The effect of biochar on sorption and leaching of pesticides

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A number of studies in the scientific literature show the possibility to use biochar for improvement of the soil nutrient binding capacity. Studies also show that biochar can bind some pesticides and thereby potentially affect pesticide mobility and degradation. Here we present results on 1) the capacity of some in Sweden available biochars and differently processed biochars to bind pesticides, and 2) the effect of biochar on pesticide leaching in laboratory soil columns.

Tests of the pesticide binding capacity of biochar

Initial tests of Skogens kol (biochar made from wood), Ecoera (biochar made from harvest residues) and activated carbon showed that all materials possess a large adsorptive capacity for several different pesticides. Based on function and costs, Skogens kol was considered to be the most interesting biochar to be used for further studies.

A number of studies were performed in order to characterize how factors such as size of biochar particles, adsorption time, pesticide type and concentration affect the adsorption of pesticides to Skogens kol. The studies of adsorption were performed according to the OECD standard test protocol for batch adsorption (Anonymous, 2000). The initial experiments were conducted using a number of different pesticides that were also available as ^{14}C-labeled. Four of those pesticides were selected for further characterization of adsorption and leaching: MCPA, diuron, glyphosate and chlorpyrifos (Figure 1). They were chosen since they represent pesticides with very different chemical and physical properties (Table 1) and could thereby be expected to give additional information on the adsorptive properties of the biochar.

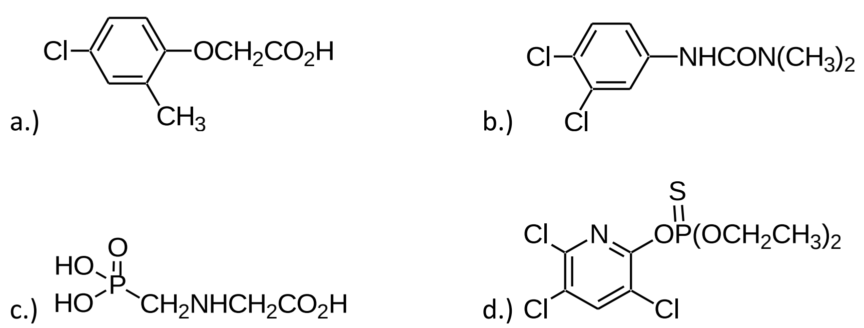

Figure 1. Chemical structures of the four model substances used *a.) MCPA, b.) diuron, c.) glyphosate and d.) chlorpyrifos.*

Table 1. Some properties of the model substances used

Active substance (a.s.)	Example of product containing the pesticide	Amount added per column (mg a.s.)	Corresponding field dose (g a.s. ha^{-1})
Glyphosate	Roundup Bio	0.096	1800
Diuron	Karmex 80	0.425	8000
MCPA	BASF MCPA	0.119	2250
Chlorpyrifos	Nufarm Chlorpyrifos 500 EC	0.053	1000
	Water solubility	**Lipid solubility**	**Adsorption to soil**
Glyphosate	high	very low	high-very high
Diuron	low	high	Moderste
MCPA	very high	high	low
Chlorpyrifos	very low	very high	high

The adsorption of MCPA was high up to an added concentration corresponding to about 500 mg/kg of char (99-88% adsorption) Diuron was almost completely adsorbed (99% adsorption) up to an added amount of 100 mg/kg char, and to a very high degree at the highest concentrations (93-87%). Glyphosate was apparently not adsorbed at all, independently of concentration. The adsorption of chlorpyrifos was about 70% at the low concentrations tested and about 50% at the higher ones

Some general conclusions are:

- Skogens kol has a large capacity (>500 mg/kg) to bind most pesticides (MCPA, 2,4-D, diuron) but a relatively low capacity to bind glyphosate (some few mg/kg) and the lipophilic chlorpyrifos.
- Adsorption equilibrium is rapidly obtained at realistic environmental concentrations.
- The size of the char particles is important, with increasing adsorption with decreasing particle size.
- It is possible to improve the adsorptive properties of the char by different pre-treatments (for instance the adsorption of glyphosate increases by pre-treatment of the char with iron salts).

Tests of the potential to decrease leaching

In order to study the potential of biochar to decrease leaching in a soil normally vulnerable to leaching (i.e. sand), studies were performed using laboratory soil columns. The studies show that the leaching can be substantially reduced for many pesticides by incorporating a thin biochar layer in the column.

The leaching of MCPA and diuron was reduced substantially or even completely inhibited by biochar. The leaching of glyphosate was not affected by the char but still was low at normal field concentrations due to binding of glyphosate to the sand.

The retention of the pesticides increased with decreasing particle size of the biochar and when the char was placed as a layer in the column rather than being mixed into the sand.

To conclude, Skogens kol shows a high capacity to adsorb some of the pesticides we tested in these studies. The soil column experiments also show a large promising potential for use of this capacity to reduce pesticide leaching. For both diuron and MCPA it was possible to obtain large reductions of the amounts of pesticides leached through the columns.

The adsorption of glyphosate and chlorpyrifos to the char was much weaker compared to the other substances tested. Interestingly these are substances that normally adsorbs strongly to soil and therefore it is generally considered that the risk of leaching of these substances is small. The experiments with pre-treatments of the char show that there is a potential to modify the biochar properties in order to obtain a high adsorption capacity on the char also for these substances.

In order to evaluate how adsorptive biochar layers will function and how much material that would be required in practical applications, the experimental setup has to be scaled up. Such up-scaling to lysimeters is currently studied which will make it possible to assess the adsorptive capacity of the biochar under more realistic conditions. The conditions used in the studies represent a worst case scenario. The soil columns used in principal simulates leaching from the uppermost 10 cm of the soil after a heavy rainfall directly after pesticide application. In practical application it is likely that both pesticide concentrations and the water flows will be much lower. On the other hand larger particle fractions than those used in the studies reported here should probably be used in practical applications, which should also affect the results. More realistic assessments of which fractions and amounts of biochar that would be required to obtain a sufficient effect should also give a basis for cost assessments of materials for practical application.

Reference: Anonymous. (2000). *OECD Guideline for the Testing of Chemicals/Section 1: Physical-Chemical properties. Test No. 106: Adsorption - Desorption Using a Batch Equilibrium Method*.

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