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# Soil Pollution in the Azov Territories of Rostov-on-Don and Taganrog

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**ABSTRACT**
The research on the topic of the dissertation was carried out within the coastal (southern) part of the Azov oblique dissected accumulative-denudated plain and the coastal strip of the coast of the Sea of Azov, as well as the valleys of the lower reaches of the Don and Kalmius rivers. The research area covered the modern territory of Taganrog and Rostov-on-Don cities and a suburban area up to 15–20 km away from the borders of these cities. According to the materials of the USSR soil map, as well as modern schemes of soil zoning in Russia, the study area covers the distribution area of ordinary chernozems and partially southern low-humus chernozems on loess rocks. The main zonal soil studied was ordinary chernozem. Ordinary warm chernozems with a short freezing period, belonging to the Azov-Ciscaucasian province of powerful and super-powerful chernozems, predominate in the soil cover of the Azov inclined plain, extending from the Donets Ridge to the shores of the Sea of Azov and the lower Don River.

**Keywords:** soil, pollution, heavy metals, Azov.

## INTRODUCTION

The soil-producing rocks of these soils are mainly represented by carbonate loess-like clays and loams with a thickness of 6 to 50 m of fluvio-glacial, alluvial and alluvial-deluvial origin, containing from 4 to 17% $CaCO_3$. According to the granulometric composition, these soils belong to heavy powdery loams and light clays (the content of physical clay is 50-66%, silt-28–41%). The humus content in the upper horizon is 3.8–4.7 %, the actual acidity ranges from pH 7.2 to pH 8.0.

The structure of the profile of ordinary low-humus chornozem on loess rocks is illustrated in Figure 1 and the description given below. The section is located on the watershed plateau at a distance of 12 km to the north-east of the Taganrog city.

- At 0–25 cm-humus horizon, arable layer, dark gray, loose, compacted in the lower part, dusty-granular, abundantly permeated with plant roots.
- H 26–48 cm-humus horizon, pydor layer of the same color, slightly compacted, grainy. There are few molehills available, and the transition is gradual.
- Hp (k) 49–75 cm-transitional humus, brownish-gray, coarse-grained, few molehills, compacted. The transition is well defined.
- P(h)k 76–85 (90) cm-dark fawn carbonate loess, unevenly slightly humic, with wormholes, slightly compacted, gradual transition.
- Pk 86–180 cm and deeper-carbonate loess, inclusions of light clay, porous, fresh.

## MATERIALS AND METHODS

Soils of this type with undisturbed structure are distributed mainly in recreational areas, as well as on agricultural land around the studied cities.

However, according to our observations during the research, despite the overgrowth of the soil cover of urbanized territories, superficially transformed urban areas with minor mechanical disturbances in the profile are more common.

An example of such a soil can be the urban-chernozem loam (Fig. 2) in the area of the forest-park zone of the city, which has signs of mixing of humus-accumulative and transition horizons. The profile of this soil is described below:

- H 0–25 (45) cm – humus horizon, dark gray, loose, lumpy-grainy, profusely permeated with roots of woody vegetation, dry, uneven roughness, the transition is sometimes very clear, sometimes gradual.
- Hp (H)k 26–65 cm – humus transition, brownish-gray, with large areas of humus horizon material, coarse-grained, in the lower part there is a mole hole, weakly compacted in the undisturbed part, loose in inclusions of humus horizon material, fresh, the transition is well expressed.
- P (h)k 66–90 cm – pale-brown carbonate loess, unevenly humic in places, with wormholes, weakly compacted, grainy-rough, gradual and uniform transition.

In addition to zonal automorphic soils, the soils of varying degrees of hydromorphicity that

**Figure 1.** Profile of ordinary low-humus chernozem on loess rocks

**Figure 2.** Profile of low-humus urbanozem to forest-like loam

**Figure 3**. Natural landscape of salt lakes in the lowland part coastal territory of the Azov Sea region

were formed on alluvial and deluvial deposits of river backwaters and the coastal strip were studied.

The Taganrog coast is more than 20 km long and consists of washed-up sand and shell deposits, with a predominance of larger fractions in the basal part (the so – called "Near Spit") and smaller particle size deposits in the final part ("Far Spit"). In the low-lying coastal strip of the territory several kilometers wide, which passes into the spit, landscape complexes of salt lakes with very sparse vegetation are common, represented by willow, silver olive, common reed, succulents and halophytes (Fig. 3).

The salinity type is sodium chloride ($Cl^- >$ 2 mmol/l, $Na>^+ >$ 2 mmol/L). The soil cover of these landscapes consists of undeveloped sod soils of sandy, clay-sand and sandy loam granulometric composition of alluvial deposits, in combination with sands. The roughness of the profile of such primitive soils ranges from 5–7 cm to 15 cm, with the humus content in the upper part up to 0.7–1.0% and inclusions of charred lobules and shell fragments.

The genesis of these soils is due to the periodic deposition of alluvial sand and clay-sand material, and in the coastal zone – deposits. In this regard, the low-lying coastal part of the territory is characterized by a significant variety of soils. Thus, on alluvial sandbanks in the remote part, there are soddy underdeveloped soils (Fig. 4a), which have the following profile:

- H 0–15 (18) cm – humus horizon, gray-fawn color, homogeneous with isolated inclusions of charred wood residues and dilapidated shells, incoherent, moist, permeated with plant roots.
- P (h) 15 (18) – 27 cm-sandy deposits with some low-humus deposits spots, fawn and yellow-fawn color, not coherent, wet.
- Rgl-from 27 cm – clay alluvial sand, gray, slightly sticky, with a slightly pronounced, wet.

The alluvial deposits near saline lakes of the mainland contain alluvial meadow layered soils (Fig. 4b), the profile of which consists of the following horizons:

- Hd 0–4 cm – sod, dark gray, slightly lumpy, moisture, tightly permeated by plant roots, boils up from the surface, sandy loam.
- $Hp_{al}$ 4–34 cm – alluvial deposits with layers of silty dark gray and sandy (sandy loam) light yellowish-yellow washed material, not coherent, wet, clearly passes into
- $Rgl_{al,\ s}$ – from 34 cm – alluvial material, dark gray with a bluish tinge, with 40 cm submerged by ground water.

In the basal part of the coastal strip, from the abrasive line of loess deposits to the floodplain of the Don River, the soils are formed on alluvial-deluvial deposits of a heavier granulometric composition, which, combined with the close occurrence of subsurface waters, is favorable for dense grass and hydrophilic vegetation, including such rare ones as tarsa (*Stipa capillatae*), Leesing's carpet or feather grass (*Stipa lessingiana*), low almond (*Amygdaleta nanae*), and double-spined ephedra (*Ephedra distachya* l.) (Fig. 5).

**Figure 4**. Profile of sod soil (left) and aluvial meadow soil on saline (on the right)

**Figure 5.** Natural landscape of the floodplain. Don

The soil cover consists of alluvial meadow and meadow-marsh soils of light and medium loamy granulometric composition (Fig. 6), which pass into alluvial sod soils on deluvial deposits with a well-humified profile with a roughness of 50 cm or more.

In contrast to the alluvial soils of the riverbed part of the floodplain and salt lakes of the former river oxbow lakes, these soils do not have such boreholes, although they are mostly covered in the lower part of the profile. The profile of one of them – alluvial meadow-marsh mid-loamy soil is given below:

**Figure 6.** Profile of aluvial meadow-marsh soil in a river floodplain

- Nd (t) 0–6 cm – sod, dark gray, lumpy-grainy, slightly torn off, fresh, densely permeated with plant roots, boils up from the surface, sandy loam.
- H (t)s 6–37 cm – humus horizon is slightly torn off, dark gray with a bluish tinge in the lower part, grainy-dry chestnut, medium loam, moist, during drying there are individual salt discolorations, abundantly permeated with small roots.
- $Hp_{gl,\,s}$ 37–58 cm – transition horizon, grayish-brown with numerous salt deposits during drying, with signs of caking.
- $Rgl_s$ – from 58 cm – clay alluvial material of loamy granulometric composition, brownish-bluish, with 65 cm submerged by ground water.

The city of Rostov-on-Don is one of the largest industrial centers of Russia, which has specialized in the metallurgical industry since the end of the 18th century.

In order to obtain representative samples, the key-analog method was used, and the locations of the test sites were linked to the sites of the basic survey of the soil cover of these cities conducted in 2002–2003.

The studies of urban soils were carried out behind an uneven network, the density of which was determined by the necessary detail of studying the internal structure of technogenic areas and the functional significance of the territory.

In order to obtain a representative, the method of mixed samples taken from test sites that had an area of at least 2500 $m^2$ was used for runt material. The configuration of the test sites was determined by the terrain and layout features of the urban area. On recreational land and outside the city, the combined sample consisted of 10–12 individual samples, and in rural and industrial areas – 18–20 samples. The depth of soil sampling at the test sites was 0–20 cm runt sections that were laid on separate sites, the soil samples were taken from the depths of 0–20, 20–50(48), 50(48) – 70(75) and 70(75) – 100 cm, which corresponded to the roughness of the humus-accumulative and transition horizon of the background common chernozem. The soil sampling technique met the requirements of GOST 17.4.3.01-83 and GOST 17.4.4.02-84. The total sample weight was about 2 kg.

The soil samples were stripped of impurities, crushed, sifted through a sieve with pores 1 mm in diameter, distributed in a thin layer on a sheet of paper or tracing paper in the form of a square or rectangle, and divided into 4 parts. Two opposite parts of the soil were piled in one pile, repeating this operation until the weight of the soil sample was 100 g.

In the case of the presence of grassy vegetation on the test site, the samples of its aboveground part were taken, cutting at a height of 3–5 cm from the surface.

For prompt measures to prevent man-made pollution, regular bioindicational studies are needed that can characterize the composition of atmotechnogenic emissions to the earth's surface, clarify the localization of cities that are most intensively polluted, assess the quality of plant products that are grown on private development lands, and so on. As noted by scientist, the research on the content of heavy metals in vegetation can be useful for planning the placement of agricultural land around industrial facilities and determining areas where there should be restrictions on cultivation agricultural products [13].

For this purpose, the authors suggest monitoring the accumulation of heavy metals in terrestrial vegetation by selecting annual and perennial grasses, which grow almost everywhere, as indicators of atmotechnogenic inputs.

It is known that the absorption of heavy metals from the soil and atmosphere is characterized by certain species specificity. In particular, for the grasses, clear species differences were established between the accumulation and changes in morphological parameters under the influence of heavy metals for the red fescue *Festuca rubra* L. and the perennial chaff *Lolium perenne* L. [9]. Therefore, the results obtained for bioindicational studies only approximately reflect soil contamination. In the performed studies, the authors preferred creeping wheatgrass as one of the most common types of cereals, which should reduce the influence of species diversity on the results of bioindication. At the same time, the proven fact that for the creeping wheatgrass *Elitrigia repens* L. the accumulation of heavy metals is dominated by the aeric, rather than the soil component, was taken into account [13]. If the monitoring task is to reflect the relationship between the accumulation of heavy metals in soil and plants, then preference should be given to other species that have the highest values of the relative accumulation coefficient of elements. Such species are: dandelion *Taraxacum officinale* Wigg. – for Mn, Fe, Pb, Ni, Cr, wormwood *Artemisia vulg* for aris L. – for Mn, Fe, Cu, Ni, Cr, Ti, plantain medium *Plantago media* L. – for Cu, Zn, Mo, Ni, Cr, Ti, Pb, common knotweed *Polygonum aviculare* L. – for Mn, Cu, Mo, Pb [12].

An important aspect of bioindicational studies to monitor soil contamination is the period of plant sampling. As L.M. Bortnik notes, if during the period of active growth, the accumulation of heavy metals in tissues lags behind the increase in phytomass, then at the end of the growing season, pollution per unit mass is the largest [13]. Therefore, to characterize the arrival of heavy metals on the Earth's surface, it is better to take plant samples starting from the second half of summer.

The results of measurements of the heavy metal content in the dry matter of the aboveground mass of plants are shown in Table 1. Since in the vast majority of cases it was hay that was practically dried up on the root, the maximum permissible levels in coarse and juicy feed for farm animals were used to evaluate the data obtained [14].

According to the data presented, the level of accumulation of cadmium, cobalt, copper, iron, manganese, nickel, lead and zinc in grassy vegetation at the observation sites in Rostov-on-Don is significantly higher than in Taganrog. This is another evidence of a gradual increase in technogenic contamination of the soil cover, which will eventually become noticeable according to the results of chemical and analytical monitoring. For the average geometric values, which reduce the impact of abnormally high indicators in certain areas, lead, copper, cadmium and cobalt are 5.2–5.5 times higher, zinc – four times higher, iron and manganese – 2.4–2.8 times higher. The content of heavy metals in many plant samples significantly exceeded the maximum permissible values, which excludes the use of herbal products for fattening animals.

**Table 1**. Heavy metal content in cereal plants on the territory of monitoring sites

| Map items | Indicators | Element content. mg/kg of dry matter | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cd | Co | Cr | Cu | Fe | Mn | Ni | Pb | Zn |
| Taganrog | oscillation limits | 0.050,5 | 0.07-0.47 | 1.2-37.0 | 0.3-4.1 | 32.5255 | 12.0-80.0 | 0.35-10.7 | 0.5-3.7 | 4.2-50.0 |
| | arithmetic mean | 0.1 | 0.30 | 3.9 | 1.6 | 138 | 42.9 | 1.76 | 1.3 | 12.5 |
| | geometric mean | 0.07 | 0.25 | 4.8 | 1.3 | 111 | 36.8 | 1.04 | 1.2 | 10.4 |
| Rostov-on-Don | oscillation limits | 0.010,8 | 0.052,2 | 1.5-13.0 | 1.1-45.0 | 180-800 | 27.5100 | 0.7-5.8 | 0.625 | 4.8-330 |
| | arithmetic mean | 0.37 | 1.46 | 4.3 | 14.6 | 325 | 73.7 | 3.15 | 6.8 | 64.7 |
| | geometric mean | 0.35 | 1.37 | 3.7 | 7.2 | 270 | 68.8 | 2.98 | 6.3 | 40.2 |
| Maximum allowed level [10] | | 0.3 | 1.0 | 0.5 | 30.0 | 100.0 | - | 3.0 | 5.0 | 50.0 |

Thus, the observations of the content of heavy metals in grassy vegetation growing at monitoring sites confirm the feasibility of conducting regular bioindication in order to quickly predict the trends in the development of technogenic soil pollution processes. The combination of soil and plant diagnostics of pollution will contribute to a more objective monitoring of urbanized areas and the adoption of timely measures

## CONCLUSIONS

The regional specificity of the microelement composition of soils on the territory of the Azov Plain is due to the carbonate profile and weakly alkaline reaction of the medium, on the one hand, and the natural agitation of coastal geochemical landscapes and the influence of technogenic heavy metal emissions, on the other. For automorphic soils on loess deposits of the Azov region, the background content of mobile forms of heavy metals (mg/kg) was established: Zn – 0.81±0.11, Cd – 0.19±0.02, Ni – 1.48±0.59, Co – 1.37±0.23, Fe – 2.53±0.31, Mn – 10.7±3.8, Pb – 1.87±0.72, Cu-0.45±0.13. Mobile and potentially accessible forms of heavy metals are observed in the upper part of the profile, as well as in the horizons of carbonate accumulation.

In the structure of the soil cover of the elevated part, ordinary low-humus chernozems predominate in combination with weakly saline varieties, which are able to accumulate a significant amount of heavy metals in the profile. In the low-lying part, poorly developed sod soils of sandy, clay-sand and sandy loam composition predominate in combination with weak humus sands, in which the content of heavy metals is low due to the tendency to “dump” them into the ground water already due to weak contamination. For this, priority protection from man-made pollution is required. It was revealed that the statistical distribution of heavy metal content in the soils of the study area differs from normal and is mostly lognormal in nature, which is caused by technogenic anomalies. In order to characterize the level of technogenic pollution in urban areas, it is proposed to calculate the urbanized background as the geometric mean value of the content of mobile forms of heavy metals in the upper soil layer. For the soils of Rostov-on-Don, the urbanized background of mobile forms of heavy metals are (mg/kg): Zn – 5.2, Cd – 0.28, Ni – 2.50, Co – 2.08, Fe – 5.5, Mn – 23.1, Pb – 8.7, Cu – 0,77, and Cr – 0,71. For the soils of Taganrog, urbanized background of mobile forms of heavy metals are equal to (mg/kg): Zn – 3.3, Cd – 0.12, Ni – 0.91, Co – 1.04, Fe – 2.2, Mn – 16.7, Pb – 4.5, Cu – 0.62, and Cr – 0.85.

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