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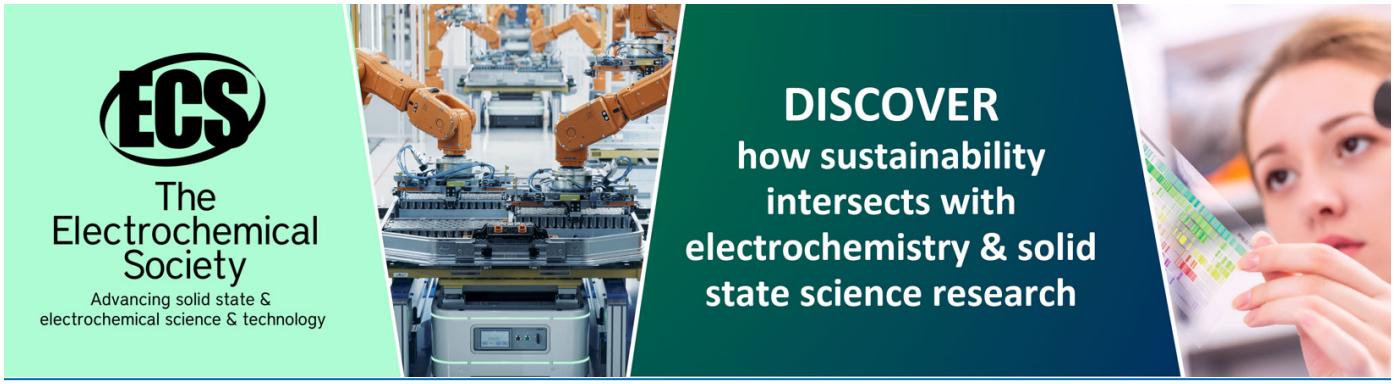

Humus state of buried soils of different age archaeological monuments on the territory of Ufa (Russia, Republic of Bashkortostan)

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Abstract. The paper studies the humus state of buried soils on the territory of archaeological monuments: the New–Ufa Burial Ground (early Iron Age) and the Settlement Ufa–II (early Middle Ages), located in the urban district of Ufa (Russia, Republic of Bashkortostan). The soil cover of archaeological monuments is represented by Greyzemic Phaeozem over Grayzemic Phaeozem (**gz–PH over gz–PH**). The humus content in buried horizons is 2.06–5.26%, which is 2–4 times less in comparison with the native soil. There are two types of humus such as humate and humate–fulvate. Among humic acids, the fraction associated with calcium (HAs–2) predominates. The spectral curves of humic acids HAs–2 at different wavelengths for the buried humus–accumulative horizon of the New–Ufa Burial Ground have a steeper character and lower optical density values compared to the background soil. The spectral curves of the buried horizons of the Settlement Ufa–II have flatter disposition and, in terms of optical density, are close to the values of the native soil. Obtained results make it possible to estimate the transformation of organic matter in the soils after their burial in comparison with the modern native soil Greyzemic Phaeozem (**gz–PH**) of the city park.

1. Introduction

Human impact on the global environment is manifested in unprecedented magnitudes, rates, and spatial scales. For example, at least half of the ice-free Earth's surface has already undergone significant changes as a result of various human activities [1].

According to various authors, the total area of urbanized territories ranges from 1 to 7% of the total soil area on Earth [2, 3]. One of the aspects of studying the soil cover of urban areas in space and time is the study of the soil cover of archaeological monuments. In complex soil-archaeological studies of the soil of archaeological monuments of modern urban areas, it is possible to determine the chronological transformation of the urban landscape [4] and the date of the occurrence of settlements

[5], assess the impact of human activity [6] and restore the urban environment at the early stages [7, 8], identify the features of agricultural practice [9].

At present, the archaeological monuments in the European part of Russia are most fully covered by comprehensive soil-archaeological research [10–14]. Similar works have been performed for the forest-steppe zone of the South Urals only once [15, 16].

As a result of anthropogenic activity, all the main features of the native soil are transformed. Changes record morphological and physic-chemical parameters, including organic matter. The first attempts to determine the thickness of the humus horizon and the amount of carbon in the soil organic matter were made as early as the 19th century using the soils of archaeological monuments as an example [17, 18]. Of course, archaeological monuments of different ages, like other similar objects of different ages, have certain limitations [19, 20], but in general, this practice shows that they can be successfully used to cognize and analyze the nature of soil formation and the development of soil organic matter.

Thus, our research aimed to study the humus state of buried soils of different age archaeological monuments in comparison with the native soil.

2. Objects and methods

The studies were conducted on the territory of Ufa city (Russia, Republic of Bashkortostan), the objects were the Greyzemic Phaeozem over Greyzemic Phaeozem (**gz**–**PH over gz–PH**) of the New–Ufa Burial Ground (IV century BC – II century AD, the early Iron Age) and Settlement Ufa–II (I century BC. – I century AD., the beginning of the II millennium BC., the early Middle Ages). The soil cover Phaeozem Greyzemic (**gz**–**PH**) of the M.I. Kalinin City Park was taken as the comparison native soil, which has insignificant anthropogenic impact [21]. The Classification of soils and soil horizons is given in accordance with the World Reference Base (WRB) 2015 and Field Soil Identifier 2008 [22, 23].

Soil samples were taken from the humus-accumulative horizon of buried soils of archaeological monuments and from genetic horizons of the native soil. Chemical analysis was carried out using the methods reported in the manual of E. V. Arinushkina [24]: the carbon content was determined using the Tyurin method and the soil reaction by potentiometry. The particle size distribution was determined by N. A. Kachinskii method [25]. The indicators proposed by D. S. Orlov and L. A. Grishina were used to characterize the humus state of the studied soils [26]. Optical density was determined on Shimadzu VU–1650ps spectrophotometer in the wavelengths range from 400 to 750 nm, recalculated by the carbon concentration in a solution 1 mg/ml. The change in the chromaticity coefficient was determined by E. Welte for optical pair E4 : E6 (465 : 665 nm) [27].

3. Results

The territory of the New–Ufa Burial Ground is a leveled area. In the upper part of the soil profile, an AYurban horizon with a capacity up to 35 cm was formed consisting of a mixture of loam, clay, construction and household waste. The buried AYhh horizon (New–Ufa Burial Ground, AYhh, 35–46 cm) lies under the AYurban horizon. The territory of the Settlement Ufa–II is located on the edge of the gully, along the bottom of which a stream flows. An AYurban horizon with a thickness of up to 67 cm was formed on the surface of the site, which is differentiated into separate horizons by color, density, structure, and admixtures of construction waste, then the buried soil is located (Settlement Ufa–II, AYhh, 67–110 cm). The depth of humus-accumulative horizon AY of the native soil (M.I. Kalinin City Park, AY) is ~30 cm.

Morphological comparison shows that the buried humus–accumulative horizons of archaeological monuments compared to the native undisturbed soil of the Kalinin Park include fragments of animal bones, ceramics and coal. According to the particle ratio of physical sand (> 0.01 mm) and physical clay (< 0.01mm) all studied soil horizons are classified as heavy loam and light loam. Actual acidity value pH(H_2O) in the soils of archaeological monuments varies within the range of 6.6–7.3 at 5.7 pH in the native soil (table 1). The humus content in the buried horizon of the New–Ufa Burial Ground is 5.26%, in the Settlement Ufa–II – 2.06%, while in the native soil of the M.I. Kalinin City Park it is 8,05%.

Allegedly, this low humus content in the soils of the archaeological monuments is most likely due to the development of the diagenesis process [14, 20, 28–31] (table 2).

Table 1. Some properties of humus-accumulative horizons of native and buried soils of archeological monuments.

Horizon; depth, cm	pH H_2O	Humic acids	Fulvic acids	Humus type	Sand >0.01mm	Clay <0.01mm	Classification by particle size distribution composition
		% of total C soil			%		
M. I. Kalinin City Park							
AY, 0–30	5.7	48.39	10.05	humate	51.8	48.2	heavy loam
New–Ufa Burial Ground							
AYhh, 35–46	7.3	33.44	20.25	fulvate–humate	49.3	50.7	heavy loam
Settlement Ufa–II							
AYhh, 67–110	6.6	63.06	9.25	humate	77.2	22.8	light loam

Table 2. Content of humic acid fractions in the native soil and buried soils of archaeological monuments.

Horizon; depth, cm	Humus, %	Humic acid fractions		
		1	2	3
		% to the amount of humic acids		
M. I. Kalinin City Park				
AY, 0–30	8.05	14.2	77.0	8.8
New–Ufa Burial Ground				
AYhh, 35–46	5.26	8.8	72.5	18.6
Settlement Ufa–II				
AYhh, 67–110	2.06	8.0	80.0	12.0

Analysis of the group and fractional composition of humus shows that the content of humic acids (HAs) in the organic matter of the investigated soils exceeds the fraction of fulvic acids. Humus in the humus horizons of the background soil is of the humate type, while in the humus horizons of buried soils and studied archaeological monuments – humate and fulvate-humatic type (table 1). Among the humic acids of the soil organic matter, the fraction of humic acids of the second group (HAs–2) prevails, these are humic acids associated with calcium. The fraction of humic acids of the third group (HAs–3) is in the second place in terms of content, and the lowest value is associated with the fraction of humic acids of the first group (HAs–1).

The humus horizon of the native soil AY (0–30 cm) is characterized by the largest share of the humic acid fraction HAs–2 among the fractions HAs–3 and HAs–1. Free humic acids are the second most concentrated acids in the humus horizon of the M. I. Kalinin Park (HAs–1) (table 2).

The distribution of optical density curves at different wavelengths and carbon concentrations of 1 mg/ml, on the example of humic acids of the HAs–2 fraction shows that the buried humus horizon of the New–Ufa Burial Ground (AYhh, 35–46 cm) contains humic acids HAs–2 that optically are less dense than in the humus horizon AY of the background soil of the M. I. Kalinin City Park. The humus

horizon of the buried soil of the Settlement Ufa–II (AYhh, 67–110 cm) was close to the native soil of the M. I. Kalinin City Park (AY, 0–30 cm) in terms of optical density (figure 1).

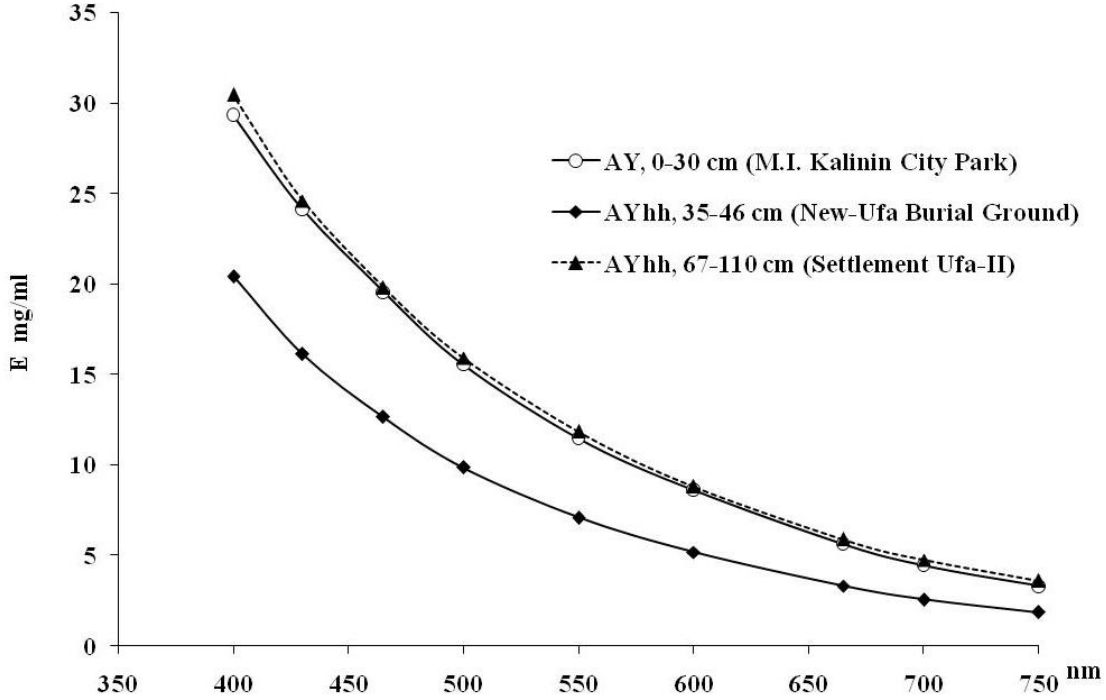

Figure 1. Optical density curves HAs–2 for native soil and buried soils of archaeological monuments (color coefficient E4 : E6: AY, 0–30 cm (M. I. Kalinin Park) – 3.47; AYhh, 35–46 cm (New–Ufa Burial Ground) – 3.81; AYhh, 67–110 cm (Settlement Ufa–II) – 3.36).

Comparison of the spectrophotometric curves by the value of the chromaticity factor shows that for the buried humus horizon AYhh (35–46 cm) of New–Ufa Burial Ground, the ratio E4 : E6 is 3.81 and the curve of optical density has steeper character of an arrangement. While for the buried humus horizons AYhh (67–110 cm) of the Settlement Ufa-II E4 : E6 is 3.36, the optical density curve has a smoother distribution and approaches the values of the M. I. Kalinin City Park native soil where E4 : E6 is 3.47.

4. Conclusions

The conducted researches have shown that the morphological comparison in the buried soils under the embankment of an urbanized horizon New–Ufa Burial Ground and Settlement Ufa–II compared to the native undisturbed soil of the M. I. Kalinin Park, inclusions were found that represent the result of anthropogenic activities of ancient man (fragments of animal bones, ceramics, coals).

Against the background of soil formation conditions close to neutral pH values of and the prevalence of humic acids over fulvic acids, the humus content in the buried humus horizons of the studied archaeological sites was 2–4 times lower than in the native undisturbed soil of the M. I. Kalinin Park. This may confirm the development of the diagenesis process in the buried soils.

Among the humic acid fractions of the studied soils, the HAs–2 fraction predominates, which is associated with calcium. In the buried humus horizons of the archaeological sites of New–Ufa Burial Ground and Settlement Ufa–II the humic acids (HAs–3) associated with clay particles are on the second place. While in the native undisturbed soil of the M. I. Kalinin Park the free humic acids (HAs–1) are on second place. This result can be related to the nature of the soil formation process, which continues in the humus horizons after their burial.

The comparison of optical characteristics of spectrophotometric curves using humic acid solutions of the HAs–2 fraction shows that the HAs–2 fraction in the buried humus horizon of the New–Ufa Burial

Ground archaeological site is optically less dense. The optical curve drops sharply and has a steeper location of E4 : E6 – 3.81. The HAs–2 fraction is optically denser in the buried humus horizon of the archaeological monument Settlement Ufa-II. Here the optical curve drops smoothly, has a flatter arrangement E4 : E6 – 3.36, and approaches the values of the native soils – 3.47.

The Optical parameters on the example of humic acid solutions of the HAs–2 fraction may indicate that at the time of the burial, the buried humus horizon of the New–Ufa Burial Ground archaeological site received strong anthropogenic impact, while the buried humus horizon of the Settlement Ufa–II site underwent weak anthropogenic impact.

As the soil cover of both the buried soils of different age archeological monuments located on territory of Ufa city (Russia, Bashkortostan Republic) and the native undisturbed soil of the M. I. Kalinin City Park is represented by Greyzemic Phaeozem, it is assumed that the conditions of soil formation from the moment of burial until the survey remain unchanged.

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