Influence of Electro-osmosis on Properties and Structure of Clay Soils of Various Mineral Types

V.A. Korolev and D.S. Nesterov*

Lomonosov Moscow State University, Faculty of Geology, Department of Engineering and Ecological Geology 119991, Leninskie hills, 1-1, M.V. Lomonosov Moscow State University, Moscow, Russian Federation.

**dsnesterovmsu@gmail.com*

Treatment of clay soils from various contaminations is a difficult task due to their low permeability and high physicochemical affinity to the contaminants. Electrokinetic method in its different variants can be concerned as a perspective technology to treat such soils. Transformations of physical, physicochemical, electrosurface properties, and microstructure of clay soils were studied in the present paper, a new model of electro-osmosis which is considering the recharge of clay soil particles is also presented here. Four clay soils were chosen as the objects of the study: polymineral mantle till loam (Moscow), Glukhovtsy kaolin (Ukraine), Biyasalinian illite clay (Crimea), and Makharadzian smectite clay (Georgia). Physicochemical parameters of soils increase in the row 'loam-kaolin-illite clay-smectite clay'.

The study was undertaken at the lab scale. The experiments were conducted on clayey pastes, which were made at the moisture content of the upper plasticity index (w_L) with 0.01 M $CaCl_2$ used as a pore solution. Electro-osmotic treatment was undertaken in a one-compartment open-type electrokinetic cell under 10 mA DC (current density 32 A/m^2) with the ability of efflux to escape in the cathodic zone. The electric current was kept constant by a gradual voltage increase while electro-osmosis, the experiment was ceased when the current decreased dramatically, or voltage exceeded 200 V. After the treatment was finished, the soil specimen was divided into 5 fragments. Moisture content, density, and pH were determined in each fragment. Also, the samples for the preparation of water extractions and suspensions were taken here. Total salinity was measured in water extractions at the 'solid: liquid' ratio 1:10. Electrokinetic potential was determined in suspensions at 'solid: liquid' ratio 1:40. The same parameters were determined for the initial clayey pastes. Soil microstructure was studied by SEM in initial samples and both near-electrode zones after the treatment.

Water content of all the soils decreased during electro-osmosis, the most intense drainage effect was observed for Glukhovetsk kaolin. Total salinity of the loam almost did not change while one of the illite clay increased, which was caused for both soils by the dissolution reactions in the anodic zone. Kaolin's salinity decreased by the factor of 2.

The pH gradient formed due to water electrolysis reactions was almost the same for loam, kaolin, and illite clay: about 1-2 at the anode and near 12 at the cathode. Acidification (pH≈1) occurred along the whole specimen in the case of smectite clay except for the cathodic zone. Alterations of pH and salinity in the interelectrode space caused transformations of double diffuse layer (DDL) parameters of clay particles, including their electrokinetic (ζ) potential. Initial ζ-potential of all clays particles was negative (-36 mV for kaolin, -18 mV for smectite clay). Its absolute value increased in the cathodic zone in alkaline medium (-63 mV for kaolin, -120 mV for smectite clay), while ζ-potential sign changed in the anodic zone in acidic medium (+72 mV for kaolin, +120 mV for smectite clay). An almost equal gradient of ζ-potential was formed along the specimen length for loam and kaolin. Absolute ζ-potential values of loam decreased near the electrodes due to compaction of DDLs under high ionic strength, whereas the ones of kaoline increased further. Conversely, the change of ζ-potential sign took place within the entire interelectrode space in the case of smectite clay. That caused the formation of backward electro-osmotic flow and rapid fading of electro-osmosis.

Drainage, the impact of electro-osmotic flow, and alteration of DDL parameters resulted in the transformations of soil structure. The per cent of large micropores (10-100 μm) increased in the loam structure, which is caused by DDL envelopes compaction and aggregation of clay particles. In the case of kaolin, the share of small micropores (0.1-1 μm) increased in its structure, which illustrates the expansion of kaolin's DDL envelopes near the electrodes and the intense electro-osmotic flow impact. Pores size distribution became more homogeneous for both soils compared to the initial one. Also, both loam and kaolin structures became more anisotropic (anisotropy index of loam increased in general by the factor of 2, and the kaolin one – by the factor of 12).

The alterations of clays' DDL parameters and compaction effect of the flow caused the increase of density and decrease of porosity for all soils. The most drastic change of these parameters was observed for Glukhovetsk kaolin.

Keynotes: Electro-osmosis, Clays, DDL, Glukhovetsk and Kaolin.