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Enhanced Magnetic Susceptibility of Burnt Soils – Does it Evolve with Time?

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Abstract

A well known outcome of fire on soil magnetism is extremely high magnetic enhancement of top-most soil depths (Tite and Mullins 1971) compared to non-burnt soil. It was anticipated that due to thermal transformations in iron oxyhydroxides (mainly goethite) during heating a strongly magnetic maghemite is produced. This mechanism is further considered as one of the possible processes causing widely observed soil magnetic enhancement (e.g., Dearing *et al*. 1996, Evans and Heller 2003). Several studies, however, evidence that vegetation ashes also exhibit high magnetic susceptibility, typical of ferrimagnetic substances (McClean and Kean 1993, Lu *et al*. 2000, Jordanova *et al.* 2006, Petrovsky *et al*. 2018) in spite of diamagnetic nature of the raw vegetation. Thus, it could be supposed that magnetic signature of burnt soils reflects a more complex enhancement processes than previously thought. Apart from this, another major question arising in considering the magnetic properties of fire-affected soils is whether their magnetic enhancement is stable in time since the firing event, or it changes. In order to answer this question, an experimental fire was set up and magnetic susceptibility of samples taken from two depth levels (ash-rich level (0-3 cm) and soil mineral level (3-6 cm)) immediately after the fire was monitored during 2.5 years period. In addition, several samples from these two depth levels were taken after different time span since the firing event and their magnetic susceptibility again was monitored during that period. Besides, soil samples were taken one week after natural wildfires in 2017 year and magnetic susceptibility of samples from different depth intervals was tracked during the following 8 months. Reference soil samples from non-burned soils from the respective sites were included in the collection well. The main results from the study show that: 1) Magnetic susceptibility of burnt soil changes since the firing event and this change depends on the intensity and duration of fire, being more pronounced in soils suffering low-severity fire; 2) Magnetic susceptibility increases in soil samples taken immediately after the fire during the first ~10 days and slowly decreases afterwards for ash-rich samples or remains semi-constant in mineral-rich samples; 3) Magnetic susceptibility increase with time varies in a wide range between 2–3% and almost 40% with respect to the initial value, being higher in mineral-rich samples; 4) Magnetic susceptibility of soil samples taken after high-severity natural wildfire show a weak decrease (varying between 0–4%) with time which is the most pronounced in top-most depths; 5) Magnetic susceptibility of reference non-burnt soil samples practically does not change with time. The most probable reason for the observed fast changes in magnetic susceptibility after fire is related to soil dehydration as revealed by the data of weight loss with time. It is supposed that severe wildfires lasting several days produce more stable new magnetic minerals, while experimental fire and low-severity natural fires generate ultra-fine unstable magnetic grains which continue growing and further oxidize during laboratory monitoring period. Different implications of the observed changes in magnetic enhancement of fired soils related to environmental applications in practice will be discussed.

Keywords: soils, wildfires, magnetic susceptibility, temporal changes.

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