

# Phosphate factor and phosphate-buffer capacity as the basic instruments for diagnostics and optimization of phosphate state of soils

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**The purpose.** To improve the way of diagnostics and optimization of phosphate state of soils. **Methods.** Theoretical generalization, laboratory-model experiment, chemical analysis, calculation-analytical. **Results.** It is established that all existing techniques of diagnostics of phosphate state are based only on use of different extractants, in specific extent adapted to soil substrate depending on acid-alkaline state of calcimorphic earth, granulometric composition, etc. Researches showed that phosphate nature of soil can be objectively evaluated on its phosphate-buffer ability in view of phosphate-buffer of capacity and index of density of phosphate ions (PI) in soil solution. By curve of buffering it is possible to determine amount of phosphate fertilizers counting upon the matching mass of soil or to realize other technological measures in order to transfer actual value of phosphate intensity factor (FIF) into optimum state. For all soils irrespective of their phosphate-buffering capacity the upper admissible meaning of FIF is fixed at the level of 3,1 – 3,3 units. In average-buffering soils and soils with the big buffering power it is almost impossible to reach that value. Necessity of uiy for diagnostics of trophic regimen of soils of processes of its self regulation is justified. Diagnostic-optimization graphical model is developed for this purpose on the basis of curve buffering with drawing on this curved line of optimum parameters of phosphate stat. Parameters of phosphate-buffer of properties of soils are determined. That made it possible to develop the way of diagnostics of phosphate state, level of its stability and a path of optimization. **Conclusions.** Results of researches have displayed that in gley soils for optimization of phosphate state in comparison with not gleyed ones it is necessary to deposit essentially high dose of fertilizers. It is caused by higher buffering capacity of gleyed soils in immobilized spacing. Optimization of phosphate state of soils on the basis of indexes of phosphate-buffer capacity and phosphate factor with creation of graphical model matching phosphate-buffer is the most objective and efficient way of diagnostics and assessment of the level of stable provision of plants with phosphate feed.

**Key words:** soils, phosphate regimen, phosphate-buffering, fertility, accumulation of phosphorus, mobilization of phosphorus, diagnostics of phosphate state, optimization of phosphate state, phosphate factor.

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**Introduction.** In today's land-use conditions, accuracy and simplicity in the diagnostics of trophic soil conditions are of particular importance. On how accurately, quickly and qualitatively will be the diagnostics of each individual fertility element depends on the reproduction of the productive function of the soil and the effectiveness of fertilizer application. One of the most problematic in diagnostics is the diagnosis of the phosphate state of the soil, since phosphate ions can form various compounds and complexes according to the strength of the joints, which in general complicates the process of their determination [1]. Today, for the determination of phosphorus in soil, it is possible to calculate several hundred methods, which are based mainly on the use of chemical extragrants - neutral salts ("soft methods"), acids and alkalis ("hard methods"). The most common methods for determining the mobile phosphorus in soils are the methods of Kirsanov, Chirikov, Machichin, Olsen, Karpinsky-Zamyatinoy, Scofield. The choice of method depends on the chemical, physical and physical and chemical properties of the soil. For example, on acidic and slightly acidic soils acidic extracts and various buffer mixtures with initial pH of 1-5 are used, and on carbonate soils - buffer mixtures and alkaline extracts with a pH of 8.5-9.0 (Table 1).

## 1. Methods of determination of mobile phosphates for soils of different genesis

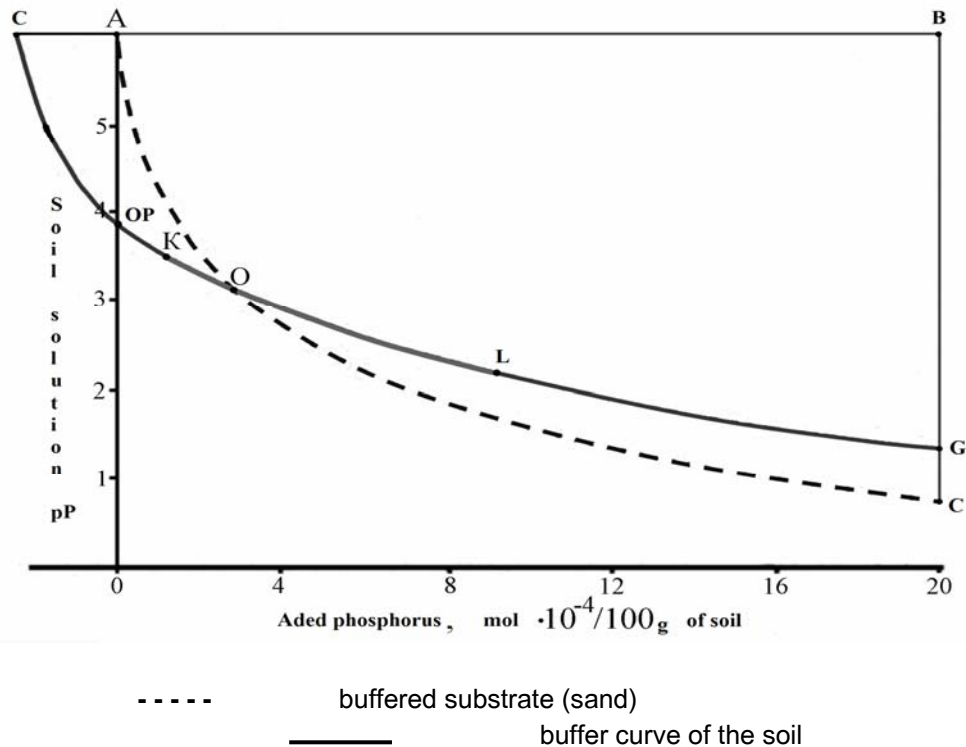
Way	Method	Extract	Soils that are used
H AR D	Kirsanov	0,2 n HCl	turf-podzolic and gray forest
	Chirikov	0,5 n CH <sub>3</sub> COOH	black earths and gray forest

			(unsuitable for carbonate soils)
	Machichin	1 % $\text{NH}_4\text{HCO}_3$	grayish-gray, gray-brown, brown, chestnut, black earths, in which there are carbonates
SOFT	Karpinsky-Zamyatinoy	0,03 n $\text{K}_2\text{SO}_4$	for most soils
	Scofield	0,01 M $\text{CaCl}_2$ .	for most soils
	Olsen	$\text{NaHCO}_3$	for most soils

Unfortunately, the application of the above hard methods on all types of soils, without taking into account their genetic features and degree of agronomy, namely indicators such as soil pH, granulometric composition and the presence of phosphorus-containing minerals, can lead to biased results [2-5] According to cited authors, the use of rigorous methods (acidic and alkaline), in particular on acid soils, can lead to understated results on the content of plant phosphates in the soil, which is due to the phenomenon of secondary reactions between the extractant and the soil mass. And, on the contrary, overestimate the data received if the amount of apatite-like compounds in the soil is increased. Regarding alkaline soils, even their insignificant alkalinity leads to a partial neutralization of the acid used as an extractant, which also results in poor results from the analysis. The soft methods can be considered universal, which are suitable for determining the mobile forms of phosphorus on the different genetic nature of the soil [6]. Proceeding from this, we used for the diagnosis of phosphate state the most soft methods - the method of Scofield and Karpinsky-Zamyatinoy, which determine the most available plants phosphate ions (the so-called phosphate intensity factor). It turned out that the data obtained by the above methods are closely correlated with the crop solely within the limits of one agroecological type of soils or soils with the same phosphate buffer properties.

Thus, as our previous studies [7, 8] show, the phosphate state of the soil can be objectively evaluated in terms of the phosphate buffer capacity of the soil, taking into account the magnitude of the phosphate intensity factor (PFI). Indicators of changes in phosphate buffer properties are determined by the ratio of phosphorus additives to the soil or their removal from it to a corresponding change in the magnitude of the activity of monophosphate ions. Consequently, our research is aimed at improving the method of diagnosis and optimization of the phosphate state of soils.

Research methodology. The research was carried out on theoretical principles of the buffer properties of soils. It is best to diagnose the phosphate state of the soil using a phosphate buffer graphic (Figure 1) model, which is constructed according to DSTU 4724: 2007 and allows to obtain a number of buffer indices for diagnostics, optimization and prediction of the phosphate state of the soil under study. Each soil has its characteristic buffer curve relative to the fertility element, which is obtained under the influence of increasing doses of meliorants, fertilizers and other types of exposure. The deviation of the buffer curve from the so-called zero-buffer curve (depicted in the figure with a dotted line) characterizes the buffer capacity (BE). It is determined in the accumulation (BE) and in the mobilization (BE) intervals of the buffer curve (in balls, on a 100-point scale).



**Fig. 1 General view of the graphic model of phosphate buffer soil (on an example of a sample of eutrophic peat) [7]:**

- OP – the initial state of the fertility element;
- O – point of thermodynamic equilibrium of phosphate exchange;
- ABC – standard buffer capacity (100 points);
- OGC – buffer capacity positive area (BCp);
- OCA – Buffer Capacity Negative area (BEn);
- KL – the segment of the buffer curve within the optimal parameters of the phosphate "factor of intensity".

To determine the norms of agrochemical loads and assess the quality of trophic nutrition of plants on one or another ground, the mandatory condition is to obtain information about the optimal parameters of the intensity factor (FI), which is represented by the corresponding segment on the buffer curve (see section CL in Fig. 1). The optimal parameters of the phosphate ion concentration indices for grain crops in soil solutions for the main types of soils are given in the monograph [7]. The optimum parameters of the phosphate intensity factor (FFI) must be established for each soil or close to each other for the genesis and level of cultivated soil.

In this paper, we used the most revealing results from the study of the phosphate buffer capacity of different types of soils that contrast with each other by morphological structure and properties, namely: sod-podzolic, clear-gray forest, chernozems podzolized, peaty soils of low-lying type (alkalitrophs strongly expanded and eutrophic weakly decomposed).

Each sample, selected from the upper horizon of the soil profile, has a genetically inherent buffer curve. It characterizes the dynamics of changes in the factor of intensity (FI) of this soil under the influence of naturally increasing phosphate loads.

The selection of soil samples and buffer parameters was performed on the basis of the relevant normative documents: sampling according to DSTU 4287-2004; phosphate buffer soil - according to DSTU 4724: 2007.

**Research results.** Diagnostics of the phosphate state based on not only the indicators of the content of mobile phosphate (PFI) but also phosphate buffer capacity allows obtaining clear information about the phosphate state of the soil at the time of determination and provides an opportunity to predict the change in the phosphate state of soils during the ontogenetic development of plants and rotation of crop rotation.

It has been experimentally determined that for all types of soils, regardless of their phosphate buffer capacity, the upper optimum limit of the phosphate intensity factor (PP) is equivalent to 3.25 units or 440 mg P<sub>2</sub>O<sub>5</sub> per kilogram of dry soil. In the practice of agriculture, starting with medium buffer soils and above, it is almost impossible to achieve this value, even at an intensive phosphate load. Under the same conditions, but in poorly buffered soil phosphorus, the indicated value of pP is much easier. Reducing the pH below the upper limit of the optimum (3.25 units) is unacceptable because of the possible risk of adverse effects of the excess phosphate ion concentration on soil fertility and plant development.

It is well known that on soils with excess phosphate (phosphate) content the processes of absorption of iron, zinc, and potassium and other biogenic elements by the root system of plants are violated, which leads to premature aging of plants, they quickly fascinate, the formation of chlorophyll ceases, ammonia accumulates in the cells, from which vegetable fabrics die. Therefore, the phosphate parameter (pP) 3.2 should be estimated as the threshold of the maximum permissible concentration of phosphate ions in the soil solution, regardless of the type of soil. It is almost impossible to achieve the value of 3.2 at high and very high buffer soils even under conditions of too high doses of phosphate fertilizers (up to 2000 kg and more P<sub>2</sub>O<sub>5</sub> per 1 ha in a 20 cm soil layer). This is evidenced by the data of a stationary field experiment on typical chernozem, conducted under the scientific guidance of B.S. Noska [1]. On these soils, phosphate fertilizers can be put into stock for several years, if there is such an opportunity and it is economically beneficial.

Phosphate factor of intensity is the most dynamic in low buffer soils. Therefore, in them the lower optimum occurs in the conditions of a higher concentration of phosphate ions in the soil solution than in the medium, and even more so in high and very high buffer soils in relation to phosphorus.

We have calculated the required amount of phosphorus fertilizers to achieve the optimal intensity factor (the degree of mobility of phosphate ions) on the five soil species studied by us, differing not only in gelation, but also phosphate buffer capacity in the immobilization load interval using a graphic model of phosphate- buffer for grain cereal crops. The parameters of the optimum are used by us [7]. The main parameters of the phosphate state (FFi, BEp) and the doses of phosphate fertilizers necessary to reach the lower limit of the optimal FFI are given in Table. 2.

The results of studies have shown that in gulous soils, to optimize the phosphate state, compared with non-gelling, it is necessary to make a substantially higher dose of fertilizers. This is due to the fact that glued soils have a higher buffer capacity in the immobilization interval. Under the conditions of the change in the technology of introduction can significantly save phosphate fertilizers. The high efficiency of localization of phosphate fertilizers is well-known [9]. According to our calculations, in order to achieve the optimal concentration of phosphorus for local fertilization, it is enough to add 13-15 kg of P<sub>2</sub>O<sub>5</sub> per hectare on the most high-buffered soils relative to phosphorus. However, it may turn out that these doses are not sufficient for the normal mineral nutrition of plants throughout the growing season. Therefore, calculated for local administration of the dose should be adjusted to take into account the needs of a specific culture and the coefficient of efficiency of phosphorus use in the conditions of its local application, not allowing the concentration of phosphate ions in the soil solution.

### **Conclusion.**

The phosphate buffer indices give us a higher estimate of the phosphate state of the soil and phosphate nutrition of plants. They guide us to take additional measures, depending on the phosphate buffer capacity of the soil. The proposed method for optimizing the phosphate state of soils on the basis of phosphate buffer capacity and phosphate factor intensity (concentration of phosphate ions in soil solution) with the construction of the corresponding phosphate buffer graphic model should be attributed to the most objective and effective in terms of diagnosing and evaluating the level of the stable providing plants with phosphate nutrition.

**2. Optimal doses of phosphate fertilizers, calculated on the buffer curve for different technologies of their introduction**

Soil	Actual pP	Lower limit pP [7]	Buffer capacity, points	Doses of phosphate fertilizers		
				Technology of fertilizing under continuous plowing	Technology of fertilizing for cultivation	Fertilizer technology locally
				kg P <sub>2</sub> O <sub>5</sub> per 1 ha		
Deep-podzolic non-glued sandstone (overhang)	5,2	4,4	3,8	148	102	11
Deep-podzolic gleyed drained sandwich	5,6	4,7	7,2	166	115	13
Buroso-podzolic surface gleyed medium-sand	5,8	5,1	31,8	111	77	9
Deep-podzolic, medium-grainedlime	5,5	4,7	10,4	148	102	11
The clear gray forest is superficially glued light-sand	5,6	4,8	12,5	148	102	11

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