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POLLUTION OF SOIL ENVIRONMENT WITH MINERAL FERTILIZERS AND WAYS OF THEIR MIGRATION DEEP INTO THE SOIL

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Abstract. One of the major problems of pollution of soil environment, namely by components of mineral fertilizers due to their massive and continuous use in agriculture was analysed in the article. Possible ways of penetration of not absorbed mineral fertilizers deep into the soil as the main reason for getting fertilizers in the lower layers of the soil environment were investigated. A comparison of the impact of soil and climatic conditions on the rate of penetration of fertilizers deep into the soil was done.

Key words: mineral fertilizers, penetration, soil environment, adsorption, pollution.

1. Introduction

Mineral and organic fertilizers are widely used in agricultural practice, as basic substances that increase soil fertility and increase crop resistance to the variability of climatic conditions, thus allowing to obtain high harvest. Considering the fact that assimilation of components of mineral fertilizers occurs gradually, and the period of their bringing in is at the beginning of the plants growing season, there is a real danger that a lot of fertilizers, and according to the literature [1–4] this number is within 40 to 60 %, will penetrate into the deep layers of the soil and contaminate them. In this case, nitrogen and potash fertilizers that are soluble in water and can easily migrate in vertical soil profile occupy the main place among all types of fertilizers.

The rate of penetration of fertilizers deep into the soil is determined by various factors. This process affects both soil-adsorption capacity of the soil and the soil and climatic conditions (temperature, humidity balance, content of clay and sand fractions, etc.) [5]. One of the most important properties that characterize the soil is its adsorption capacity, because it affects both the soil formation processes, and the processes of establishment of its fertility. The adsorption capacity regulates the nutrient regime of soil and causes the accumulation and maintenance of nutrients in it. This property of the soil also affects the distribution and penetration of mineral fertilizers in the soil environment. This makes it possible to reduce the frequency of bringing in doses of fertilizers and increase the amount of fertilizers at a time.

Moreover the process of penetration of fertilizers deeper into soil is affected by the processes of molecular and convective diffusion that are constantly present in the soil environment. It can be proved by the fact that fertilizers penetration is different on sandy soils and humus or dark grey ashed soils. On the one hand, this is due to different penetrating ability, that is water permeability of the soil, which affects mostly the convective transfer of fertilizers deep into the soil, on the other hand, this depends on how humidified soil environment where molecular diffusion process is possible is.

Considering the current ecological status of most soils, a lot of research has been conducted to establish the ways of penetration of pollutants in vertical and horizontal soil profile [6-9], but not enough attention has been paid to study the migration of components of fertilizers, which can also become pollutants. Taking into consideration the fact that migration of various components of fertilizers occurs in the soil environment in different ways, as some components, for example, NH_4^+, K^+, Ca^{2+} are adsorbed by the soil adsorbing complex, and NO_3^- is not adsorbed, the study of the basic processes of penetration of fertilizers in vertical profile of soil is an urgent and important task for predicting possible ways of penetration of fertilizer components deep into soil.

2. Experimental part

The main fertilizers that are widely used in agriculture are nitrate fertilizers, which include anion NO_3^- and cation or NH_4^+, or K^+, or Ca^{2+} etc. These fertilizers are well soluble in water and are made mainly in the spring season. According to the literature [1, 2], the loss of these fertilizers is within 40 % of the

introduced amount, thereby leading to constant accumulation, including nitrates, in the deep layers of soil and subsoil waters. That is why we have chosen to study the following fertilizers: potassium nitrate, calcium nitrate and ammonium nitrate.

Research of the adsorption properties of soil was carried out on the example of potassium nitrate and calcium nitrate, where there are ions K^+ and Ca^{2+} that are well adsorbed by the soil and kept in its pores, and studies of convective diffusion were performed on the example of ammonium nitrate where there is an ion NO_3^- that is not adsorbed by the soil-adsorbing complex and easily penetrates deep into the soil, especially during precipitation. Potassium and calcium are essential nutrients, full plant nutrition is impossible without them, but abundance of these elements in the soil leads to its pollution and getting into surface and underground aquifers.

2.1. Research of adsorption capacity of the soil

Research of adsorption properties of soil was carried out on the example of potassium and calcium ions. Podzolic humus, that is widespread in the Lviv region was used as soil. During experimental studies dried to constant mass soil was used.

Samples of dried to constant mass soil (≈1 g.) were put in measuring tanks and the tanks were then filled up with 100 ml of calcium nitrate or potassium nitrate with known concentrations. The solutions were mixed thoroughly and left for two days in the thermostat. Determination of the concentration of calcium ions in the solution was conducted by titrimetric analysis. The mass of adsorbed calcium was determined by the difference of concentrations of the primary and final solutions. Analysis of solutions on ionomer was performed to determine the concentration of potassium ions and the mass of adsorbed ions was determined by the difference of concentrations in the primary and final solutions. The results of experimental studies are presented in Fig. 1, 2.

2.2. Research of convective migration of fertilizers

Investigation of convective transfer of fertilizers deep into the soil environment and the possibility of contamination of the lower layers of soil was carried out on the example of ammonium nitrate, which is most widely used in agricultural practice. Here there is an ion NO_3^-, that is easily adsorbed by the root system of plants, but at the same time it easily penetrates deep into the soil environment with precipitation, as it is not kept in the pores of the soil. Two types of soil, such as sandy and clay loam were chosen for the research. These soils have varying water permeability, thereby affecting the penetration of fertilizer components in the deeper layers of soil. Measurements of quantity of filtrate which has passed through the soil were conducted during the study, the rate of filtration and content of nitrates in the filtrate and quantity of fertilizers washed out from the soil were determined. Soil layer with the thickness of 20 cm was chosen for the research since, according to the previous studies, the main part of the root system of plants is in the layer with the depth of 30 cm [5]. Ammonium nitrate was applied on the surface layer of the soil and regular watering of the soil depending on the amount of rainfall in the Lviv region in April was carried out [10]. The results of experimental studies are presented in Fig. 3, a, b, 4, a, b.

3. The results of research

The results of experimental studies of soil adsorption properties (Fig. 1, 2) indicate that the adsorption capacity of soil affects on the rate of penetration of fertilizers deep into the soil.

The results indicate that soil adsorption of ions as calcium or potassium in different concentrations is different. So, at low concentrations adsorption and ion exchange filling of the pores is possible, which leads to lower adsorption capacity of the soil. In this case, impact of adsorption capacity of the environment has less impact on the penetration of fertilizer components deep into the soil and is manifested by smaller quantities. In the case of increasing of the concentration of the substance in the solution the adsorption capacity of the soil environment increases. This is because it is possible to form a bimolecular layer of the soil that increases the static activity and increases adsorption properties of soil.

Considering the fact that the impact of adsorption properties is greater at high concentrations of the substance, the newly applied high concentrations of soluble fertilizers (fertilizer doses are calculated for the entire vegetation season) will be adsorbed by the soil-adsorbing complex of soil and kept in its pores. Besides, such a property of the soil significantly reduces amount of fertilizers that will penetrate deep into the soil immediately after their rapid dissolution in moist soil and they will be available for adsorption by the root system of plants for a long time.

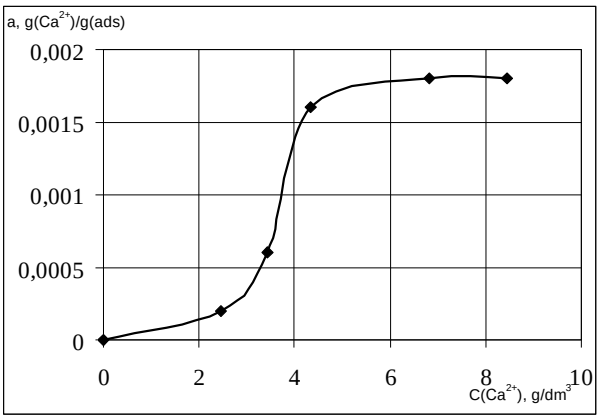

Fig. 1. Determination of adsorptivity of podzolic humus *a* to the concentration of calcium ion C in a liquid

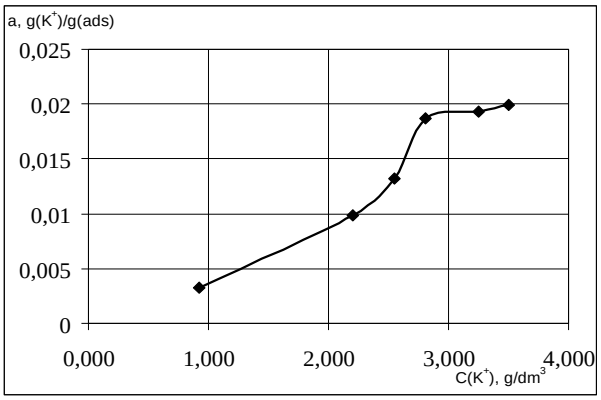

Fig. 2. Determination of adsorptivity of podzolic humus *a* to the concentration of potassium ion C in a liquid

The results of experimental studies of washing out of fertilizers during precipitation are presented in Fig. 3, a, b and 4, a, b.

The study of washing out of components of fertilizers from the soil environment was based on the filtration rate of fertilizers through the soil environment. Considering the fact that soil has the ability to retain water and to become saturated the penetration of fertilizers will continue even after the rain. This type of filtration is called filtration under the forces of gravity. We have experimentally investigated filtration rate during rainfall, which is on selected soils 15,8 and 0,8 m/day (on sandy soil and clay loam soil respectively) and filtration rate under the forces of gravity, which is 0,06 and 0,03 m/day respectively.

From the submitted graphic dependencies it can be seen that the main part of fertilizers is washed out from sandy soil in up to 10 days after application, while fertilizers are washed out from clay loam soil much more slowly, which reduces harmful effect on the environment. According to the results of research, in 30 days of the experiment the degree of washing out of fertilizers from the sandy soil is 97 %, and from the clay loam is 58 %. Considering the fact that the washing out process is constant, the fertilizer residues that remain in the soil layer in autumn and winter will be completely washed out to the lower layers of soil and will become the pollutants of subsoil waters.

The accumulation of fertilizers in the lower layers of the soil is constant with each rainfall, because there is a constant penetration of fertilizers in vertical soil profile (Fig .4, a, b). So, application of excessive doses of nitrate fertilizers leads to a constant flow of nitrates in the deeper layers of soil.

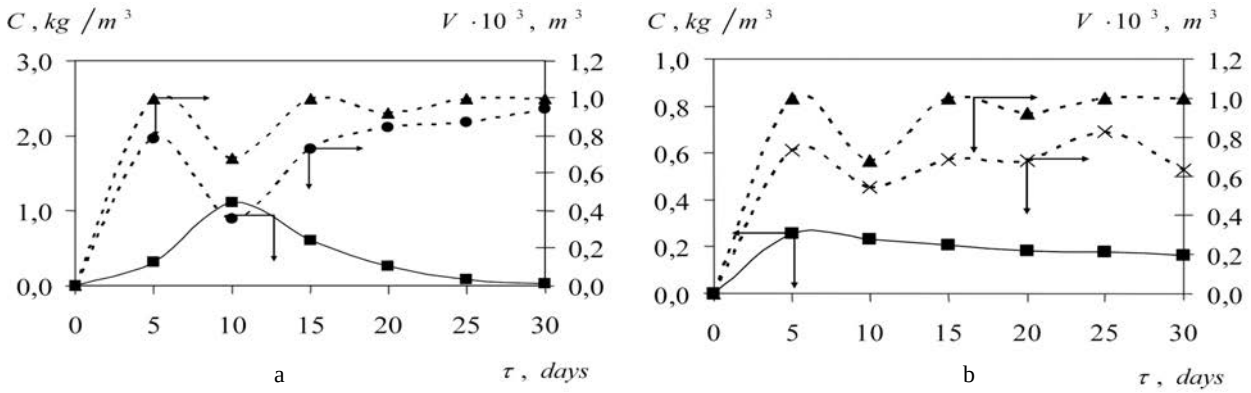

Fig. 3. Kinetics of washing out of ammonium nitrate from sandy (a) and clay loam (b) soil layer:
■ – the concentration of ammonium nitrate in the filtrate, kg/m^3; ▲ – precipitation volume, V, m^3;
• – the volume of filtrate from the sandy soil, V, m^3; × – the volume of filtrate from clay loam soil, V, m^3

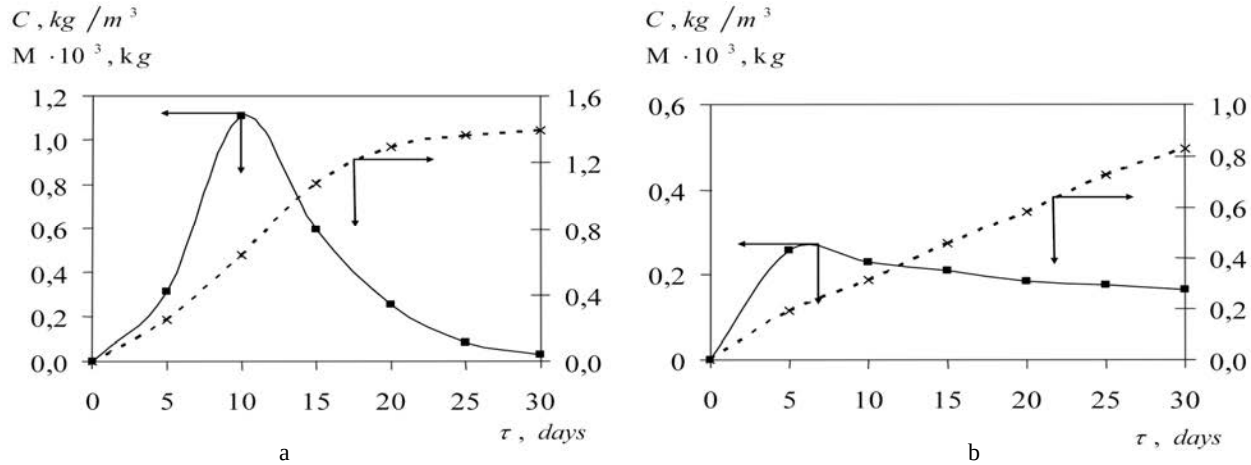

Fig. 4. Kinetics of ammonium nitrate accumulation in the filtrate from sandy (a) and clay loam (b) soils:
■ – concentration of the fertilizer in the filtrate, kg/m^3; × – accumulation of ammonium nitrate in the filtrate, M, kg

4. Conclusions

Contamination of soil and groundwater aquifers is perhaps one of the major problems of environmental pollution. One of the most widespread pollutants that are spread throughout Ukraine are fertilizers, particularly nitrogen, which cause accumulation of a number of pollutants in soil and groundwater. This applies to nitrates and other nutrients that are a part of fertilizers because abundance of all these substances causes negative processes in the environment.

Experimental studies have shown that soil adsorption properties have significant impact on penetration and distribution of components of fertilizers in the vertical soil layer. This impact is particularly significant at high concentrations of substances, which creates favourable conditions for the gradual assimilation of the components of fertilizer by plants for a long period of time. The results of experimental studies makes it possible to assess and predict the possible losses of fertilizer from the soil, and thus adjust the doses of mineral fertilizers.

At the same time experimental studies of the process of washing out of fertilizer components and particularly nitrates from the soil, shows that there is a real danger of pollution of the lower layers of soil and groundwater, especially while application of high concentrations of fertilizers. This process is affected by many factors, but the main one is the type of soil with its water permeability, since the higher the water permeability of the soil is, the faster nitrates are washed out from it and the bigger their amount is. So, it is more appropriate to use encapsulated fertilizers on sandy soils, which will reduce the amount of losses to the environment due to the gradual flow of components to the soil.

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