# Effects of kaolinite and drying temperature on the persistence of soil water repellency induced by humic acids

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**ABSTRACT**

The effects of kaolinite additions and drying temperature on the persistence of soil water repellency, induced by humic acids from peat, were assessed in this study. It was found that additions of 5 and 10% kaolinite (referred to as the most effective material in combating the water repellency) did not result unambiguously in a decrease of the persistence of water repellency. In case of the higher humic acids contents, an increase of the persistence of water repellency was even noticed in comparison with the samples without kaolinite. Establishment (re-establishment) of water repellency was observed for the samples wetted to 30% after drying at temperatures of 30, 60°C (in both cases 36 of the 48 samples containing humic acids became water repellent) and after drying at 210°C (a few samples with the higher humic acids contents became slightly water repellent).

**Keywords:** water repellency; humic acids; kaolinite

Soil water repellency (hydrophobicity) is a widespread phenomenon related to an organic coating of soil particles and soil water content. It is not a static soil property but is known to follow short-term or seasonal variations. Water repellency is generally found to be the most extreme when soils are dry and disappearing as soils become wet, although notable exceptions have been reported. Hydrophobicity can re-appear when soils become dry again. This re-establishment of water repellency is not only due to a decrease in soil water content, but is likely to be associated with the energy input during heating and new input of hydrophobic substances (Doerr and Thomas 2000).

Water repellency of the topsoil may cause increased surface runoff resulting in soil erosion (Shakesby et al. 2000) and a nutrient washout (Lennartz et al. 1999, Pekárová et al. 1999) mainly during heavy rainstorms after prolonged dry periods (as a consequence of the climate change). Another detrimental effect of water repellency is formation of preferential flow (fingering) which can lead to accelerated leaching of both the conservative and non-conservative solutes, such as surface-applied agricultural chemicals (Ritsema and Dekker 1996). Soil water repellency causes a delay in germination and the patchy growth resulting in a reduction of the effective growing season and yields, respectively (McKissock et al. 2000).

There is conflicting evidence regarding the effect of drying temperature and water content on water repellency. Ritsema et al. (1997) found no changes in water repellency after drying dune sand samples at 25, 45, or 65°C, whereas Dekker et al. (1998) found ambiguous changes in water repellency after drying sandy soil samples at 25 and 65°C. For four of the seven sandy soil sites studied in the Netherlands, potential water repellency was greater after drying at 65°C relative to drying at 25°C, whereas it decreased at two sites and remained unchanged at one. Dekker and Ritsema (1996) found important changes in water repellency after drying peaty clay and clayey peat soil samples at 25 and 65°C. Franco et al. (1995) reported differences in water repellency of sand samples dried at 25, 70, and 105°C and found that water repellency was highest when dried at 105°C.

As to the effect of water content on water repellency, there exists a critical soil water content threshold above which the soil is wettable and below which the soil becomes water repellent (Doerr and Thomas 2000). De Jonge et al. (1999) found that some soils are not water repellent at the very low water contents, but become water repellent as soil water content increases. After the single peak, water repellency decreases until the soils become wettable above certain water content. Such behaviour could be associated with fungal or other microbiological activity, which increases initially with soil moisture before disappearing as soils become wet. Some soils (most sandy topsoils) showed the double-peak behaviour. These soils are water repellent at very low water content (< 1%). As soil water increases, water repellency falls, but increases again to a second maximum. After the second peak, water repellency decreases and the soils finally become wettable above a certain water content (De Jonge et al. 1999).

Amelioration of water repellent soils by the addition of clay has been demonstrated by several researchers. It was found that additions of 1–2% clay can prevent water repellency and achieve up to threefold yield increases. Texture (clay + silt content) and proportion of the clay fraction that consists of kaolinite are the most significant factors in determining the effectiveness of clayey subsoil materials in reducing water repellency (McKissock et al. 2000).

Table 1. Particle size distribution of the coarse and fine quartz sand used in this study

| Particle size (µm) | Coarse sand (% weight) | Fine sand (% weight) |
|---|---|---|
| > 800 | 13.4 | 0.1 |
| 400–800 | 86.3 | 16.7 |
| 315–400 | 0.3 | 57.3 |
| 250–315 | – | 20.2 |
| 180–250 | – | 5.7 |

The aim of this study was to assess the effects of kaolinite (referred to as the most effective material in combating the water repellency) and drying temperature on the persistence of soil water repellency, induced by humic acids. Humic acids extracted from peat were chosen, as they were found to be good initiators of water repellency, even in the case of heavy clay soils (Babejová et al. 2000).

## MATERIAL AND METHODS

Coarse and fine quartz sand, kaolinite and humic acids solution was used to determine the persistence of soil water repellency at different soil water contents. Particle size distributions of the coarse and fine quartz sand are presented in Table 1. Kaolinite used in this study was extracted from the Sedlec kaolin. It contains 20% of particles < 0.03 µm and consists mainly of $SiO_2$ (47.5%) and $Al_2O_3$ (37.0%). The humic acids solution was extracted from peat and contains 3.25% humic acids. Organic carbon content of the humic acids solution is 1.28%. The percentages by weight are used in this study.

Six porous materials with different texture were used in this study: 1. fine sand, 2. fine sand (95%) + kaolinite (5%), 3. fine sand (90%) + kaolinite (10%), 4. coarse sand, 5. coarse sand (95%) + kaolinite (5%), 6. coarse sand (90%) + kaolinite (10%). No humic acids solution was added to two 50-g samples from each sort of the porous material. Then two 50-g samples from each sort of the porous material were mixed with humic acids solution to achieve humic acids contents of 0.19, 0.38, 0.57, and 0.76%. Those values correspond to the humic acids content of cultivated soils ranging from 0.1 to 2% (Kononova 1975). Finally, water was added to all the 60 samples to arrange the soil water content of 30%, and the samples were homogeneized by mixing. Water content of the samples was lowered by drying at 30°C and subsequent equilibrating at the room temperature for a minimum of 12 hours.

The persistence of water repellency was determined using the water drop penetration time (WDPT) test. One to three drops of distilled water from a medicinal dropper were placed onto the soil surface and the time required for infiltration was recorded. The volume of water in a droplet was 77 ± 3 µL. A standard droplet release height of approximately 10 mm above the soil surface was used to minimise the cratering effect on the soil surface (Wylie et al. 2001). Evaporation of water from the drop is considered negligible during the relatively short exposure times to the water drops (Gerke et al. 2001). The following classes of the persistence of water repellency can be distinguished: wettable or non-water-repellent soil ($WDPT < 5$ s), slightly ($WDPT = 5$–60 s), strongly ($WDPT = 60$–600 s), severely ($WDPT = 600$–3600 s), and extremely ($WDPT > 3600$ s) water-repellent soil (Dekker and Ritsema 1996).

The above-mentioned procedures (wetting to $w = 30\%$, homogenization, drying, equilibrating at the room temperature for a minimum of 12 hours, measurement of *WDPT* at several water contents) were repeated on the same 60 samples after drying at temperatures of 60, 90, 150, 210, and 270°C.

## RESULTS AND DISCUSSION

All twelve samples of porous material without humic acids were wettable ($WDPT \approx 1$ s) for the range of water content $w = 0$–30% and the drying temperatures of 30, 60, 90, 150, 210, and 270°C. Establishment (re-establishment) of water repellency was observed after drying the samples at temperatures of 30, 60°C (in both cases 36 of the 48 samples containing humic acids were water repellent) and after drying at 210°C (only a few samples with the higher humic acids contents were slightly water repellent).

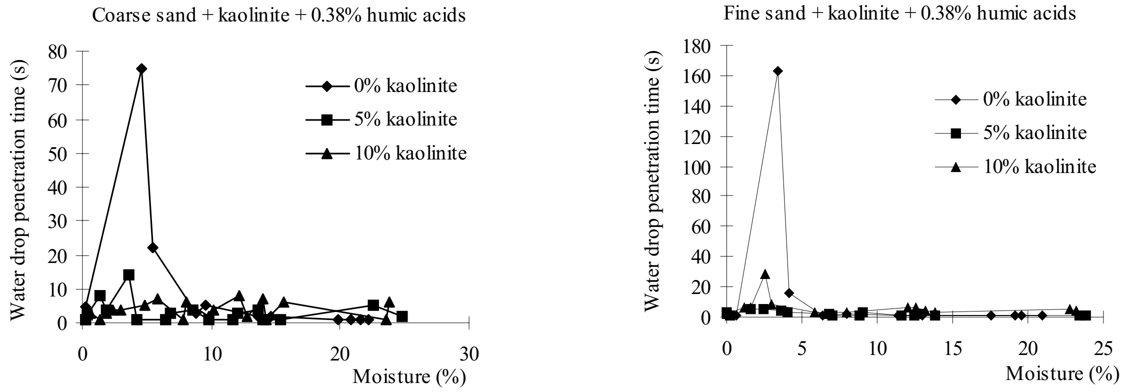


Figure 1. Water drop penetration time vs water content for the samples with 0.38% humic acids dried at 30°C

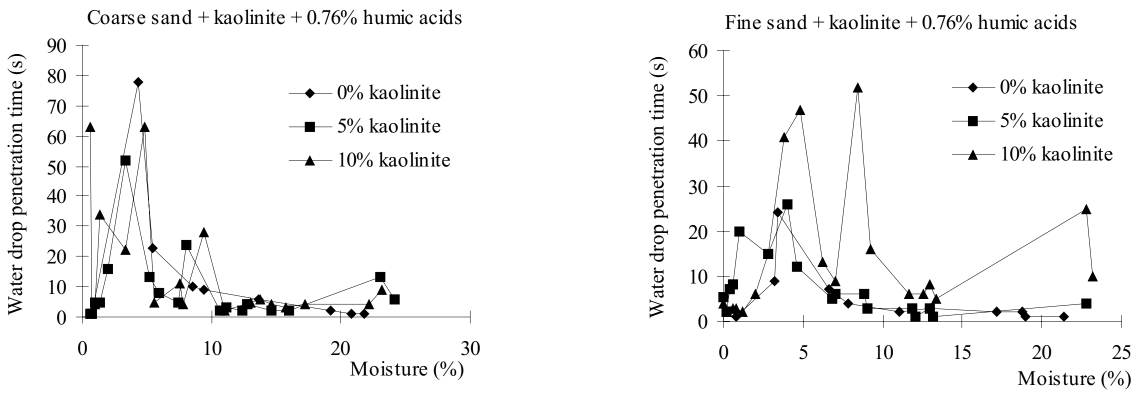


Figure 2. Water drop penetration time vs water content for the samples with 0.76% humic acids dried at 30°C

## Drying at 30°C

The samples with 0.19% humic acids were wettable in case of fine sand. For the coarse sand without kaolinite was *WDPT* = 7 s for *w* = 4.2%, and for the coarse sand (95%) + kaolinite (5%) was *WDPT* = 8 s for *w* = 1.4%. In the remaining cases, the coarse sand samples were wettable.

In the samples with 0.38% humic acids, the addition of kaolinite resulted in a drop of the persistence of water repellency (Figure 1) as also reported by McKissock et al. (2000). However, the samples with kaolinite remain slightly water repellent for some water contents.

In the samples with 0.57 and 0.76% humic acids, the addition of kaolinite resulted in an increase of the persistence of water repellency for a wide range of water contents (Figure 2).

## Drying at 60°C

The coarse sand samples containing 0.76% humic acids were wettable, the samples containing 0.19 and 0.38% humic acids were slightly water repellent, and the samples containing 0.57% of humic acids were severely water repellent (*WDPT* = 1160 s for *w* = 3.4% was the maximal *WDPT* value measured in this study).

Addition of 5% kaolinite to the coarse sand resulted in changing (increase for the samples containing 0.38 and 0.76% humic acids, and drop for the samples containing 0.19 and 0.57% humic acids) the class of the persistence of water repellency in comparison with the coarse sand: for the samples containing 0.19% humic acids from the slightly water repellent to wettable soil, for the samples containing 0.38% humic acids from the slightly to strongly water repellent soil, for the samples containing 0.57% humic acids from the severely to slightly water repellent soil, and for the samples containing 0.76% humic acids from the wettable to the slightly water repellent soil.

The coarse sand (90%) + kaolinite (10%) samples were wettable for 0.19% humic acids contents, and slightly water repellent for 0.38, 0.57, and 0.76% humic acids contents.

Fine sand samples containing 0.19, 0.57, and 0.76% humic acids were wettable, and only the sand samples containing 0.38% humic acids were slightly water repellent.

Addition of 5% kaolinite resulted in an increase of the persistence of water repellency for all the humic acids contents and for a wide range of water contents in comparison with the fine sand. In all the cases, the class of the persistence of water repellency was changed: for the samples containing 0.19, 0.57, and 0.76% humic acids from the wettable to the slightly water repellent soil, and

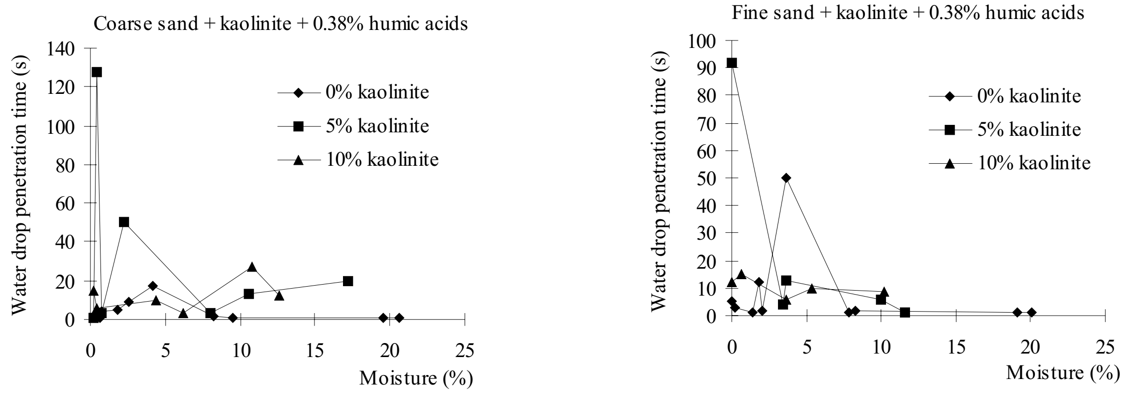


Figure 3. Water drop penetration time vs water content for the samples with 0.38% humic acids dried at 60°C

for the samples containing 0.38% humic acids from the slightly to strongly water repellent soil where *WDPT* = 92 s for $w = 0\%$ (Figure 3). It should be noted that all the *WDPT* measured are depicted in Figures 1–3.

Addition of 10% kaolinite resulted in a drop of the persistence of water repellency for the samples containing 0.19 and 0.38% humic acids, and an increase of the persistence of water repellency samples containing 0.57 and 0.76% humic acids in comparison with both the fine sand and the fine sand (95%) + kaolinite (5%) samples.

It should be noted that the surface temperature in the uppermost centimetre of soils can reach 60°C, and therefore, the re-establishment of water repellency can occur under natural field conditions (De Jonge et al. 1999).

### Drying at 90–270°C

All the samples of porous material dried at temperatures 90, 150, and 270°C were wettable ($WDPT \approx 1$ s) for the range of water content $w = 0–30\%$. For the drying temperature 210°C, the samples with 0.57 and 0.76% of humic acids were slightly water repellent.

## CONCLUSIONS

This study shows that kaolinite is not very effective in combating the water repellency. Additions of 5 and 10% kaolinite did not result unambiguously in a drop of the persistence of water repellency, and in case of the higher humic acids contents an increase of the persistence of water repellency was even noticed in comparison with the samples without kaolinite. Establishment (re-establishment) of water repellency was observed after drying the wetted samples at temperatures of 30, 60°C (in both cases 30 of the 48 samples became water repellent) and after drying at 210°C (a few samples with the higher humic acids contents became slightly water repellent). However, drying of samples at 90, 150, and 270°C did not induce water repellency.

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**ABSTRAKT**

**Vliv obsahu kaolinitu a teploty sušení na vodoodpudivost vyvolanou huminovými kyselinami**

Vodoodpudivost půd je velmi rozšířený jev spojený s pokrytím povrchu půdních částic organickými látkami. Může způsobit erozi půdy a smyv agrochemikálií během bouřky, preferované proudění prsty (fingering) spojené s rychlým vylouhováním agrochemikálií, opoždění klíčivosti rostlin a jejich nepravidelný růst. Zaměřili jsme se na vliv obsahu kaolinitu (podle literárních odkazů nejúčinnější látky používané proti vodoodpudivosti půdy) a teploty sušení na vodoodpudivost vyvolanou huminovými kyselinami z rašeliny, používané běžně v zemědělské praxi. Zjistili jsme, že přidání 5 až 10% kaolinitu nezaručuje pokles vodoodpudivosti, naopak v případě vyššího obsahu huminových kyselin jsme pozorovali růst vodoodpudivosti v porovnání se vzorky bez kaolinitu. Obnova vodoodpudivosti byla pozorována u 70 % vzorků po vysušení při 60 °C a u několika vzorků s vyšším obsahem huminových kyselin také po jejich vysušení při 210 °C.

**Klíčová slova:** vodoodpudivost; huminové kyseliny; kaolinit

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