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COMMUNICATIONS

Research of magnetic properties of spolic technosols (alcalic/hyperartefactic) on the landfill of industrial waste from nickel production

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The article presents the results of measurements of magnetic properties of samples spolic technosols (alcalic/hyperartefactic) form the landfill of black nickel mud at Sered', Slovakia. We measured the dependence of magnetic moment as a function of temperatures (240-340 K) and applied magnetic fields up to 7.2 MA/m (90 kOe). We observed at room temperature the tendency to saturation of magnetic moment. The temperature dependences showed possible ferromagnetic behaviour.

K e y w o r d s: black nickel mud, spolic technosols (alcalic/hyperartefactic), magnetic properties

1 Introduction

The landfill of black nickel mud has developed during the 30 years of operation (the technology of wet Caron process in processing of Albanian iron-nickel ore) of the former metallurgical plant in Sered' (1963-1993). After the end of production in 1993 from economic and ecological reasons remained here the landfill of black nickel mud the volume of almost 9 mil tons and an area of 38 hectares, [2]. The chemical composition of mud is: 50-80% Fe, 3.5 % Cr_2O_3, 8% SiO_2, 8% Al_2O_3, 3.5% CaO, 0.17 %Ni, 0.18 % P_2O_3

The black nickel mud has fine texture and unnatural black coloration and contains 17.5% particles smaller as 10 μm airborne dust, which is respirable dust [1] and contains heavy metals (*eg* Cr). Black nickel mud is a very porous material with total porosity of 68 vol% and the volume density is 1.42 $\mathrm{g\,cm^{-3}}$ and retention water capacity increases with the depth on 44.5 vol% in the depth more than 45 cm, [3]. According to the WRB (2015) Soil Classification System, the spolic horizons must have at least then 20% artefacts of the volume and 100 cm from the surface must contain more than 35% the artefacts. Black nickel mud is a 100% alkaline industrial waste and has more than 50% volume of artefacts.

Spolic technosols (alcalic/hyperartefactic) from the aspect of development are not subject to natural soils-forming processes and have no developed soil horizons which are characteristic of the soils of the climate zone in which they are located. The landfill of black nickel mud is a technogenic surface that represents the deposit of secondary raw material (mainly iron, nickel and chrome) with the surface mining and for that we investigated its magnetic properties.

We present the results of measurements of magnetic properties of samples of spolic technosols (alcalic/hyperartefactic) form the landfill site of black nickel mud from Sered'. We measured the dependence of magnetic moment as a function of temperatures (240-340 K) and applied magnetic fields up to 7.2 MA/m (90 kOe). We observed at room temperature the tendency to saturation of magnetic moment. The temperature dependences showed possible ferromagnetic behaviour. We studied the dependence of different degree of black nickel mud on magnetic moments.

2 Experimental

The samples of spolic technosols (alcalic/hyperartefactic) were prepared by ŠGUDŠ Accredited Geoanalytical Laboratories in Spišská Nová Ves. The all samples we taken from dig out probes according to the structure of the profile of probe. In some probes the profile was homogeneous and that why we took only one sample from the middle part of the profile of probe. The structure of the black nickel mud probes was dependent on sludge deposition during the production process of nickel.

The chemical analysis shows changing amount of magnetic impurities (Tab 1.)

Magnetic properties measurements, in the temperature range of 240-320 K and DC applied magnetic field range of 0 to 7.2 MA/m (90 kOe), were carried out using the Vibrating Sample Magnetometer (VSM) on DYNACOOL device of Quantum design. We measured in this

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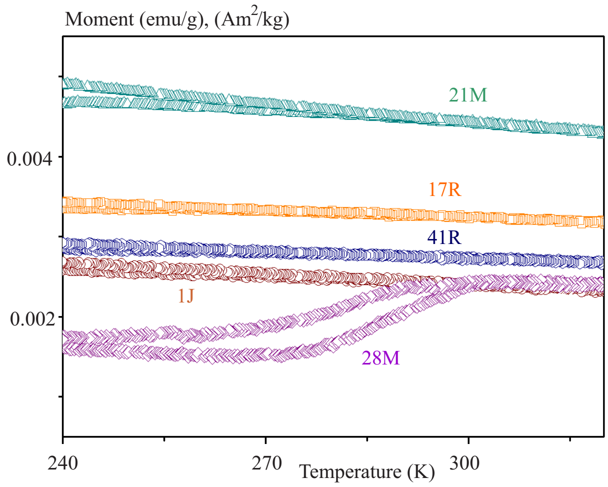

Fig. 1. Temperature dependence of magnetic moment for samples 28M, 1J, 41R, 17R and 21M at 8 kA/m (100 Oe) applied magnetic field

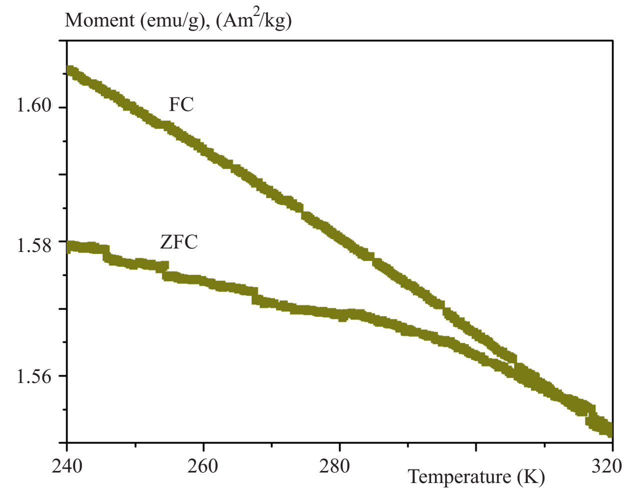

Fig. 2. Temperature dependence of magnetic moment for sample NSpas at 8 kA/m (100 Oe) applied magnetic field

Table 1. Concentrations of different magnetic contributions in samples

magnetic compound	NSpas	21M	17R	41R	1J	28M
Fe_2O_3 (%)	78	47	28.5	18.7	10.6	4.92
Ni(mg/kg)	2920	1782	1165	641	198	54
Cr(mg/kg)	24300	13870	8937	4873	1443	108

Table 2. Values of magnetic moment in emu/mg (Am^2/g) at different applied magnetic fields and temperatures

Sample	240 K		320 K	
	8kA/m (100 Oe)	80 kA/m (1000 Oe)	8 kA/m (100 Oe)	80 kA/m (1000 Oe)
NSpas	1579.3	6991.4	1552	6714
21M	4.7	17.9	4.3	15.7
17R	3.4	11.7	3.2	10.5
41R	2.9	10.5	2.7	9.5
1J	2.6	12.3	2.3	10.4
28M	1.6	28.5	2.4	12.3

temperature range in order to be more close to real conditions. The temperature dependence of magnetization data was measured under both zero-field cooling (ZFC) and field cooling (FC) modes.

3 Results

In Fig. 1 the measured temperature dependency of magnetic moment are presented. The applied magnetic field was 8 kA/m (10 Oe). Because we do not know the molecular weights of our samples (only chemical compositions) we used this unit. One could see that samples differ by magnitude of magnetic moment per weight. This is directly connected with amount of magnetic impurities presented in samples. Moreover, one could see for samples 28M and 21M that the ZFC and FC measurements show hysteresis behaviour which is connected with the presence of magnetic impurities with transition temperature around 300 K. Probable origin is connected with local increasing of Cr concentration for sample 21M and 28M.

In Fig. 2 the dependence for last sample NSpas is presented. Main difference is the intensity of magnetic moment per gram, which is about 3 orders of magnitude higher than in the previous samples. There is again present transition at about 300 K.

Similar behaviour appears when one applied the magnetic field 80 kA/m (1000 Oe). In Tab. 2 the values of magnetic moments are summarized for all samples. One could see that with increasing amount of impurities as the intensity of moments is increasing.

In Fig. 3 the dependencies of magnetic moments on magnetic field for different temperatures are presented for sample NSpas which has largest moments. One could see that sample is showing the bulk magnetic ordering presented by tendency to saturation of moment when 7.2 MA/m (90 kOe) is applied.

This behaviour is confirmation of dominating presence of Fe_2O_3 magnetic impurities with transition temperature order of 950 K. Contrary all other samples are not showing the tendency to saturation (*eg* Fig. 4, samples 28M and 1J).

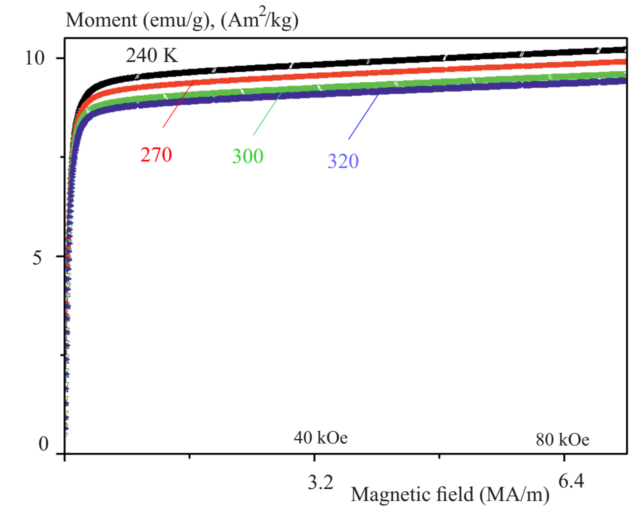

Fig. 3. Magnetic moment of sample NSpas dependence on magnetic field at different temperatures

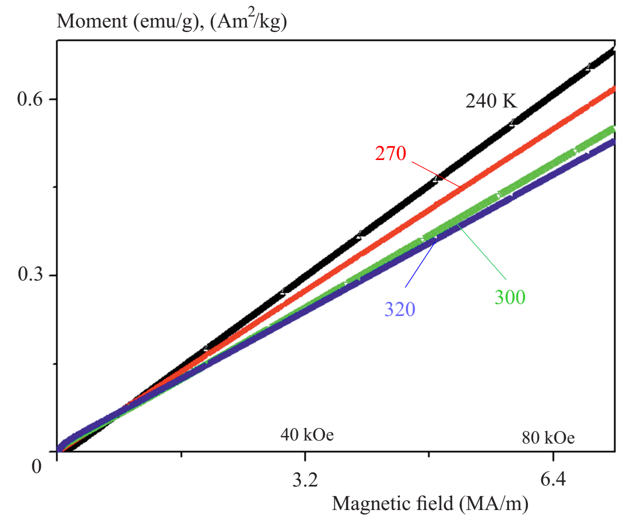

Fig. 4. Magnetic moment of sample 28M dependence on magnetic field at different temperatures

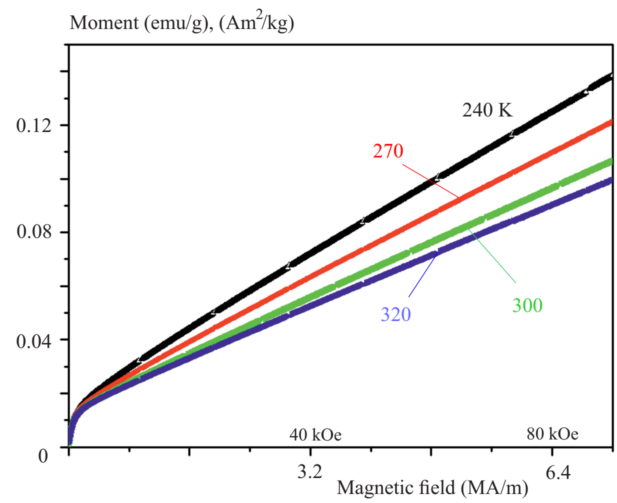

Fig. 5. Magnetic moment of sample 17R dependence on magnetic field at different temperatures

However, some of them at small applied fields order of 200 kA/m (2.5 kOe) show the shoulder which is confirmation of presence of magnetic impurities. The content of them is not enough to produce the bulk magnetization of samples as for NSpas (*eg* Fig. 5, samples 21M, 17R and 41R).

We could connect observed dependencies with the magnetic impurities presented in soil. At least then the detailed chemical analysis could start.

Thus the measurements of magnetic properties confirm the presence of different content of magnetic impurities in spolic technosols (alcalic/hyperartefactic). We showed that it is possible to use the study of magnetic properties as the estimation of the grade of contamination of soil.

Acknowledgements

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