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DETECTION OF HEAVY METALS IN SOIL TO DETERMINE PHOSPHORUS AND POTASSIUM LEVELS

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Summary. The presence of heavy metals in the soil can significantly affect the formation of available levels of the main macronutrients, in particular, phosphorus and potassium. This dependence is used in modern technologies for determining the content of phosphorus and potassium in soils, for example, based on the rapid determination of gamma irradiation of K40, U238, Th232, Cs237. These interactions are influenced by several factors, including soil properties, heavy metal concentrations, and plant species. Understanding these interactions is essential for effective soil management, environmental protection, and increasing the productivity of agrophytocenoses. The use of these technologies enables the development of highly sensitive methods for rapid assessment of phosphorus and potassium in soils and for regular soil monitoring to mitigate the negative effects of heavy metals in agrophytocenoses and to ensure balanced nutrient availability for plants.

Keywords: heavy metals, phosphorus, potassium, cultivation technologies.

One of the current threats is the contamination of ecosystems and their components with heavy metals (HMs). HMs are characterized by high toxicity, mobility and bioaccumulation capacity [1-3]. The HMs group is usually represented by transition elements, metalloids, and lanthanide actinides, which are toxic even in minimal concentrations [4]. Of all the inorganic elements found in nature, 53 are classified as HMs. Beyond the "classical" understanding of the toxic effects of HMs [5, 6], their content in soils can affect the formation of phosphorus and potassium pools available to plants. The study of these interactions is important for the management of soil fertility, ecosystem stability and crop production in general. As for the mechanisms that can be implemented in the implementation of these technologies, they can be described as follows.

HMs such as lead (Pb), cadmium (Cd) and zinc (Zn) can form insoluble complexes with phosphate in the soil, resulting in phosphorus fixation and reduced availability to plants. These complexes can precipitate out of the soil solution, making phosphorus less available for plant uptake.

Soil pH affects the solubility of both phosphorus and HMs. In acidic soils, HMs tend to be more soluble, which can increase their interaction with phosphorus and reduce phosphorus availability. In alkaline soils, phosphorus tends to precipitate with calcium, which can also be affected by the presence of HMs.

HMs can compete with phosphorus for adsorption sites on soil particles. For example, high concentrations of HMs can displace phosphorus from adsorption sites, resulting in increased phosphorus leaching and a corresponding decrease in phosphorus availability to plants.

Potassium availability is influenced by the cation exchange capacity of the soil. HMs such as copper (Cu), nickel (Ni) and cadmium (Cd) can compete with potassium for exchange sites on soil

colloids, with a corresponding decrease in the concentration of exchangeable potassium available for plant uptake.

HMs contamination can affect soil structure and lead to soil compaction, which can affect the availability and movement of potassium in the soil. Compacted soils can inhibit root growth and limit plant access to potassium.

Certain HMs can have an antagonistic effect on potassium uptake. For example, excess zinc (Zn) or copper (Cu) can interfere with plant uptake of potassium, resulting in a potassium deficiency even if the soil has adequate potassium.

The presence of HMs in the soil can have both synergistic and antagonistic effects on the availability and uptake of phosphorus and potassium. The specific manifestations of the interaction depend on the types and concentrations of HMs, soil properties, and plant species.

HMs contamination can cause nutrient imbalances in plants. For example, reduced availability of phosphorus and potassium can affect plant growth, development, and stress tolerance. Plants may also alter their nutrient uptake patterns in response to HMs stress, further complicating the relationship between HMs and soil nutrient levels.

Plants have evolved numerous mechanisms to detoxify HMs and mitigate their effects on nutrient uptake. For example, plants can produce chelating substances such as phytochelatins and organic acids that can bind HMs and reduce their toxicity. These mechanisms can also affect the availability and mobility of phosphorus and potassium in the soil.

The use of organic fertilizers, such as lime and phosphate fertilizers, can help mitigate the negative effects of HMs on the availability of phosphorus and potassium. Organic matter can improve soil structure, increase cation exchange capacity, and enhance the binding of HMs, reducing their availability and toxicity.

The use of plants capable of accumulating HMs (hyperaccumulators) can help remediate contaminated soils and reduce the negative impact on phosphorus and potassium availability. These plants can absorb HMs and store them in their tissues, thereby reducing the concentration of HMs in the soil.

Regular soil testing and monitoring can help assess the levels of HMs, phosphorus and potassium in the soil. This information can be used to make informed decisions about soil management practices, fertilization, and remediation strategies based on the indirect determination of phosphorus and potassium in soils. For example, it is possible to determine potassium content by detecting a range of HMs, uranium-238, etc. Uranium-238 (U-238) is a naturally occurring radioactive isotope of uranium. The relationship between U-238 and potassium content in soil can be considered from geological, geochemical and environmental points of view. Soils formed by granite and other igneous rocks often contain high levels of uranium and potassium. These rocks typically contain minerals such as feldspar, mica, and other potassium minerals, as well as uranium minerals such as uraninite. Uranium may also be associated with phosphate minerals in sedimentary rocks. These phosphate deposits can also contain significant amounts of potassium. Both uranium and potassium can be mobilized under similar geochemical conditions. For example, in oxidizing environments, uranium can form soluble uranyl complexes that can be transported by groundwater. Potassium, as a soluble ion, is also easily mobilized under such conditions. Clay minerals in the soil, which often have a high cation exchange capacity, can adsorb both uranium and potassium. Therefore, the presence of clay minerals may correlate with increased levels of both elements. The composition of the soil parent material is a factor that determines the concentration of both uranium and potassium. Soils formed from uranium-rich rocks will naturally have higher uranium levels, which may also correlate with potassium levels if the parent rock is rich in potassium-containing minerals. Soil pH can affect the mobility and availability of both uranium and potassium. Acidic soils can increase uranium availability, while neutral or slightly alkaline conditions can increase potassium availability. Reducing conditions in the soil can cause uranium to precipitate as insoluble minerals, while oxidizing conditions can mobilize uranium. Potassium, as the major cation, is less dependent on redox conditions, but its availability can be affected by soil moisture and other factors that also affect uranium mobility. Phosphate fertilizers, often derived from phosphorites, may

contain detectable amounts of uranium. The use of these fertilizers can result in uranium leaching into agricultural soils. These fertilizers may also contain potassium, which contributes to the direct relationship between uranium and potassium in fertilized soils. Uranium mining and processing can result in elevated uranium levels in nearby soils. Potassium levels can also be altered if potassium-containing minerals are present in the mined materials. Industrial activities, including coal combustion and metal processing, can result in the release of both uranium and potassium into the environment, potentially leading to a correlation between their concentrations in soil. Thus, the correlation between U-238 and potassium in soils is influenced by several factors, including the geological origin of the soil, geochemical behavior, environmental conditions, and human activities.

For example, the presence of HMs in soil can significantly affect the availability and uptake of essential nutrients such as phosphorus and potassium. These interactions are complex and depend on a variety of factors, including soil properties, HMs concentrations and plant species. Understanding these relationships is critical for effective soil management, crop production and environmental protection. Appropriate soil amendments, phytoremediation methods and regular soil monitoring can help mitigate the negative effects of HMs and ensure balanced nutrient availability for plant growth and development. The dependencies described above are used in modern technologies for determining the content of phosphorus and potassium in soils, for example, based on the rapid determination of gamma irradiation of K40, U238, Th232, Cs237 and calibration of the results according to the data of classical laboratory studies of agrochemical soil diagnostics allows to achieve high resolution for determining phosphorus, potassium, etc. and to manage the parameters of field productivity zones and potential soil fertility [https://www.syngenta.com/en/innovation-agriculture/interra-scan].

This approach can produce high-resolution cenosis maps with up to 27 layers of information for grain producers. The use of gamma detection data provides high-resolution mapping of nutrient content, pH, soil texture, organic matter, carbon and cation exchange, as well as elevation and water available to plants. The importance of this approach is that it is unaffected by soil moisture, compaction, vegetation cover, tillage, etc. This approach determines the organic and active carbon in the soil. This makes it possible to adapt farming systems with corresponding long-term benefits for soil fertility. Fertile soils can not only improve food production, but also mitigate climate change. They play an important role as natural carbon sinks.

Other approaches use satellite-based methods and algorithms to quantify changes in soil carbon and other nutrients, or intensive sampling methods to minimize measurement error. Each of these methods still requires significant time and money for laboratory soil analysis [7].

Conclusions

The content of HMs in soils can influence the formation of phosphorus and potassium pools available to plants. This dependence is used in modern technologies for determining the content of phosphorus and potassium in soils, for example, based on the rapid determination of gamma irradiation of K40, U238, Th232, Cs237 and calibration of the results based on the data of classical laboratory studies of agrochemical soil diagnostics, which allows high resolution in determining phosphorus, potassium, etc. and managing the parameters of field productivity zones and potential soil fertility.

The study of these interactions is important for the management of soil fertility, ecosystem stability and crop production in general. Understanding these relationships requires comprehensive soil sampling and analysis, taking into account both natural and anthropogenic influences. By studying the relationship between HMs and micronutrients such as phosphorus and potassium in soils, we can gain insight into soil formation processes, nutrient availability, potential environmental impacts, and create agrophytocenoses with high levels of productivity.

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