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REDOX REGIME OF ALLUVIAL SOILS IN THE SIVERSKY DONETS BASIN

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Abstract

Alluvial soils are a special product of pedolithogenesis, which takes place in floodplain conditions. Their formation is associated with the passage of floodplain and flood processes. This leads to the formation of soils that have maximum biogenicity and fertility levels. Changes in the conditions of soil formation during the year (changes in the level and composition of groundwater, the presence or absence of floods, features of the activity of the biological factor) cause changes in the physical and chemical parameters of soils, the intensity of the passage of biochemical processes, which is necessarily reflected in redox processes. This relationship is not only direct, but also reverse. The indicators of the redox potential of alluvial soils of the floodplains of the rivers of the Siversky Donets basin are given in the article. They were determined by the seasons of the year in layers at depths from 0 to 40 cm. The ORP level was determined in the field using the potentiometric method. Both for soil layers and for the seasons of the year, the indicators of the redox potential indicate the passage of reduction processes, and only in summer these processes can have the character of low-intensity oxidation. The restoration processes in the soil are most intense in spring. The bog alluvial soils of the near-Teras depression are characterized by more pronounced processes of reduction, as evidenced by the minimum values of the redox potential.

Key words: *alluvial soil, floodplain, redox potential.*

INTRODUCTION

The Siversky Donets River is one of the largest rivers in Ukraine and the main water artery in the east of the country. More than 64% of the territory of the east of Ukraine is the drainage basin of the Siversky Donets. This is the area from which atmospheric water is collected in the channel of this river. The basin occupies 9.1% of the territory in relation to the area of the country and is the fourth by largest- 54,500 km^2.

There are 3,112 rivers at this area, of which 118 are small and medium-sized. There are 106 such rivers on the territory of the Kharkiv region, which belong to the Siversky Donets basin (Vasenko at al., 2006).

Floodplains are areas that are inundated by river waters during a flood and are components of a river valley. Alluvial soils, which are unique in their genesis and properties, were formed on floodplains. Gleyic Fluvisol, Calcari-Gleyic Fluvisol and Humi-Gleyic Fluvisol prevail among them (Vepraskas & Craft, 2017). The area of soils with weak waterlogging within Kharkiv region is 23,000 hectares, and with strong waterlogging is 770 hectares. A significant area of soils with waterlogging is alluvial soil (Fluvisol) (Ecological, 2021).

The relevance of the study of floodplain soils is beyond doubt, neither from a purely scientific point of view or from a practical point of view.

The floodplain alluvial soils occupy a special place among the great variety of soils. They differ from watershed soils in genesis, composition indicators, and economic use. These soils are formed in complex biogeochemical conditions due to the heterogeneity of the floodplain process. It is related to the flood regime, features of the granulometric and mineralogical composition, physic-chemical and physical properties of alluvial deposits in different parts of the floodplain, features of the composition and regime of the groundwater level, the specifics of the species composition of plants, and the microclimatic conditions of the river valley. These soils are in a pronounced development and transformation. This is due to flooding processes, the location of this territory at the point of intersection of several geochemical pathways of substances and the peculiarities of variegated changes in the physical, chemical and physic-chemical parameters of soils both during the day and according to the seasons of the year. The combined effect of these factors causes the formation of soils of complex genesis and with specific properties.

Floodplain soils were distinguished by a higher level of fertility compared to soils of flat interfluve. A valuable natural sources of cheap and biologically complete feed for animals were located here (Fageria et al., 2002; Lóránt & Podmaniczky, 2015).

The alluvial soils of the floodplains of the Siversky Donets basin, in contrast to the zonal soils located in the adjacent territories, are occupying a relatively small area. They are almost not studied from the point of view of the properties and mode of the level of oxidation-reduction processes in natural conditions. A more thorough assessment of the ecological state of the functioning of alluvial soils and a clearer understanding of their genesis will be provided when studying this issue. The purpose of the research: to investigate the level of redox potential during the growing season in field conditions of alluvial soils of small and medium-sized rivers of the Siversky Donets basin.

Each type of soil is distinguished by a unique level of redox potential and its dynamics. Changes in the conditions of soil formation during the year (changes in the level and composition of groundwater, the presence or absence of floods, the peculiarity of the activity of biological factors) cause changes in the physical and chemical parameters of the soil, the intensity of biochemical processes. As a result, redox processes are change. This connection is not only direct, but also inverse. Aeration and chemical composition of the soil affects the size of the redox potential. The above-mentioned indicator affects the transformation of soil components (Davidson et al., 2015; Denef & Lehmann, 2016; Nunan & Boivin, 2016; Zak & Tilman, 2018; Bragato et al., 2019).

There is the most contrasting dynamics of the redox potential in soils with a close occurrence of groundwater and a variegated biological factor, which is associated with significant changes in the water-air regime of the soil and large fluctuations in soil temperature. These types of soils include alluvial (Fluvisol) soils (Chen et al., 2017; Herrmann & Werban, 2017; Fuentes-Rodriguez et al., 2018).

There is heterogeneity of redox potential not only in time, but also for each genetic horizon separately and even for microzones within one genetic horizon for the prevailing majority of alluvial (Fluvisol) soils. A lower indicators of redox potential exist in overmoistened glial horizons of the hydromorphic series of soils. According to scientists, this is due to the heterogeneity of microbiological activity and aeration in the soil profile (Zhelezova et al., 2013; Komatsu & Sato, 2021).

I. Kaurichev separated into independent groups semi-hydromorphic and hydromorphic soils, which also include alluvial (Fluvisol) soils, according to OVP indicators. The first group has seasonal waterlogging in the upper or lower horizons or their entire profile. The contrast indicators of ORP are typical for the soils of this group. Another group has rewetting throughout the soil profile throughout the year (Kaurichev, 1982).

Redox potential (ORP or redox potential) determines the redox conditions in the soil, that is, the degree of aeration and the level of biogenicity in it (McDaniel et al., 2006; Belyaeva et al., 2017).

The value of ORP at the level of 600-750 mV is typical for maximally aerobic conditions, 400-600 mV - for normally aerated conditions, 300-400 mV - for conditions with moderate waterlogging, where aeration is difficult, 200-300 mV - for conditions with medium waterlogging, where aeration is significantly complicated, and less than 200 mV - for conditions with a predominance of recovery processes, sludge formation actively occurs in the soil and compounds toxic to plants accumulate (Khtryan, 1976).

MATERIALS AND METHODS

The studies were carried out within the following territories: the central and terraced parts of the floodplain of the Mokryi Izyumets River and the riverbed, central and terraced parts of the floodplain of the Voloskaya Balakleyka River, Izyumsky District, Kharkov Region.

Mesophilic and hygrophilic herbaceous vegetation grows on the territory of floodplains. The territories are used as natural hayfields and pastures.

The soil covering the flood of the river Mokriy Izyumets and Voloska Balakliyka to the basin of the Siversky Dintsya is to be folded and formed from different taxonomic units.

On the territory of the central part of the floodplain of the Mokriy Izyumets river, Izyumsky district, Kharkov region, Humi-Gleyic Fluvisol (N 49°24'03,0", E 37°19'39,2") studied.

On the territory of the near-terrace part of the floodplain of the Mokriy Izyumets river, Izyumsky district, Kharkov region, Humi-Gleyic Fluvisol (N 49°24'00,7", E 37°19'47,5") studied.

On the territory of the near-channel part of the floodplain of the Voloska Balakliyka river, Izyumsky district, Kharkov region, Alluvial Gleysol (N 49°32'43,2", E 37°02'36,4") studied.

On the territory of the central part of the floodplain of the Voloska Balakliyka river, Izyumsky district, Kharkov region, Alluvial Gleysol (N 49°32'41,1", E 37°02'35,8") studied.

On the territory of the near-terrace part of the floodplain of the Voloska Balakliyka river, Izyumsky district, Kharkov region, Alluvial Gleysol (N 49°32'37,9', E 37°02'39,9") studied.

Determination of ORP was carried out in soil layers 0-10, 10-20, 20-30 and 30-40 cm in field conditions immediately after the opening of the horizons according to the seasons of the growing season - spring, summer and autumn.

The EMF was measured (in mV) between the EPV-1 thin-layer platinum electrode (Figure 1) and the EVL-1M auxiliary silver chloride electrode (Figure 2), which were lowered into the soil ball, to determine the soil redox potential. The electrodes were connected to a portable millivoltmeter pH-150 (Figure 3). The temperature compensation was performed before each measurement according to the readings of an electronic temperature sensor. ORP was measured after 15 min after the installation of the electrodes – during this period, equilibrium is established between the soil and the electrodes. For the final calculation of the ORP index, 201 was added to the obtained figure to take into account the value of the potential of the auxiliary electrode with silver chloride.

Figure 1. Platinum electrode EPV-1

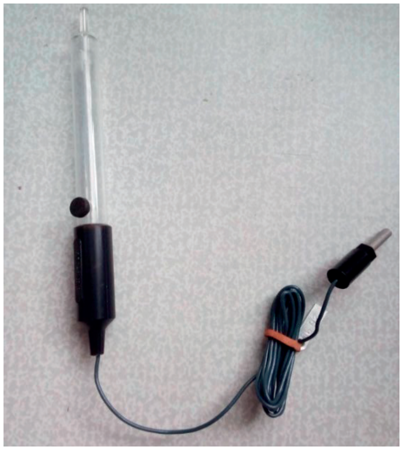

Figure 2. Auxiliary silver chloride electrode EVL-1M

Figure 3. Portable millivoltmeter pH-150

A mixture of salts (3.8018 g $K_4[Fe(CN_6)]$ and 13.5001 g $K_3[Fe(CN_6)]$) in 1 liter of distilled water is used as a reference solution for ORP measurements. The EMF of the circuit at 20°C±1°C relative to the auxiliary electrode with silver chloride is 272 mV±5 mV. A check against the reference solution is carried out before each new test point.

RESULTS AND DISCUSSIONS

As mentioned earlier, alluvial soils have quite specific properties. This originality is also manifested in the dynamics of the redox potential (Table 1).

The floodplain of the Voloska Balakliyka river is monotonous in terms of soil cover. There is Alluvial Gleysol irrespective of the part of the floodplain. At the same time, regardless of the homogeneity of the soil, the indicators of redox potential is differ depending on the part of the floodplain.

The ORP of the Alluvial Gleysol of the near-channel part of the floodplain of the Voloska Balakliyka river, which is somewhat elevated above other parts of the floodplain, is differs both with depth and with the seasons of the year. The ORP index indicates the weakly reducing nature of redox processes in the spring in the 0-10 cm soil layer. Deeper, the degree of reduction processes increases and reaches a maximum in the 20-30 cm layer, where the ORP is equal to 238 mV. In the summer, the ORP indicator changes dramatically in this soil in almost all the studied layers. Moderately reducing conditions are created in the 0-10 cm layer, which change sharply to weakly oxidizing conditions with increasing depth. This is indicated by the ORP indicators in the 10-20 cm soil layer is 438 mV and in 20-30 cm - 404 mV. Moderately reducing conditions are created at a depth of 30-40 cm - 282 mV. This digital does not differ significantly from the indicator recorded in the spring.

Table 1. Content and profile distribution of ORP index in floodplain soils of Siverskyi Donets basin

Rivers	Part of floodplain	Soils	Depth, cm	ORP, mV Selection period		
				Spring	Summer	Autumn
Mokriy Izyumets	Central	Humi-Gleyic Fluvisol	0-10	324	464	339
			10-20	339	176	361
			20-30	280	351	305
			30-40	300	129	329
	Near-terrace	Humi-Gleyic Fluvisol	0-10	300	255	303
			10-20	291	449	327
			20-30	330	440	334
			30-40	304	417	315
Voloska Balakliyka	Near-channel	Alluvial Gleysol	0-10	306	239	323
			10-20	253	428	280
			20-30	238	404	263
			30-40	280	282	307
	Central	Alluvial Gleysol	0-10	321	271	333
			10-20	295	342	316
			20-30	311	252	318
			30-40	300	202	302
	Near-terrace	Alluvial Gleysol	0-10	283	369	295
			10-20	258	160	267
			20-30	315	423	326
			30-40	279	198	288

In autumn, the pattern of the profile distribution of the potential repeats the spring distribution with a slight increase in the level. Weakly reducing conditions are formed in the upper soil layer (0-10 cm - 323 mV) and the deepest layer under investigation (30-40 cm - 307 mV). At a depth of 10-30 cm, the ORP indicator does not exceed 300 mV, which indicates moderately reducing conditions.

With regard to the redox conditions of the Alluvial Gleysol of the central part of the floodplain of the Voloska Balakliyka river, it is possible to assert, based on the OVP indicators, that the restoration processes are intensified compared to the conditions in the soil of the near-channel part of the floodplain. In the spring, in the layers of 10-20 cm and 30-40 cm, the indicators of redox potential differ by only 5 mV and are equal to 295 mV and 300 mV. These indicators indicate that the intensity of recovery processes is on the border between weak and moderate intensity. Between the 0-10 cm and 20-30 cm layers, the difference in the ORP level is somewhat larger - 10 mV. In these layers, restoration processes begin to manifest themselves well. In summer, the intensity of recovery conditions increases almost throughout the profile. On the contrary, only at a depth of 10-20 cm, the intensity of regeneration processes is suppressed compared to spring. Here the ORP level exceeds the mark of 300 mV and is equal to 342 mV. In autumn, with increasing depth, there is a clear tendency to decrease the ORP indicator from 333 mV in the 0-10 cm layer to 302 mV in the 30-40 cm layer. According to the indicators studied, the soil layers of 10-20 cm and 20-30 cm are almost the same. In general, regeneration processes take place here with moderate activity.

The ORP indicators of the Alluvial Gleysol of the near-terrace part of the floodplain of the Voloska Balakliyka river, which is lower relative to the level of the central floodplain, indicate that this soil is more moist than the previous ones. In spring, the maximum value of ORP is fixed at a depth of 20-30 cm - 315 mV. In this part of the soil profile, the nature of the processes acquires the manifestation of weak recovery. Higher and deeper, recovery processes is intensify and has reach maximum development for a part of the profile up to a depth of 40 cm in a layer of 10-20 cm (258 mV). In the summer, there was a sharp differentiation of the layers of the Alluvial Gleysol according to the nature of oxidation-reduction processes. In addition to reduction processes, weak oxidation processes also appear here. As evidenced by the ORP indicator in the 20-30 cm layer - 423 mV. Intensive recovery processes that take place in the soil layers of 10-20 cm (160 mV) and 30-40 cm (198 mV) create an unfavorable nutrition regime for plants. In the upper part of the soil, 0-10 cm, weakly reducing conditions are created, which is indicated by the ORP of 369 mV. In autumn, the variability of the ORP level decreases with depth and is within 200-300 mV in most soil layers. Moderate recovery processes are underway here. The intensity of these processes decreases somewhat at a depth of 20-30 cm, where the redox potential rises to 326 mV.

The soil cover of the Mokryi Izyumets floodplain is represented by one type of soil - Humi-Gleyic Fluvisol. Compared to Alluvial Gleysol of the Voloska Balakliika river floodplain, the redox potential index is on average higher, which indicates a lower moisture content of the Humi-Gleyic Fluvisol and a decrease in the intensity of recovery processes.

At the spring, the redox potential of the Humi-Gleyic Fluvisol of the central floodplain was within 280-339 mV. With depth, there is a general tendency to decrease this indicator. The nature of the processes is variable and weakly reversible. In summer, there is a significant change in indicators compared to spring and autumn, and a sharp change in them is recorded by soil layers. Three groups of indicators are distinguished here. The first group - those that are less than 200 mV. They were found in layers of 10-20 cm - 176 mV and 30-40 cm - 129 mV. In these layers, the intensive recovery processes take place, which, as mentioned earlier, have a negative effect on plant nutrition. The second group of indicators, which are within 300-400 mV. Such an indicator is in the layer of 20-30 cm - 351 mV. In this layer, the intensity of recovery processes is very weak. The last group of indicators - in the range of 400-500 mV - is in the 0-10 cm layer - 464 mV, where weak oxidation processes take place, which are favorable for the formation of nitrate nitrogen during the nitrification process. In autumn, the ORP level stabilizes and no sharp changes are recorded. With depth, there is a general tendency to decrease the level of ORP, which indicates an increase in the intensity of recovery processes, which is associated with an increase in soil moisture and a decrease in its aeration.

The ORP indicator of the Humi-Gleyic Fluvisol of the soil differs from the indicators of the previous soil. In the spring, a general tendency to increase the ORP level is observed with increase of depth. The lowest indicator was found in the 10-20 cm soil layer - 291 mV, and the highest - 330 mV in the 20-30 cm layer. These indicators indicate that recovery processes are weak and moderate in nature. At the summer, the level of redox potential in most soil layers increased sharply - to 417-449 mV. Which indicates the change of reduction processes to oxidation processes. The fluctuation of the potential here is not large and is in the range of 303-334 mV and slightly increases with depth.

CONCLUSIONS

The obtained data testify to the specificity of the oxidation-reduction potential and the nature of the oxidation-reduction processes of the alluvial soils of the river floodplains of the Siverskyi Donets basin.

In most cases, both by soil layers and by seasons, indicators of redox potential indicate the passage of redox processes, and only in summer these processes can change to the opposite, namely, oxidation processes. Oxidation processes are characterized by weak intensity. According to the averaged data, the lowest indicators of redox potential are observed in spring. They tend to grow seasonally from spring to fall. This indicates the greatest intensity of soil recovery processes in the spring.

Alluvial Gleysol soils, especially those of near-terrace subsidence, are characterized by more pronounced recovery processes, which is evidenced by the minimum indicators of redox potential.

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