Soil Chemical Properties Influenced by Water-Washed Charcoal: Abiotic and Biotic Processes

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Introduction:

- Using charcoal as a soil amendment for agriculture has a long history. Past studies have focused on improving soil properties by using charcoal residues, including organic carbon and ashes. High content of the base ions in the ashes could lead to increase the pH and strongly affect the study results. The results would also mask the potential effects of the forms of organic C in the charcoal. In this study, we reduced the influence of ashes by using water-washed charcoal and studied its effects on soil chemical properties after incubations under abiotic and biotic conditions.

Materials and Methods

- Charcoal was produced from black locust (*Robinia pseudoacacia* L.) by combusting it at 300□ for 16 hours in a muffle furnace and grinding it to pass through a 2 mm sieve (Figure 1). The resulting charcoal was repeatedly leached with deionized water until the electrical conductivity was below 50 μS dm^{-1}.
- Adsorption isotherm of the water-washed charcoal were determined for ammonium and nitrate ions.
- An incubation experiment was performed in which either water-washed charcoal or a charcoal-soil mixture in a ratio of 50:1 was incubated at either 30°C or 70°C. The soil was sampled from a subsoil horizon of an anionic Acrustox in Brazil and sterilized by gamma irradiation. The individual and combined effects of the addition of a complete mineral fertilizer, manure and/or microbial inoculation (at 30°C only) on the chemical properties of the charcoal and charcoal:soil treatments were determined. Some of the sample pictures could be seen in Figure 1.

Figure 1. (a) Wood chunk, (b) charcoal chunk, (c) charcoal powder, (d) soil sample, (e) soil + charcoal mixture, and (f) soil + charcoal + manure mixture.

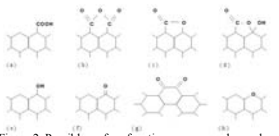

Figure 2. Possible surface function groups on charcoal. Group 1: (a) carboxyl groups, (b) carboxylic anhydrides. Group 2: (c) lactone groups, (d) lactols, (e) hydroxyl groups. Group 3: (f), (g) quinone-like functions, (h) ether-type arragements.

Results and Discussion

- The charcoal making process was at low temperature (300 °C) and it could lead to more acidic functional groups and exhibit a negative zeta potential (Figure 2, group 1 and group 2). Adsorption experiments showed that the charcoal more strongly adsorbed ammonium than nitrate. Table 2 showed the that contents of surface acid groups (group 1 & group 2 in Figure 2) were higher than basic groups (group3).
- The pH (H_2O) increased with charcoal and manure additions. However, potential pH (KCl) significantly decreased when samples were incubated at 70 °C. The charcoal that was incubated at a higher temperature (70 °C) also showed increased their exchangeable acidity and aluminum contents (Table 1).
- Addition of charcoal increased the cation exchange capacity (CEC).
- Microbial inoculation or amendments of mineral fertilizer did not enhance CEC, whereas temperature and manure additions significantly increased the CEC. A higher temperature during incubation (70 °C) increased CEC more effectively than a lower temperature.

Table 1. The values of pH, exchangeable acididty, exchangeable aluminum, effective CEC and potential CEC in soil with water-washed charcoal mixtures.

Treatment		pH (H_2O)	pH (KCl)	Ex-Acidity	Ex-Al	E-CEC	P-CEC
				mmole/kg			
30	Soil	4.33	4.12	3.61	1.90	5.60	24.9
	Soil+C	4.48	4.13	3.85	1.45	9.23	47.2
	Soil+C+F	4.48	4.21	2.96	1.06	15.04	46.1
	Soil+C+Mic	4.83	4.37	2.14	0.73	8.15	44.5
	Soil+C+Man	6.31	5.59	1.25	0	47.74	65.9
	Soil+C+F+Mic	4.61	4.27	2.38	1.11	12.37	42.6
	Soil+C+Mic+Man	6.71	6.15	0.84	0	50.23	61.3
	Soil+C+F+Mic+Man	6.50	5.85	0.73	0	49.37	62.2
70	Soil	4.14	3.94	10.06	4.03	9.30	22.8
	Soil+C	4.17	3.68 (-)	17.50 (+)	7.00 (+)	24.77 (+)	87.8 (+)
	Soil+C+F	4.17	3.58	15.34	6.14	25.35	92.4
	Soil+C+Man	4.59	4.12	15.78	6.31	60.68	79.8

- Boehm's titration method was used to assess surface functional groups of the pure charcoal treatment. It showed that the density of surface functional groups increased with incubation, especially at the higher temperature (Figure 2 and Table 2).
- Chemi-sorption of oxygen atoms via an aging processes was more important in increasing CEC and decreasing the pH than microbial oxidation in our experiment.

Table 2. The values of surface functional groups in charcoal. Group 1: carboxyl groups; Group 2: lactones and hydroxyl groups; and Group 3: carbonyl groups.

	Group 1	Group 2	Group 3	Total
	m mole H^+ equiv/g			
Original charcoal	0.16	1.59	0.15	1.90
30°C incubation	0.20	1.64	1.78	3.62
70°C incubation	0.86	2.64	0.75	4.25