



## Transformation of soils in areas with active recreational activity on the Russian Black sea coast

### Transformación de suelos en áreas con actividad recreativa activa en la costa rusa del Mar Negro

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#### ABSTRACT

This paper examines the influence of recreational activities on the components of coastal landscapes on the territory of the municipal formation of the resort city of Gelendzhik, Russia (the Betta farm). The authors provide an estimation of the anthropogenic impact on the soils. The paramagnetic activity of meadow-chernozem soils is studied using electron paramagnetic resonance spectroscopy. The authors also review other aspects related to soil changes. Finally, conclusions are drawn about the progress of the study, and appropriate recommendations are given.

**Keywords:** coastal landscapes, Betta, anthropogenic impact, tourism, soil transformation, electron paramagnetic resonance spectroscopy, soil.

#### RESUMEN

Este artículo examina la influencia de las actividades recreativas en los componentes de los paisajes costeros en el territorio de la formación municipal de la ciudad turística de Gelendzhik, Rusia (la granja Betta). Los autores proporcionan una estimación del impacto antrópico sobre los suelos. La actividad paramagnética de los suelos de pradera-chernozem se estudia mediante espectroscopía de resonancia paramagnética de electrones. Los autores también revisan otros aspectos relacionados con los cambios del suelo. Finalmente, se extraen conclusiones sobre el progreso del estudio y se dan las recomendaciones apropiadas.

**Palabras claves:** paisajes costeros, Betta, impacto antropogénico, turismo, transformación del suelo, espectroscopia de resonancia paramagnética electrónica, suelo.

#### 1. INTRODUCTION

The peculiarity of the development of tourist and recreational activities in the coastal zone of the Black Sea within the Krasnodar Territory, Russia is characterized by a combination of various types of recreational activities within a limited space. Determining the impact of various types of recreational activities on the components of coastal landscapes is an important and necessary stage for the formation of a system of sustainability indicators for coastal tourism development (Volkova et al., 2022). The territory of the municipal formation of the resort city of Gelendzhik belongs to the most actively developing municipalities

in the field of tourism in the Krasnodar Territory. A unique combination of physical and geographical conditions, recreational resources, a good location, and developed infrastructure have attracted tourists and vacationists to Gelendzhik for several generations. The territorial organization of recreational activities here is very typical. A narrow strip along the sea is characterized by a maximum concentration of vacationists. Infrastructurally, the territory of the municipality is actively developing in the direction of creating conditions for comfortable and high-quality recreation at various levels. A large number of vacationists within the organized beach areas and picturesque coastal landscapes contribute to the active movement of vacationists outside the equipped zones. The combination of these factors and processes was the reason why we chose the territory of the Gelendzhik resort town (Betta farm) as a key site for our study.

One can note the direct and indirect impacts of tourism and recreational activities on the environment. The direct impact signs include the extermination of flora and fauna in the process of hunting, and fishing; destruction and transformation of natural habitats by including territories in economic activities, etc.; introduction and spread of infections and diseases through human waste (excrement, organic food waste), economic activities (deforestation, soil disturbances, etc., interference in the natural processes of plant and animal life by feeding the animals, breeding the plants and animals in artificially created conditions; observation of plants and animals; noise exposure; destruction of nests, burrows, etc.

The indirect effects include effects on the components of the geographical environment (soil and surface water pollution, deforestation and erosion, global climate change, atmospheric pollution, etc.); changes in the natural habitat; artificial breeding of animals, breeding of animals and plants with specified properties (genetically modified species, mutants), the impact of which on nature and humans has not yet been studied. The anthropogenic load can lead both to disruption of the functioning of individual components of biogeocenosis and general degradation. In this regard, it is important to search for indicator parameters that allow determining the critical values of anthropogenic loads at which the ecosystem remains stable.

Anthropogenic impact on biogeocenoses leads to the transformation of the structural and functional properties of the soil, which affects the resistance to anthropogenic load. Despite the significant transformation, the organic matter of the soil largely compensates for the accumulation of pollutants and the negative effect of anthropogenic load. The buffering properties of the soil are not infinite, and to assess the role of soil organic substances that support buffering, it is advisable to use the concept of ecological potential, which allows us to consider soil organic substances as active substances.

Photosynthetic plants, including media-forming species, need two groups of substances: organic substances synthesized in the assimilation tissue and propagating through the descending conductive tissue (the phloem), as well as mineral substances and water absorbed by the root system and propagating through the ascending conductive tissue (the xylem). Organic metabolism is associated with the presence of an optimal amount of light and water. Water enters the plant through the root system. Therefore, an important characteristic responsible for the growth and development of plants is the soil. The most important properties of the soil are associated with the presence of specific and non-specific soil properties. The growth and development of plants are influenced by a large number of compounds in the soil. The humus layer is primarily responsible for the optimal temperature balance, water/salt balance, etc. (Lodygin et al., 2018).

Recently, the field of soil science has been intensively developing related to the analysis of complex organic substances of soils belonging to the humus layer. Humus substances are characterized by the peculiarities of formation and transformation. Humus substances are divided into humic acids (compounds soluble in strong bases), fulvic acids (relatively small compounds with a large proportion of cyclic fragments that dissolve in an aqueous medium at all pH values), as well as humins (compounds that do not dissolve in an aqueous medium at any acidity value). Fulvic acids and humic acids are viewed as one group of compounds (humus acids). The structural and functional properties of humus acids are directly related to soil fertility and allow for concluding the stability of phytocenosis (Chukov, 2001). To study the degree of

transformation of the fertile soil layer, we used both physico-chemical (spectral, chemical methods) and microbiological research methods.

Humus acids play an important role in the functioning of any phytocenosis. Moreover, semiquinoid-type free radicals play an essential role in biochemical processes. The radicals in humus acids are intermediate participants in step reactions. Radical particles are formed during homolytic bond breaking and have a very short life span. Due to the large energy reserve and high activity of radical particles in most chemical reactions, they play a central role in biochemical processes. Electron paramagnetic resonance (EPR) spectroscopy is an effective method for determining the concentration of free radicals.

Humic acids and fulvic acids are the main components of soil organic matter. The main feature of these compounds is thermodynamic and biochemical stability (Lodygin et al., 2018). Modern physico-chemical methods of substance research allow us to study in detail the structure and composition of humus substances. The formation of the humus layer is one of the most difficult and controversial issues in this area. Humus substances are high-molecular compounds formed by polymerization reactions and stepwise polycondensation. The formation of humus involves, first of all, vegetative and generative organs of plants, as well as saprotrophic and chemotrophic microorganisms and products of their metabolism. The complexity of the analysis of these substances lies in the fact that, unlike individual low-molecular compounds, humus substances are a multi-component system characterized by a complex chemical structure (Chukov, 2015). Due to the presence of the aliphatic and aromatic parts in humus substances, free radicals are generated, the concentration of which can be determined using the method of EPR.

Together with other physical and chemical parameters of the soil, paramagnetic activity makes it possible to determine the ecological potential of soil organic matter under conditions of various anthropogenic loads (Chukov, 2001). The concentration of free radicals in humus substances determines the degree of biochemical activity of high-molecular compounds. According to modern concepts, radical particles are intermediate participants in a stepwise redox reaction of polycondensation (Knyazev et al., 2009). Both the bioclimatic conditions of the formation of the soil layer and the anthropogenic load on natural ecosystems lead to a change in paramagnetic activity.

## 2. MATERIALS AND METHODS

The search and development of indicator parameters that allow monitoring the degree of transformation of ecosystems due to anthropogenic load is an important field of study. Agriculture is the main way of direct human impact on the ecosystem. Agricultural activity, for example, on rice lands leads to the accumulation of thermodynamically stable and inert high-molecular compounds in the arable horizon, which reduces the concentration of free radicals (Bolotin et al., 2020). In the course of the study, we evaluated the paramagnetic activity of meadow-chernozem soils by EPR spectroscopy. The involvement of soils in agriculture both in dryland conditions and in irrigated agriculture leads to the formation of humus substances with a high concentration of free radicals. A decrease in the concentration of thermodynamically stable radical compounds determines the nature of the distribution along the profile, namely, leaching from the arable horizon and accumulation in the sub-arable one. In this case, mineral fertilizers contribute to the accumulation of these compounds.

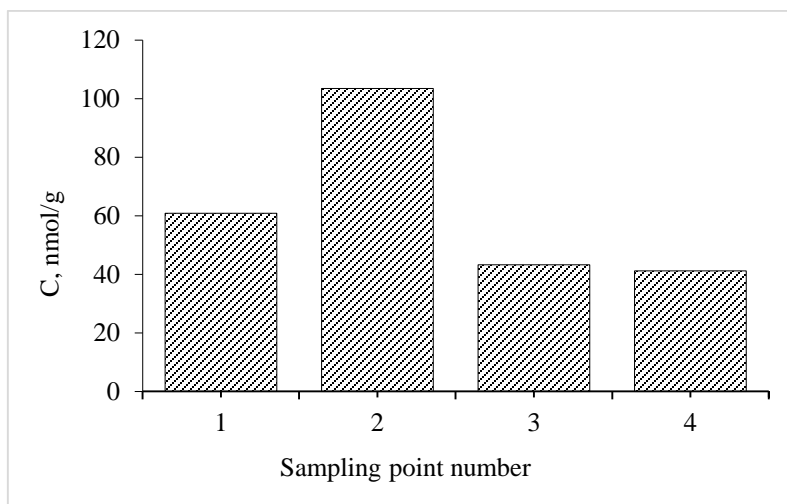
Paramagnetic particles in the humus layer are also influenced by other types of anthropogenic load, for example, recreational load (Neto et al., 1994). To assess the contribution of anthropogenic influence on humus substances, it is necessary to exclude the impact of abiotic factors. Some authors (Jia et al., 2017) have investigated the content of free radicals in humus matter in the soils of carbonization sites that are contaminated with polycyclic aromatic hydrocarbons. Samples were taken at different depths (0 to 30 cm). The influence of three different sources of pollution was analyzed, for which samples were taken at different distances from the polluting object (0 to 1,000 m). The influence of polynuclear aromatic hydrocarbons

(PAHs) and structural and functional components of the soil on the concentration of free radicals was also analyzed. Clay, iron ions, and PAHs contribute to the formation of free radicals, and organic substances, on the contrary, reduce the concentration of free radicals. The authors associate the continuous formation of free radicals with a high concentration of PAHs in the soils of carbonization sites, which largely determines the presence of relatively stable radical particles in these soils.

When studying the processes of soil formation, the issues of determining the role of the anthropogenic factor on the ecosystem come to the fore. When studying the transformation of soils, most of the works are devoted to the study of the influence of agriculture on the structural and functional properties of humus substances. The formation of the humus layer is significantly influenced by both forest litter and edifier species.

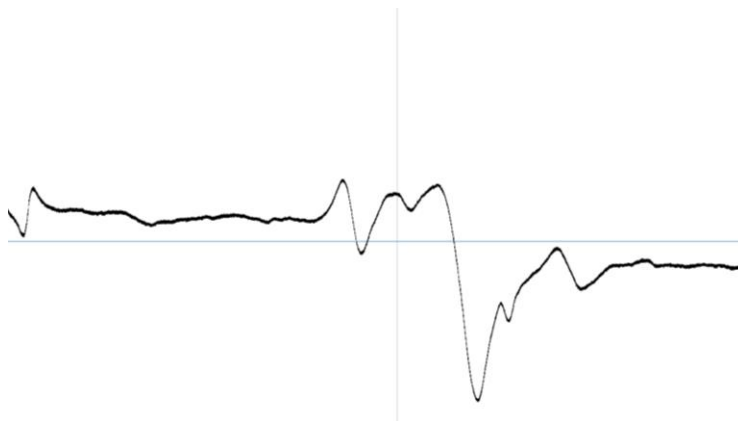
### 3. RESULTS AND DISCUSSION

Soil samples were taken on the territory of the Betta farm, in areas with a high recreational load. At each point, test sites with an area of  $10 \times 10 \text{ m}^2$  were established. Soil samples were taken by the envelope method at 5 points at a depth of 0-10 cm and an average sample was analyzed. The concentration of free radicals of humic acids was determined using EPR spectroscopy, and pH, phosphate anions, chloride anions, nitrate anions, sulfate anions, and iron ions were determined. In the study of the paramagnetic activity of soils, concentrations of free radicals were obtained (Figure 1).



**Figure 1.** Concentration of humus acid-free radicals

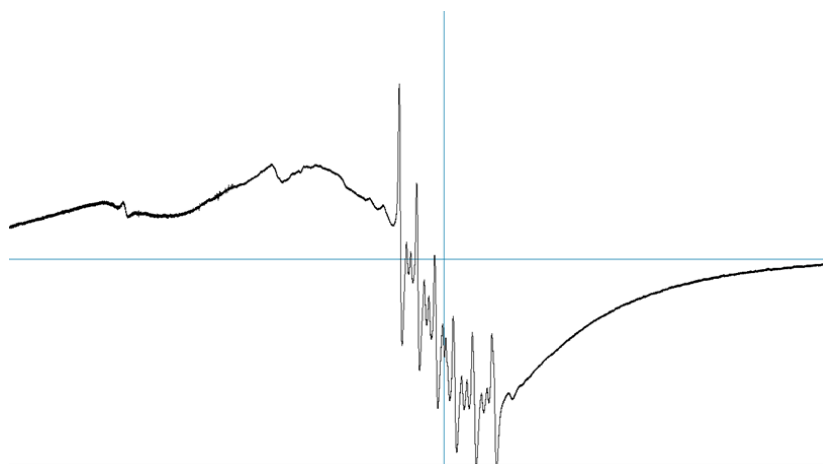
In the study of paramagnetic activity, general low values of the concentration of free radicals were noted, which indicates a high anthropogenic load on this territory. The highest paramagnetic activity was observed for the sampling point located on the tourist trail from the campsite to the beach (103 nmol/g). At this site, the recreational load consists only of the movement of tourists from the campsite to the beach, which ensures minimal anthropogenic load compared to other sampling points (Figure 2).



**Figure 2.** EPR spectrum for soil from point No. 1

The lowest paramagnetic activity of free radicals in soil samples was noted for points 3 and 4 (43 and 41 nmol/g), which were selected on the camping grounds at a distance of more than 100 m from the sea. The minimum value of the concentration of free radicals at these points is explained by the active anthropogenic pressure. The decrease in paramagnetic activity is explained by a change in the structural and functional characteristics of the organic matter of the soil. It is caused by soil compaction, the presence of unofficial toilets, and a large amount of anthropogenic garbage, which leads to the disruption of soil formation processes and, as a result, a decrease in fertility. Besides, a low concentration of free radicals was noted for the beach area (61 nmol/g), which is also associated with a large amount of anthropogenic debris and high anthropogenic pressure on the soil.

At point 5, soil samples were taken east of the central beach (unlike the previous four samples that had been taken west of the central beach). In the selected samples, a high concentration of manganese ions with spin  $5/2$  was noted, which does not allow for determining the concentration of free radicals (Figure 3).



**Figure 3.** EPR spectrum for soil from point No. 5

Thus, the greatest degree of transformation of the organic matter of the soil was noted at campsites. There is a high anthropogenic load on the soil layer, which leads to a decrease in fertility.

#### 4. CONCLUSION

Beach recreation within the organized beach areas, of course, by itself does not have a significant impact on the natural environment. However, it is combined with additional types of recreational services often provided illegally or with other types of unorganized recreational activities.

The accompanying recreational activities multiply the negative impact on the natural environment, especially in cases when recreational activities are carried out outside the boundaries of organized beach areas. This indicates that the use of natural complexes on the Black Sea coast of the Caucasus for recreational purposes requires special and great caution. They are extremely sensitive to anthropogenic disturbances and highly vulnerable. When organizing recreational activities, it is necessary to include in recreational areas elements of an ecological framework to maintain optimal functioning and the dynamic stability of the natural environment in this area, namely the avifauna, insects, and biodiversity. It is important during the intensive development of the Black Sea coast at present not to lose the natural landscapes and the features of natural complexes, not to destroy the vegetation cover and reduce its biodiversity, and not to strengthen the digressive processes that already take place in individual natural complexes.

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