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**Anthropogenic and Genetic Conditions for the Formation of Phosphate Mobility Indicators in Individual Structural Fractions of Podzolized Chernozem**

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**Abstract**. The genetic and anthropogenic conditions for the formation of indicators of phosphate regime of podzolized chernozem are analyzed. The silt content in separate structural fractions of the soil under study is examined and the dependence of the formation of the structural state on the content of the silt fraction and the method of use is determined. The nature of the change in the degree of phosphate mobility, depending on the agronomically valuable structure, as one of the main indicators of the availability of phosphorus to plants is evaluated. The content of mobile phosphorus in separate structural fractions was monitored and its redistribution was characterized depending on the content of silt fraction. The parameters of soil buffer capacity with respect to phosphorus are established as a property of the soil to maintain the phosphorus concentration at a constant level.

**Keywords**  mobile phosphorus, degree of mobility of phosphates, structural fractions, podzolized chernozem, silt content.

**Introduction**

Modern intensive and energy-consuming system of agriculture with a negative balance of organic and mineral components of fertility has led to a moderate weakening of the material-energy exchange in agroecosystems, and as a consequence, a decrease in the ecological stability of arable land, which is accompanied by a loss of water, agronomic balance substances, including mobile phosphorus and increasing the acidity of the soil environment. It should be noted that the physical, chemical, agrophysical and humus conditions of soils of forest-steppe agro-landscapes are interconnected and interdependent. The negative balance of humus and calcium under modern agrocoenosis is one of the reasons for the deterioration of the agrophysical components of the fertility of forest-steppe chernozems. The loss of humus and calcium has a negative impact on the number of water-resistant structural units, since their formation requires the presence of organo-mineral colloids – calcium humates, which serve as a waterproof material for the formation of primary granulometric particles and aggregates of agronomically valuable macrostructure with a size of more than 0.25mm.

Soil nutrient reserves are one of the factors that characterize their potential fertility, and, with a certain interaction of physico-chemical, physical and other conditions, provide the plants with necessary nutrients. There is a regular connection between the gross nutrient content and the mobile forms of their compounds. The phosphate regime of soils has a significant effect on the manifestation of fertility and fertilizer efficiency. Phosphorus, as a biophile element, plays an important role in the exchange processes between soil and plant. It participates in all vital functions of plants and ensures efficient use of other nutrients. In its chemical properties, phosphorus has a complex nature of interaction with different soil components, which determines the large number of different forms, reactions, compounds and complexes in which it can be in soil (Tsvyk 2014).

The predominance of small clay particles, humic acids and mobile calcium in the black soil creates the prerequisites for the formation of optimal water-physical and air-physical properties. Chernozems are characterized by mechanical stability and water resistance structure, good percentage of voids and aeration, favorable technological properties, but their irrational agricultural use is of great concern. Plowing and a long process of agricultural use have changed the structure, composition and properties of the soil, thereby disrupting the normal flow of energy, reducing the level of humus recovery and release of biophilic elements. There was a loss of structure and self-packing of the soil mass. Heavy agricultural tools exacerbate this process, especially on waterlogged soils. Chernozems lose chemically bound energy in humus, aggregation, and void space, which are important for preserving fertility. The soil structure is intensely deteriorating, manifesting itself in the increase in lumpiness (Pozniak 2016; Papish 2016). Extensive, irrational use, non-observance of crop rotation, reduction of areas of perennial grasses, insufficient application of organic fertilizers, etc. significantly influences the intensity of degradation of chernozem. Over the last decades, chernozem has lost the amount of absorbed calcium by 26-37%, water resistant units (larger than 0.25 mm) - by 33%, mineral nitrogen - by 34-40%, soluble phosphates - by 39-40% , exchange potassium - by 22-24% (Nosko 2006). The structural state of chernozem soils is poorly studied. The influence of the structural state on the phosphate regime of chernozem soils requires a deeper study as well. The phosphate regime of the soil depends primarily on the parent rock, the degree of its weathering and the nature of the soil-forming process. One of the most common patterns of dependence of the phosphate regime on the soil-forming process is the close connection between gross phosphorus and its profile distribution with the content of organic matter, as well as the content of silt fraction (Tsvyk and Smaha 2011).

**Materials and Methods**

Humus horizons of podzolized chernozem with different uses were investigated. Soil samples were taken on arable land, pasture (not cultivated), perennial grasses and in the forest.

The purpose of the research was to establish the dependence of the change of the parameters of the phosphate state on the macrostructure and granulometric composition of the upper genetic horizons of podzolized chernozem of different agricultural use.

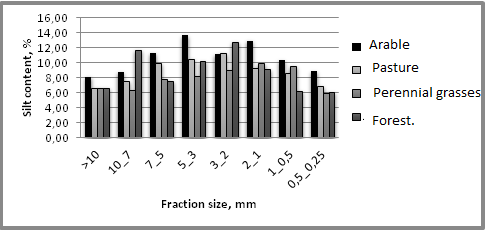
The objectives were solved by field and camera methods of research. Typical sites were selected in the study areas for soil sampling in the areas of forest, perennial grasses, pastures and arable land. In soil samples for laboratory testing, the following aspects were determined in three time’s analytical repeatability: The content of mobile phosphorus by the Kirsanov method. The method is based on the extraction of phosphorus compounds (P2O5) with a solution of hydrochloric acid molar concentration (HCl) = 0.2 n with a ratio of soil to a solution of 1:5 – for organic horizons and the subsequent determination of phosphorus in the form of blue phosphorus-molybdenum complex on a photoelectric colorimeter. The degree of mobility of soil phosphates by the Karpinsky and Zamyatin and Scofield methods. The methods are based on the displacement of phosphates 0.03 n. with K2SO4 solution and 0.01M CaCl2 solution at a soil ratio of 1:5. In the extraction, phosphorus is determined by the photometric method. By the concentration of P2O5, in milligrams per 100g of soil, we conclude on the degree of mobility of soil phosphates. The potential phosphorus buffer capacity was calculated. Granulometric analysis of soil. The method is based on the separation of different size granulometric fractions from the soil. Each fraction is withdrawn from the suspension at a specific time interval after agitation. The sampling time is calculated by the rate of sedimentation of solids in water by Stokes law.

**Results аnd Discussion**

The granulometric composition of the soil (hereinafter referred to as the granular composition) is important in pedogenesis, in the formation of soil fertility. The water, thermal, air, general physical and physical-mechanical properties of the soil depend on it. The mechanical composition of the soil determines the redox conditions, the magnitude of the absorption capacity, the redistribution in the soil of the ash elements, the accumulation of humus, etc.

The intensity of many soil-forming processes depends on the granular composition: on sandy rocks, it is insignificant, on loamy rocks it is quite high. The conditions of phytocenosis rooting and the number of burrowers, as well as the method of cultivation of the soil, terms of fieldwork, rates of fertilizers, placement of crops depend on the granular composition. For example, light (sandy and sabulous) soils are easy to cultivate, warm quickly, have good water permeability and air regime, but are low in moisture, poor in humus and nutrients, have little absorption capacity, are susceptible to wind erosion. Heavy (heavy loamy and clayey) soils have high connectivity and moisture capacity, better provided with nutrients and humus. Unstructured heavy soils have unfavorable physical and chemical properties: poor water permeability, ability to bloat and form a crust, high density.

One of the most important fractions of the particle size distribution is silt. When analyzing the results of particle size distribution, it can be stated that the content of silt fraction predominates mainly in arable land, in separate soil fractions in the grassland and perennial grasslands (Fig. 1).



**Fig. 1.**The content of silt in the surface horizon of podzolized chernozem different lands in individual structural fractions

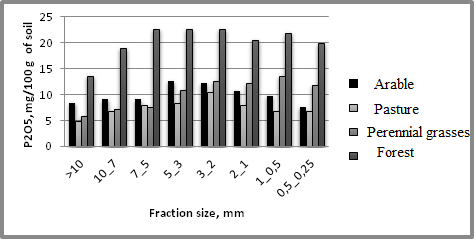
The most significant fluctuations in the lands are affected by average fractions of 7-0.5 mm. It is in these structural units that the highest average values ​​of silt content are documented. The redistribution of the silt content across all groups of fractions is clearly visible. Therefore, in the soil samples studied, there is a dependence of the formation of the structural state on the content of the silt fraction and the method of use, which may be reflected in the formation of the phosphate regime and the fertility of the soil as a whole.

**Contents of mobile phosphorus.** Gross phosphorus reserves in the arable layer are relatively high. They vary in soils of different genetic types less significantly compared to nitrogen reserves. In the humus horizon, its number is always greater than in the lower lying and the parent rock, due to the processes of biological transfer. The total phosphorus content of soils increases in proportion to the increase in fertility. The content of mobile phosphorus in the soil also changes.

Under the influence of agricultural use of soils, the dynamic equilibrium established in natural biocenosis and, first of all, in the biogeochemical cycle of substances is disturbed. When plowing soils, the phosphate equilibrium is disturbed due to changes in the physicochemical, water-physical and other properties, as well as the phosphorus balance in the soils.

The mobility of phosphorus and its absorption by plants is regulated by the nature of the equilibrium of phosphates between the liquid and solid phases of the soil. Phosphate exchange between all phases is ongoing in the soil. In order to evaluate the ability of soil to provide plants with phosphates, in addition to the content of mobile phosphorus, it is necessary to know the rate of equilibrium of phosphates in soil solution.

At the heart of modern ideas about the phosphate state of arable soils are the allegations of the close dependence of the natural content of potentially studied plant compounds of phosphorus on the soil type. This may be due to the increased content of silt fraction in these groups of structural units. The phosphorus of the primary minerals released during the weathering process is first combined with the silt fraction. Therefore, the content of its moving forms in this fraction is much higher (Fig. 2).

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**Fig.2**The content of mobile phosphorus in the surface horizon of podzolized chernozems of different lands in separate structural fractions

The pattern of mobile phosphorus content in the soil samples studied is slightly different from the parameters analyzed above. Almost all lands have seen an increase in smaller fractions.

The process of formation of water-resistant aggregates proceeds under the influence of soil colloids, which in the form of sol are able to move through soil cracks, to impregnate lumps, and then, coagulating, to pass into irreversible soil gels. Lumps glued with irreversible gels do not disintegrate under the action of water and become waterproof. The fact that colloids move in the soil and coagulate, is evidenced by shiny, varnished crusts formed on the faces of soil aggregates to a depth of 80-120 cm or more. Under other conditions, the water resistance of the lumps depends on the amount of organic matter and the mechanical composition of the soil. With a large amount of formation of humic acids and their salts, the aggregates are the strongest. In clay soils, they are also larger and more durable than in loamy ones, and even more so in sandy ones. Sandy soils are usually unstructured, have a vaguely pronounced fragile structure. Therefore, the more dispersed particles (silt, clay, colloids) in the soil, the stronger the structural aggregates of the soil.

The content of mobile phosphorus in the soil under study is characterized as average. This indicator is significantly affected by the way in which podzolized chernozem is used. The highest was the content of mobile phosphorus in the forest (19-23 mg/100 g soil). The natural content of mobile phosphates in the plowed soil of intensively used soils can range from very low to high values, but under the influence of agricultural use of soils the dynamic equilibrium formed in natural biocenoses is disturbed in the biogeochemical cycle of substances. The content of mobile phosphorus is also affected. The annual removal of crop nutrients leads to a change in this indicator on arable land. The slightly higher content of mobile phosphorus is found in the grass of perennial grasses. This is primarily due to the type of vegetation and the decrease in acidity of the humus horizon as a result of fertilizer application, which reduces the retrogradation of phosphorus.

Significant redistribution of mobile phosphorus by the fractions of structural units was also noted. This may be due to the increased content of silt fraction in these groups of aggregates. The phosphorus of the primary minerals released during the weathering process is first combined with the silt fraction. For this reason, the content of its moving forms in this fraction is much higher.

Therefore, the content of mobile phosphorus varies significantly depending on the aggregate state of the soil and prevails in the groups of fractions 7-5 mm to 0.25 mm in all areas, and is also significantly affected by the method of use.

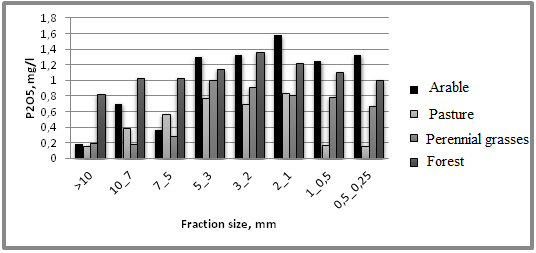
**The degree of phosphates mobility**. For the characterization of soils by the availability of plants to mobile phosphorus compounds, along with the determination of the content of mobile phosphate compounds (capacity factor), it is essential to determine the degree of phosphates mobility. The degree of phosphates mobility is the ability of phosphate ions to pass into soil solution. However, to isolate the soil solution is almost difficult, so to determine the degree of phosphates mobility aqueous and saline extracts (0.01 n CaCl2 solution and 0.03 n K2SO4 solution) at a narrow soil to solution ratio are used. The amount of phosphorus in these extracts is close to the concentration of phosphorus in soil solution.

When using salt extracts within a single soil type there is a good pattern between the values ​​of the concentration of P2O5 in the extracts of 0.03 n. solutions of K2SO4 and 0.01 n. CaCl2 solution. The advantage of salt extracts over aqueous extracts is to obtain a clear solution when filtered, whereas when applying aqueous extracts, the transparent filtrate is difficult to obtain.

It is established that the most complete supply of plants, available phosphorus reflects its total concentration in salt and water extracts.

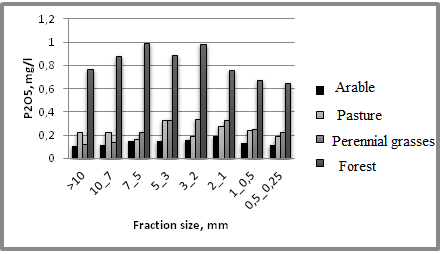
Indicators of the degree of mobility of phosphates (the factor of "intensity") can be used to characterize the provision of phosphorus to plants on soils that by their natural properties contain a large amount of acid-soluble phosphates, but it does not correspond to the actual degree of supply with phosphorus.

Compared to the capacity factor (the content of mobile phosphorus compounds), the intensity factor has a significantly low value and characterizes the degree of mobility of phosphates that pass into the K2SO4 extract and can be used by plants. This figure is almost twice the value of the degree of mobility of phosphates relative to the low-salt extract of CaCl2. As a result of researches the clear regularity of increase of degree of mobility in both extracts is established almost on all lands in fractions of structural aggregates of average sizes, namely 7-0,5 mm. Only in the pasture, the pattern is reverse. In groups 7-5, 3-2 there is a significant increase in the degree of mobility of phosphates in the K2SO4 and CaCl2 extracts (Fig. 3).



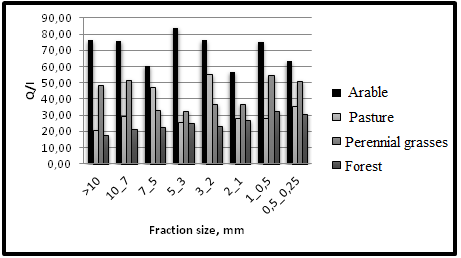
**Fig. 3** The content of P2O5 in the extract of K2SO4 0.3 n solution in the surface horizon of podzolized chernozem different lands in separate structural fractions

The degree of phosphates mobility is a rather dynamic indicator. Its changes are influenced by a number of soil properties including acidity, composition of absorbed ions, degree of saturation of bases, content of silt. The degree of mobility and the content of mobile phosphorus are increased because of cultivation and in groups of fractions where the silt content is higher.

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**Fig. 4.**The content of P2O5 in the extract of 0.01 M CaCl2 solution in the surface horizon of podzolized chernozem of different lands in separate structural fractions

An important indicator of the phosphate regime of soils is their ability to maintain the "intensity factor" at a relatively constant level by increasing or decreasing the total supply of mobile phosphates in them. The property of the soil to maintain a phosphorus concentration at a constant level is called phosphate buffer capacity and is expressed by the ratio Q/I (Q is the total stock of mobile soil phosphates; And is the equilibrium activity or equilibrium phosphate potential of the soil). The Q/I ratio indicates the amount of mobile phosphates that should go from their total stock to the soil solution. The higher the potential buffer capacity for the soil, the greater the dose of phosphorus fertilizers should be to bring the phosphate activity in the soil solution to a certain level. Soils on arable land and perennial grasses have the highest potential buffering ability (Fig. 5). In our opinion, this may also be due to the increase in the mobility and content of mobile phosphorus due to the introduction of lime. The lowest values of this indicator are found in anthropogenically unchanged (forest) soils and in pastures.



**Fig. 5** Potential buffering ability with respect to phosphorus in the surface horizon of podzolized chernozem of different lands in separate structural fractions

When analyzing the values of this indicator by the size of structural fractions, a certain pattern was established. In lands that have the least anthropogenic impact (forest), with a high sludge content, the potential buffer capacity for phosphorus acquires the lowest values. While in arable land, the values of this indicator are quite high in those fractions where there is a high silt content.

**Conclusions**

* The content of silt is predominant in medium sized structural fractions, namely 7-0.5 mm. It is here that its most significant fluctuations in the lands are observed.
* The content of mobile phosphorus is significantly influenced by both the way it is used and the size of its structural units. The highest content of mobile phosphorus in forest soils, perennial grasses, while it is slightly lower in arable land. There is a direct correlation between the values ​​of this indicator and the particle size distribution, namely between the content of the silt fraction.
* The phosphate content of low salt extracts is influenced by the method of use and depends on the size of the structural fractions and the silt content. There is an increase in phosphorus content in both low-salt extracts in medium-sized fractions. The content of P2O5 in the extract of K2SO4 significantly increases in arable land, perennial grasses and in soils under the forest. The content of P2O5 in the extract of CaCl2 increases in soils under the forest.
* The potential phosphorus buffering capacity is inversely opposite to the silt content. In almost all lands, except for sludge with high silt content, the potential buffering capacity is lower

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