

**SOIL ANALYSIS: MODERN METHODS AND THEIR IMPORTANCE FOR
AGRICULTURE AND ECOLOGY**

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Introduction

Soil is a complex multicomponent system that ensures the circulation of matter and energy in the biosphere. It performs a number of critical functions: it serves as a habitat for plants and microorganisms, is a source of nutrients, regulates water balance, and acts as a filter and buffer against anthropogenic pollutants [1].

With the growing global population and increasing demand for agricultural products, the issue of rational use of soil resources is becoming increasingly pressing. At the same time, the pressure on soils is increasing due to the use of mineral fertilizers, crop protection products, intensive mechanical cultivation, and industrial pollution [2]. All this leads to land degradation, decreased fertility, and a deterioration of the environmental situation.

Assessing the condition of the soil cover requires a comprehensive analysis, including the study of its physical, chemical, and biological properties. Of particular importance is monitoring the content of organic matter, macro- and microelements, as well as pollutants such as heavy metals, pesticides, and petroleum products [3].

Modern science has a wide range of soil analysis methods at its disposal: from traditional laboratory methods (titrimetry, photometry, gravimetry) to modern instrumental methods (atomic absorption spectroscopy, inductively coupled plasma mass spectrometry, X-ray fluorescence analysis, infrared spectroscopy) [4].

Thus, the relevance of this study is determined by the need for a comprehensive characterization of soils in the context of agricultural intensification and increasing anthropogenic load.



The aim of this study is to systematize soil analysis methods and identify their significance for agriculture and environmental monitoring.

Study objectives:

1. To review physical methods of soil analysis.
2. To characterize chemical and agrochemical research methods.
3. To analyze the capabilities of modern instrumental technologies.
4. To evaluate the practical significance of the obtained data for agriculture and environmental protection.

Methods

Soil science uses a wide range of methods, which can be divided into physical, chemical, and instrumental (instrumental).

1. Physical methods of soil analysis.

Physical properties determine the water, air, and thermal conditions of the soil, which determine its fertility.

Main methods:

- Granulometric analysis – determines the content of mechanical fractions (sand, dust, clay). The Kaczynski method (with a pipette) and laser diffraction are used.
- Determination of density and porosity – carried out using the cylinder method or pycnometry. These indicators characterize aeration and the ability of the soil to retain moisture.
- Water capacity and permeability – measured by filtration and using the thermostat-weight method.

2. Chemical methods of soil analysis.

These methods allow us to determine the chemical composition and nutrient content.

- Determination of acidity (pH) – carried out potentiometrically (using a pH meter). - Humus content is determined by the Tyurin method (oxidation of organic matter with potassium dichromate in the presence of sulfuric acid).
- Nitrogen is determined by the Kjeldahl method (mineralization of organic matter followed by titration).



- Phosphorus and potassium are determined by colorimetric and photometric methods.
- Cation exchange capacity is determined by ammonium or calcium displacement.

3. Instrumental (instrumental) methods.

In recent decades, highly sensitive analytical methods have become increasingly important:

- Atomic absorption spectroscopy (AAS) – determination of metal content (Zn, Cu, Pb, Cd, Fe, etc.) at the ppm level.
- Inductively coupled plasma mass spectrometry (ICP-MS) – allows the detection of elements in ultra-low concentrations (ppb).
- X-ray fluorescence analysis (XRF) – rapid, non-destructive assessment of elemental composition.
- Infrared spectroscopy (FTIR) – used to analyze organic matter and humic compounds.
- Gas and liquid chromatography – used to determine pesticides, petroleum products, and organic pollutants.

Results

Based on the analysis of literature data, the following patterns can be identified:

- Soils vary in acidity: from acidic (pH 4.5–5.5) in podzolic zones to neutral and alkaline (pH 7.5–8.5) in steppe regions.
- Humus content varies from 1–2% in poor soils to 10–12% in chernozems.
- Heavy metal pollution (Pb, Cd, Hg) is most often observed near industrial facilities and highways. Modern analytical methods (ICP-MS, XRF, spectroscopy) enable the detection of elements at the ppm and ppb levels, significantly improving the accuracy of environmental monitoring [5].

Discussion

The results obtained confirm that soil analysis is a vital tool for assessing soil condition and fertility. Classical methods (titrimetric, photometric) remain in demand; however, they are inferior in sensitivity and speed to modern instrumental technologies.

Modern methods, such as spectroscopy and chromatography, enable environmental monitoring and the detection of contamination by toxic elements and compounds, which is especially relevant in the context of increasing anthropogenic load.

In agriculture, regular soil analysis is essential for developing fertilization systems, forecasting yields, and preventing land degradation [6].



Conclusion

1. Soil analysis is the basis for rational land management, environmental monitoring, and food security.
2. Classical methods enable the assessment of key agrochemical parameters, while modern instrumental technologies provide high accuracy and the ability to detect contaminants in trace amounts.
3. Integrated application of traditional and innovative soil analysis methods is essential for sustainable agriculture and environmental protection.

References

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