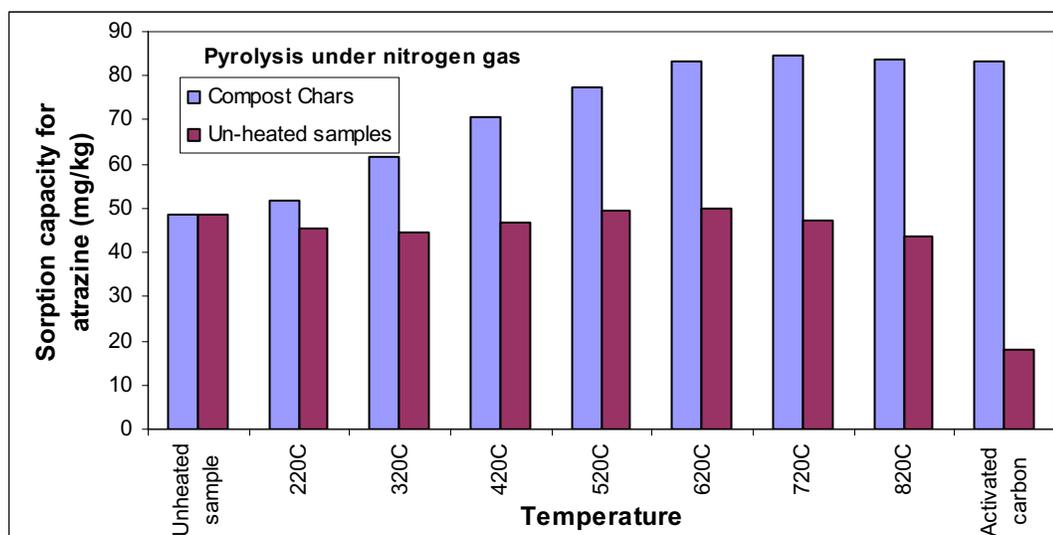


Figure 1. Comparison of the Amount of Atrazine Sorbed by Compost Chars and Corn Stillage Activated Carbon. The initial atrazine concentration was 1.71 mg/L.

It has been reported that the N₂-BET technique for measuring surface area may not be the best method to measure the surface area of organic substances because the N₂ molecules might not be able to diffuse into the micropore structures of organic matter at liquid nitrogen temperature (De Jonge and Mittelmeijer-Hazeleger, 1996; Ravikovitch et al., 2005; Makris et al., 2006). Therefore, the actual surface area of compost chars could have been much larger than the values reported in this study, and thus might help to explain their comparable sorption capacities for atrazine when compared with corn stillage activated carbon.

Conclusions

This study demonstrated that greater char yields were obtained using compost as a precursor when compared with corn stillage, suggesting that compost might have been more thermally stable than was the agricultural waste. Although the compost chars had less measured surface area than the corn stillage activated carbon, the compost chars exhibited a comparable sorption affinity for the environmental pollutant atrazine, possibly because of the micropore structure of compost. These results suggested that there are some potential advantages in producing high-quality activated carbon from compost.

References

- De Jonge, H., and M.C. Mittelmeijer-Hazeleger. 1996. Adsorption of CO₂ and N₂ on soil organic matter: nature of porosity, surface area, and diffusion mechanisms. *Environmental Science and Technology* 30:4008-413.
- Desai, S. 1999. Activated Carbon from Corn-to-Ethanol By-Product for Air Pollution Control Applications. Master Thesis. University of Illinois at Urbana-Champaign.
- Diao, Y., W. P. Walawender, and L. T. Fan. 2002. Activated carbon prepared from phosphoric acid activation of grain sorghum. *Bioresource Technology* 81:45-52.
- Makris, K. C., D. Sarkar, R. Datta, P. I. Ravikovitch, and A. V. Neimark. 2006. Using nitrogen and carbon dioxide molecules to probe As (V) bioaccessibility in soils. *Environmental Science and Technology* 40:7732-7738.
- Ravikovitch, P. I., B. W. Bogan, and A.V. Neimark. 2005. Nitrogen and carbon dioxide adsorption by soils. *Environmental Science and Technology* 39:4990-4995.
- Roy, W.R., I.G. Krapac, S.F.J. Chou, and R.A. Griffin. 1992. Batch-Type Procedures for Estimating Soil Adsorption of Chemicals. U.S. Environmental Protection Agency, Technical Resource Document, U.S. EPA/530/-SW-87-006-F.