

Influence of gley processes upon phosphatic state of soils

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The purpose. To assess phosphatic state of gleyed soils, character of influence of gley processes upon behavior of phosphatic anions, their accumulation, movability and migration. **Methods.** Theoretical generalization, laboratory-model experiment, chemical analysis, calculative-analytical. **Results.** It is established that clayey processes intensify transition of the most accessible for plants phosphatic anions of soil solution into the linked phosphate-mineral and phosphate-organic-mineral forms. The primary factor of activation of these processes is free (non-silicate) joints of iron and aluminium which content essentially increases under the influence of gley destruction of clayey minerals. **Conclusions.** Optimization of phosphatic regime in gley soils is possible and effective exclusively only on the background of agromeliorative practices. It may be successfully solved by application of author's innovative development - local organic-mineral system of farming agriculture.

Key words: *gley processes, hydromorphism, phosphatic state, behavior of phosphate, accumulation of phosphorus, migration of phosphorus.*

Introduction. The gley processes intensively develop in conditions of anaerobiosis (oxygen deficit) in the presence of compounds of elements with variable valence and organic matter. Signs of gleyiness and perforation are the main diagnostic criteria for hydromorphic soil formation. The rich variety of hydromorphic soils is due to different degrees of development of gley and gley-eluvial processes, acid-base regime and the intensity of accumulation of organic matter.

Hydromorphic soils belong to intrazonal formations - they are common in all natural zones of Ukraine. Hydromorphic soils in the soil structure dominate in the Polissya area, the Western Forest-steppe, in the Precarpathians and Transcarpathians. They occupy, as a rule, the lowered elements of relief in the floodplain of the year and the floodplain terraces, occur on the watersheds and slopes in the places of stagnation and / or clogging of groundwater. On the lowered elements of the relief the subtropical hydromorphism dominates; on elevated - superficial or ombrogenic hydromorphism. In hydromorphic soils of an ombrogenic genesis, under the conditions of a stagnant and flushing water regime, the gley processes and acidomorphism (formation of acids) are closely interrelated and interdependent - the pH in them, as a rule, does not go beyond the acid range.

The genetic features of gleyed soils are devoted to a number of scientific works [1-4]. Instead, the peculiarities of the functioning of processes and regimes that directly form the fertility of gley soils and serve as the basis for a well-founded choice of agrotechnological and land reclamation solutions remain unresolved on many sides. Therefore, issues of diagnostics and optimization of the nutritional regime of gley soils are relevant, since their solution will contribute to the successful agrarian development of the regions.

One of the most priority problems in solving soil fertility problems is the optimization of their phosphate state and the improvement of phosphorus plant nutrient conditions [5, 6]. Finding sources and ways to improve phosphorus nutrition plants, as compared to nitrogen and potassium, is more problematic. The powerful reserves of atmospheric nitrogen and ground potassium serve as inexhaustible resources for the reproduction of nitrogen and potassium nutrition of plants. Instead, natural resources for the production of phosphate fertilizers are too limited, which greatly exacerbates the solution of the phosphate problem. The growing shortage of mineral raw materials for the production of phosphate fertilizers and their high cost make the scientists and agricultural practitioners actively search for new sources and methods for optimizing the phosphate state of soils. This condition, in conditions of gleyiness of the soil and the

development of gley processes, is characterized by its peculiarities which, on many sides, remain undetermined.

The behavior of phosphorus in automorphic soils is devoted to a number of scientific works [5, 7, 8], while the issue of the influence of gley processes on the phosphate state of soils is highlighted in numerous works. The purpose of this work is to determine the nature of the influence of gley processes on the phosphate state of soils as the basis for substantiation of ways to optimize this state. The goal was achieved on the basis of the study of the laws of the influence of gley processes on the behavior of phosphate ions – their mobilization-immobilization, transformation and migration. The establishment of the laws of the course of these processes allowed to develop an innovative model for managing the phosphate state of hydromorphic soils [9] with the prospect of implementing this model into the practice of agrochemical service activities.

Content, materials and research methods. Soil samples from the arable layer of clear-gray forest, turf-podzolic and alluvial-meadow soils of different granulometry, gley, and use were used as research materials. Along with this, in order to establish the role of gley processes in the formation of phosphate regime, we conducted a series of laboratory-model experiments. The development of gley processes was carried out by artificial simulation on ground samples taken from the arable layer of the non-gley humus horizon. Glucose was added to enhance the biochemical recovery to the compacted soil mass. The duration of composting is eight months. At the end of composting (last month), occasional measurements of ORP using a platinum electrode were conducted. At the end of the experiment, samples were taken to determine the following indices: content of mobile iron forms (DSTU 4724: 2007), aluminum (GOST 26485-85) phosphorus (GOST 26204-91), $\text{pH}_{\text{H}_2\text{O}}$ (GOST 26423), phosphate buffer (DSTU 4724: 2007) - phosphate factor of intensity (FFI), mobilization and immobilization (FBE) phosphate buffer capacities (FBE). A similar experiment with a different humidification regime was also carried out on soil columns, which were washed with distilled water at the end of composting in order to determine the migration potential of phosphates under conditions of development of gley processes. In washing waters, the content of phosphorus in ionic and organo-mineral bound forms was determined. Phosphorus from organo-mineral complexes was released by destroying them with hydrogen peroxide.

Analysis of research results. Laboratory model experiments have confirmed that the acid-base and oxidative-reduction regimes are significant factors of intrinsic soil phosphate transformations, as a result of which the phosphate state of soils and the behavior of phosphate ions in the soil environment significantly change. Under field conditions, the parameters of the ORP indices and the amplitude of their oscillations in time and space are genetically determined and inherent for each particular variety of soil. However, modern climatic changes make significant adjustments to the regular pattern of soil processes. As you know, these changes are aimed at general warming of the climate. However, the equally influential processes of soil processes are the growing contrast and high dynamics of the hydrothermal regime, which should be paid special attention. The high and contrasting dynamics of moisture is a determining factor that determines the behavior of phosphorus in gleyed soil environment.

The results of the generalization of literary sources [10, 11] and stock archival materials from large-scale soil surveys are evidenced by the significant influence of soil gley on its phosphate state. The total reserves of phosphorus in surface gleyed varieties of turf-podzolic and gray forest soils are usually lower than in the same, but in the absence or with poorly expressed gelling of soil mass (Table 1).

The highest reserves of phosphorus are concentrated in an arable layer of non-sooty soils, primarily in those that are characterized by high levels of physical clay and humus. The upper humus horizon of alluvial-meadow soils with obvious signs of gelling on the content of mobile phosphates also shows a clear tendency to decrease them compared to non-gleyed analogues (based on the content of physical clay).

However, there is not always a close correlation between the content of physical clay and total reserves of phosphorus, especially in soils with a significant presence of free (non-silicate) forms of iron, interacting with them (in the presence of active humus substances - fulvates), phosphate anions form complex iron-phosphate-organic complexes. These complexes in the form of films are fixed on the surface

of mineral granules, or they undergo segregation with the formation of phosphorus-containing nodules. Organophosphorus and iron-ferruginous forms of accumulation of phosphorus in an amorphous and / or slightly crystallized state prevail in otporovyh and peat soils, for example. Peat with vivianite neoplasms (iron-oxide hydrophosphates $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$) is a very effective source of not only nitrogen but also phosphorus nutrition of plants. Oxidizing, vivianite is transformed into a betranite, in which phosphorus is strongly attached and becomes inaccessible to plants. However, in the presence of active organic substances, this process is substantially slowed down.

1. Parameters of indicators of good soil condition

Soils	pHH ₂ O	Faction <0,01	Humus, %	Gross phosphorus, %
1. Deep-podzolic Sunshine (Western Polissya)	4,3-6,0	18-22	0,97-1,32	0,074-0,079
2. They are the same, but gleyed	4,2-5,8	17-25	1,28-1,54	0,070-0,079
3. Deep-podzolic loamy loam (Western Polesye)	4,4-6,2	23-29	1,15-1,80	0,081-0,101
4. They are the same, but gleyed	4,0-5,0	25-30	1,60-2,40	0,076-0,081
5. Clear Gray Forest loam (Western forest steppe)	4,8-6,4	21-28	1,75-2,10	0,102-0,108
6. They are the same, but gleyed	4,5-5,9	22-31	1,80-2,70	0,102-0,105
7. Brownish-podzolic loamy loamy loam (Prykarpattya)	4,2-5,6	32-37	2,50-3,80	0,106-0,118
8. They are the same, but gleyed	4,4-5,5	34-40	2,20-3,90	0,099-0,101
9. Alluvial alluvial loam (Forest-steppe)	6,5-8,2	33-38	2,50-3,70	0,084-0,089
10. They are the same, but gleyed	6,1-7,5	31-41	2,30-3,90	0,082-0,089

On the balance of the phosphate pool in the upper humus-eluvial horizons of the ground surface digestion is influenced by the nature of the development and the ratio of gley and eluvial processes. Released under conditions of development of gluten processes, the compounds of iron and aluminum become powerful factors of chemical fixation of phosphate ions. At the same time, according to the data of the conducted laboratory-model experiment (Table 2), as well as the data of certain literary sources [6, 12], in the conditions of hydromorphism and drainage, the process of descending migration of full-mineral complex compounds, containing phosphorus, is possible.

2. Washing of phosphates under different conditions of humidification and fertilization

Version	Number of washed phosphorus (average of three columns)		
	in ionic form (before processing H ₂ O ₂)	in ionic form (after processing H ₂ O ₂)	in the form organo-mineral complexes
	mg		
Optimal Moisture (full of water mist 65 %)			
1. Control (without fertilizer)	0,049	0,049	-
2. Superphosphate, 20 mg /100 g	0,104	0,104	-
3. Superphosphate, 20 mg + Peat-1,5 g per 100 g of soil	0,027	0,025	сліди

Waterlogging (full of water mist 100 %)			
1. Control (without fertilizer)	0,105	0,105	-
2. Superphosphate, 20 mg /100 g	0,072	0,072	сліди
3. Superphosphate, 20 mg + Peat-1,5 g per 100 g of soil	0,081	3,151	3,07
NIR _{0,5}	0,004	-	-

The washing of phosphorus is due to the formation of migratory alumina ferro-phosphate-organic compounds by the interaction of phosphate ions of soil solution with active (fulvant) humus acids and semi-octane oxides. As a result of the development of processes of decay of clay minerals, the segregation of decay products with the formation of nodules and the partial removal of complex phosphate-containing compounds beyond the root-bearing layer, there is a significant depletion of gley-eluvial soil on the phosphate resource stock. The deterioration of the phosphate state of acid soils with developed surface hydro-morphism occurs in a well-defined seasonal contrast effect of oxidation-reducing processes. This contrast is especially characteristic of surface gleyed sod-podzolic, borozemno-podzolic soils of the Precarpathian region, as well as superficially gleyed clear gray and gray forest soils of Western Polissya and Forest-steppe. Available to plants phosphate ions in conditions of contrast humidification and drying are firmly fixed in specific neoplasms as the degree of their crystallization increases. Inorganic composition of soil specific neoplasms is determined by the hydrochemical conditions of their formation. According to the data of literary sources [1-4, 12], in the surface gelliferous soils (from pH 4.5 to 6.0 units), iron, manganese, aluminum, silicon, humus acids and mineral mud are used as ingredients of specific neoplasms.

As a result of our laboratory-model experiment with sod-podzolic soils-alkaline soils, the priority role of iron compounds in the accumulation of phosphate ions was established (Table 3).

3. Influence of iron on the accumulation of phosphate ions

Version	Optimal Moisture	Waterlogging
	P ₂ O ₅ mg/kg	
1. Control (without fertilizers)	35,64	49,42
2. Potassium dihydrogen phosphate	65,45	31,96
3. FeO	37,97	24,23
4. FeO+ potassium dihydrogen phosphate	39,96	20,74

The advantage of the influence of iron oxide hydrates on the absorption of phosphate ions was noted in the work of S.N. Ivanov [6]. On the basis of our data, there is a clear trace of the dynamics of the decrease of the mobile forms of phosphorus under the conditions of overflow in variants with the addition of iron, compared with the variants where it was not introduced. In specific neoplasms of gley-eluvial soils, as a rule, there is phosphorus. Its content in nodules can be 3-5 times higher than in the soil mass [12].

We note that limestone, limestone-gypsum, magnesite-calcium, siderite and other specific formations are formed in calcium-saturated hydromorphous soils with a neutral or alkaline reaction, differing not only in the composition of ingredients but also in the degree of crystallization. In the concretions of neutral and alkaline hydromorphic soils of the accumulative type (alluvial-meadow soils), phosphorus is present in most cases, but is usually less in number than in the concretions of gley-eluvial soils. Consequently, the processes of hydromorphism ambiguously affect the phosphate state of the soil and the balance of the phosphate pool [13]. In equally oiled sod sod-podzolic soils of sand and sandy granulometric composition, gross phosphorus reserves are significantly higher than those of similar but poor in non-silicate (free) forms of iron. The nature of soil irrigation is closely linked to hydromorphism, the intensity of the development of gley-eluvial and stagnant-glae processes. Not all known methods of soil cultivation

(fertilization, liming, cultivation, crop rotation) have a positive effect on the phosphate state of the soil and the phosphate nutrition of plants. Only strictly normalized mode of cultivation and agricultural culture on synergetic principles provides stability of phosphate state in optimal limits and high efficiency of phosphate fertilizers. Excessive sour soil, for example, leads to a sharp deterioration of phosphoric plant nutrient conditions, especially in conditions of highly developed hydromorphism and development of gluten processes.

Thus, in gley-eluvial soils, the content of total phosphorus in the upper humus layer, as a rule, decreases. It is partially washed away in the lower horizons of the soil, and is also included in the process of specific neoplasms, which impoverishes the phosphate available to plants. Phosphates are firmly fixed in the nodules and the more strongly, the higher the rate of their crystallization. In highly-crystallized concretions phosphorus becomes inaccessible to plants and depletes from the phosphate "budget" of the soil.

It should be noted that the process of intensive accumulation of reduced organic matter - the products of vital activity of anaerobic microflora – acts as a specific negative factor of fertility in gleyed soils [14, 15]. Therefore, the optimization of the phosphate state of gleyed soils, which undergoes constant and periodic overflow, is possible only with the background of the adjusted water-air regime (deep reclamation, roughness, drainage, etc.), as well as the use of scientifically substantiated doses and methods of fertilizing and meliorants. An important and non-alternative factor of self-regulation of phosphate nutrition of plants is the organic matter of the soil. The results of numerous field experiments conducted by the Institute of Agriculture of the Carpathian region NAAS [16], Lviv National Agrarian University [17], and the Uman National Horticultural University [18] have proved the high efficiency of the organo-mineral fertilizer system. Its useful ecological functions are well-grounded and no doubt, first of all, for obtaining high-quality products for consumption. Phosphate anions in organo-mineral fertilizers retain their activity and availability to plants. Pneumatic "protects" phosphate compounds from crystallization and transition to inaccessible form for plants. At the same time, the activity of microorganisms is intensified, the processes of decomposition of organic substances and the accumulation of elements available for plant nutrition are intensified.

However, the organo-mineral system of separate and continuous fertilization, which is recommended by cited and many other researchers, can be considered obsolete and environmentally unjustified. Energy costs for fully spreading technology, even with integrated fertilizer application, are too high. We have fully grounded the alternative local organo-mineral system of reproduction of soil fertility, which, with its ecological and economic efficiency, is not inferior to any of the existing systems [13, 19]. With the transition to the proposed system of local cultivation of soil mass it is possible to achieve optimal parameters not only of the phosphate state, but also of all other elements of fertility. Efficiency of use of fertilizers and chemical meliorants under the conditions of local organo-mineral system of cultivation significantly increases. At the same time, carbon dioxide emissions are reduced and sequestration of organic carbon in the soil mass is increasing.

For the local cultivation of superficially gleyed acidic soils, the lime is added to the organo-mineral fertilizers in the norm, which is determined by the pH-buffer curve. Lime additives positively contribute to the rearrangement of the phosphate pool in the localized soil mass. Iron and aluminum-phosphate forms of compounds are transformed into calcium phosphate, which improves the phosphate nutrition of plants. At the same time, the introduction of lime inhibits the development of gluten processes and the reduction of organic matter, eliminates the toxic effect on plants of ferrous iron and movable aluminum, improves the microbiological regime of the soil, conditions for the development of useful biochemical processes.

Conclusions

On the basis of literary and stock generalizations, the results of our own experimental studies, we arrive at the following conclusions:

- gleyed and gley-eluvial soils, the phosphate state deteriorates: the total phosphorus reserves in the root-bearing layer of soil decrease and availability to its plants, its accumulative and migration capacity increases, the conditions of phosphate nutrition of plants deteriorate.

- gluten processes lead to the destruction of the crystalline grate of silicate minerals, the release of semi-octane oxides, which become the main factor in the formation of a specific phosphate state, the conditions for the transformation of phosphate compounds and phosphorus nutrition of plants.

- free compounds of iron and aluminum interact deeply with phosphates of soil solution and mobile organic substances, forming complex organo-mineral complexes that are not available to plants.

- active forms of humus substances and ferrous iron, interacting with phosphates, form migratory forms of compounds that can be washed away beyond the root-containing layer of surface gleyed soils, which also impoverishes to some extent phosphate stocks available to plants.

- ecological and ecological problems with reproduction of hydromorphous soil fertility are successfully solved under the conditions of implementation of the author's local organo-mineral system of agriculture.

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