APPLICATION OF ENCAPSULATED FERTILIZERS FOR THE ECOLOGICAL SAFETY OF AGROSUSTEMS

V. Sabadash, J. Gumnitsky, O. Nagursku and O. Ljuta

National university "Lviv Polytechnic"

Abstract: The ecological aspects of mineral fertilizers application were analyzed. The mathematical model of process of the component extraction from encapsulated particles was developed and solved. The component release depending on pH and humidity of environment on kinetic of the component extraction was investigated. The comparisons of solubility of capsulated and granulated fertilizers in an environment are made.

INTRODUCTION

Chemicalixation of agriculture is by a primary factor of its intensification. It is known, that from fertilizers, which have been brought in to a ground, plants acquire only part. On the average for all agricultural cultures operating ratio of fertilizers makes: nitric - 50-60 %, phosphoric 10-25, potassium - 50-60 % [1,2]. A number of ecological problems are connected to it are, such as: salinization, penetrations of fertilizers components in underground water horizons, them has washed off by superficial waters and pollution of reservoirs, etc.

Almost all mineral fertilizers are soluble salts and consequently direct use by their plants connected with velocity of its dissolution and migration in the ground, and, so, are dependent to the quantity of applicated fertilizers during vegetative period. Overstock of atmospheric precipitates results in fast dissolution of fertilizers, its washing away and pollution of the environment. The internal reservoirs become very susceptible to this, as in water in the greatest measure passes accumulation of soluble substances, first of all nitrides. In this connection grows eutrophication of reservoirs and concentration of nitrates in drinking water raises. The insufficient quantity of atmospheric precipitations, in turn, results in dissolution mineral fertilizers mainly, due to underground water. Under such conditions fair quantity of fertilizers is not dissolved and salinization of the soil takes place. These problems in opinion of some scientists, will give rise to denitrification, and together with it the allocation in the atmosphere the fair quantity of nitrogen oxide (I) that destroys the ozone layer.

One of the ways of prevention the pollution of the environment by mineral fertilizers is application of fertilizers with controllable solubility, in particular encapsulated fertilizers. The detailed researches in this area were carried out; influence of the physicochemical properties of environment on processes of component release from encapsulated fertilizers was studied. We have found out, that the decisive influence on the component release has humidity of the ground, due to which occurs dissolution of fertilizers. The target component releases from the encapsulated particle of the fertilizer, which is in damp environment, only after penetration of water through a polymeric shell inside the particle, dissolution of a solid phase of fertilizer and diffusion of components of fertilizer through a polymeric shell in the damp environment.

Therefore mass transfer of a solid phase through a soluble polymeric cover may be separated in three stages, which has its own characteristics. Separately study of duration and the mathematical description of each stage of the extraction process were carried out by us.

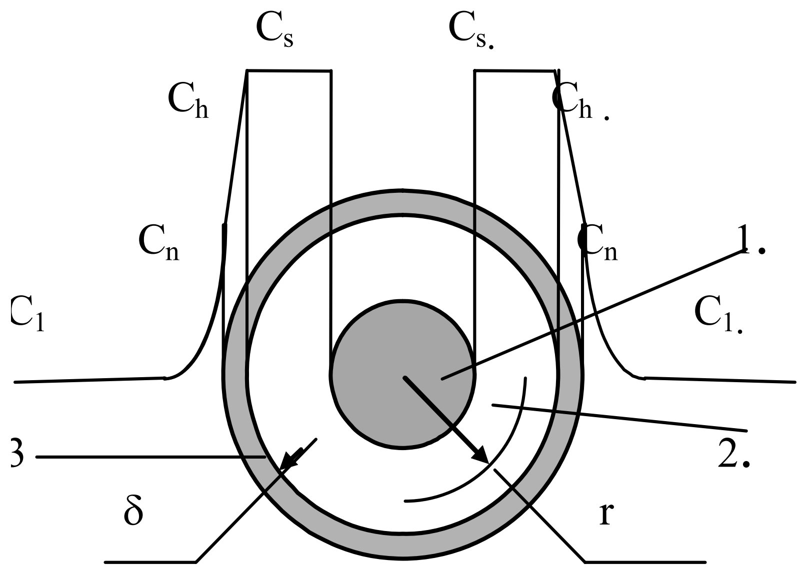


Figure 1. The scheme of the concentrations diffusion during the component extraction from the encapsulated particle: 1- solid phase; 2- the sated solution inside the capsule; 3- polymeric shell.

THE MATHEMATICAL MODEL

The mathematical description permits to calculate the time of the component release from the capsule in the environment. At the formulation of the mathematical model considered the particle to be the spherical form and supposed, that its centre coincides with the centre of the polymeric shell during the all process of the solid substance extraction. In a fig. 1 is submitted the encapsulated particle of the mineral fertilizer at the moment of time of its dissolution τ.

The initial size of the particle designated through R, thickness of the polymeric film through δ. The first stage of the process of component release begins from the moment of immersion the encapsulated particle in to the solvent, infiltration the dissolved fertilizer through the polymeric capsule, and continues to the end by occurrence of the component, which extracts on the surface of the polymeric shell. This time is defined on known dependences [3].

The mathematical model of the second stage of the process, which is by major from the point of view of the active component extraction, was considered, taking into account the following stages:

- Component diffusion from the surface of a polymeric shell, which is dissolved, inside the polymeric capsule, to internal border of the shell;
- Component diffusion through the polymeric shell to its external border;
- Mass transfer of the component from the external border of the shell into the liquid phase of the environment.

The experimental researches have shown, that for well soluble components their concentration inside the encapsulated particle changes insignificantly, so that concentration may be disregarded at the decision of mathematical model. In work it is accepted, that Cs (the concentration on a surface of solid particle) is approximately equalled Ch - concentration on the internal surface of the polymeric environment.

In view of above-stated, the process of component release useful to the component in water environment of the ground, is possible to describe by system of kinetic equations:

$$-\frac{dM}{dt} = 4\pi D_2 \frac{C_h - C_p}{\delta} = 4\pi\beta R^2 \left(C_p - C_1\right) \tag{1}$$

And equation of material balance:

$$\frac{4}{3}\pi R^3 \rho = \frac{4}{3}\pi r_0^3 \rho + \frac{4}{3}\pi \left(R^3 - r_0{}^3\right) C_s + WC_1 \tag{2}$$

Where r, r_0, R - radius accordingly: running, phase of saturation at the moment of time t, the particle at the initial moment of time, t, m;
C_s, C_h, C_1- average concentration accordingly: saturation, on an internal and external surface of an environment and in a solution, kg / m^3;
D_2 – coefficient of the component diffusion in polymeric environment, m^2/s;
β – mass transfer coefficient , m/s;
ρ - density of a solid phase, kg / m^3;
W - volume of the solvent, m^3.

The resistance masstransfer through the shell is considerably large, than resistance masstransfer in the space between the phase of saturation with radius r_0 and internal surface of the environment with radius R. According to such assumptions of outcomes of the equations (1) and (2) permits to receive dependence between the radius of solid particle and from time to time of extraction t.

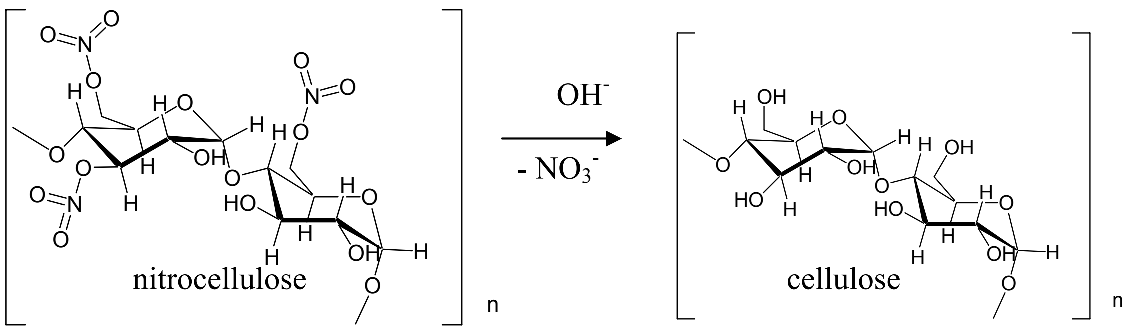
$$\frac{1}{3}\ln\left[\frac{a^3 + R^3}{a^3 + r^3{}_0}\right] = \frac{1}{\frac{\delta}{D_2} + \frac{1}{\beta}} \frac{C_S}{\rho} \frac{R^2}{a^3 + R^3} t, \tag{3}$$

Where, $a^3 = \frac{3}{4}\frac{WC_S}{\pi(\rho_T - C_S)} - R^3$

The third stage of process will begin when the solid phase inside the polymeric capsule will be dissolved and continues to the moment of achievement of dynamic balance. The time of achievement of balance is directed to limitless owing to decrease of driving force of process. The carried out researches have shown, that the basic influence on the extraction process on the second stage of the process is small, you see by insignificant increase of concentration in III-d stage is possible to ignore.

THE INFLUENCE OF PHYSICOCHEMICAL CHARACTERISTICS OF ENVIRONMENT ON THE PROCESSES OF COMPONENT RELEASE.

To research the influence of pH of the environment on kinetic of the component release an active component was used as particles of the spherical form made from magnesium sulphate and covered by nitrocellulose shell [5]. The speed of extraction of target components through the polymeric cover in the environment of the solvent depends in this or that measure on many factors such as: behaviours of polymer and active component, release of which from the capsule is by the purpose of process, conditions of the process of covering fertilizers, its thickness, structure. The permeability and electrolyte diffusion is adjusted by hydrophilic-hydrophobic balance of parts of nitrocellulose macromolecules. Besides that under the influence of pH of the polymeric shell the orientation of molecules of polymer varies. In sour environment ethers of cellulose are stable, and in alkaline environment the chemical reaction takes place, owing to which the nitric functional group substitutes by hydroxyl group [5]. These factors result in increase of coefficient of diffusion of the target component through polymer. It is explained by reduction of the factor of molecular packing of polymer, that increases the part of free volume (void content) in packing macromolecules. The hydroxyl group has the considerably smaller size, than nitric functional group: according to the accounts which have been carried out according to dependences, submitted in [4], volume of group OH^- is 6,7 $\mathring{A}^3$, volume of group NO_3 is 33 $\mathring{A}^3$. For comparison of molecular packing of cellulose makes 0,78, and nitrocellulose 1,36 [4].



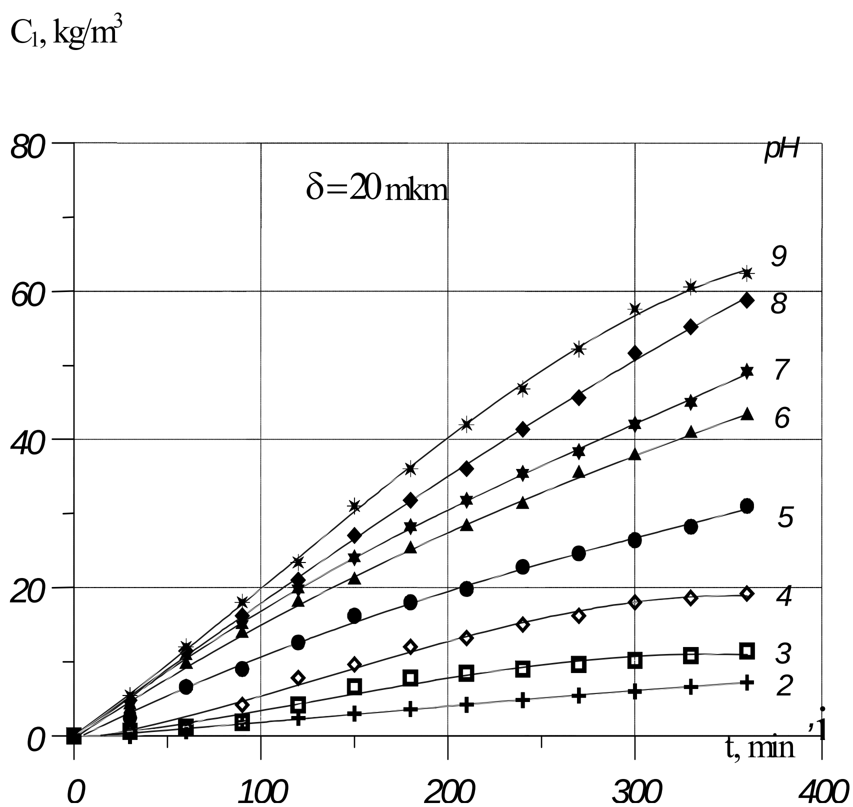


Figure 2. Dependence of the concentration of active component in a solution from the time at different pH of environment, thickness polymeric capsule is 20 microns.

Besides as a result of chemical interaction and physicochemical processes (superficial phenomena) on a surface of an capsule the micro cracks turn out which assist the increase of permeability of the polymeric shell.

Owing to increase of permeability of the polymeric shell, at increase of pH of environment the velocity of the target component extraction increases [5]. Dependence of the concentration of released component C_1 in the solution from time t at different pH of the solution is submitted in the fig. 2.

For definition of the influence of humidity of environment on kinetic of the target component release from polymeric capsule were used the spherical particles, made from ammonium nitrate (NH_4NO_3) and covered by the polysterene polymeric shell.

In this purpose measuring cell filled by sand (porosity 0,4) and filled in by distilled water, creating thus environment with the certain humidity W.

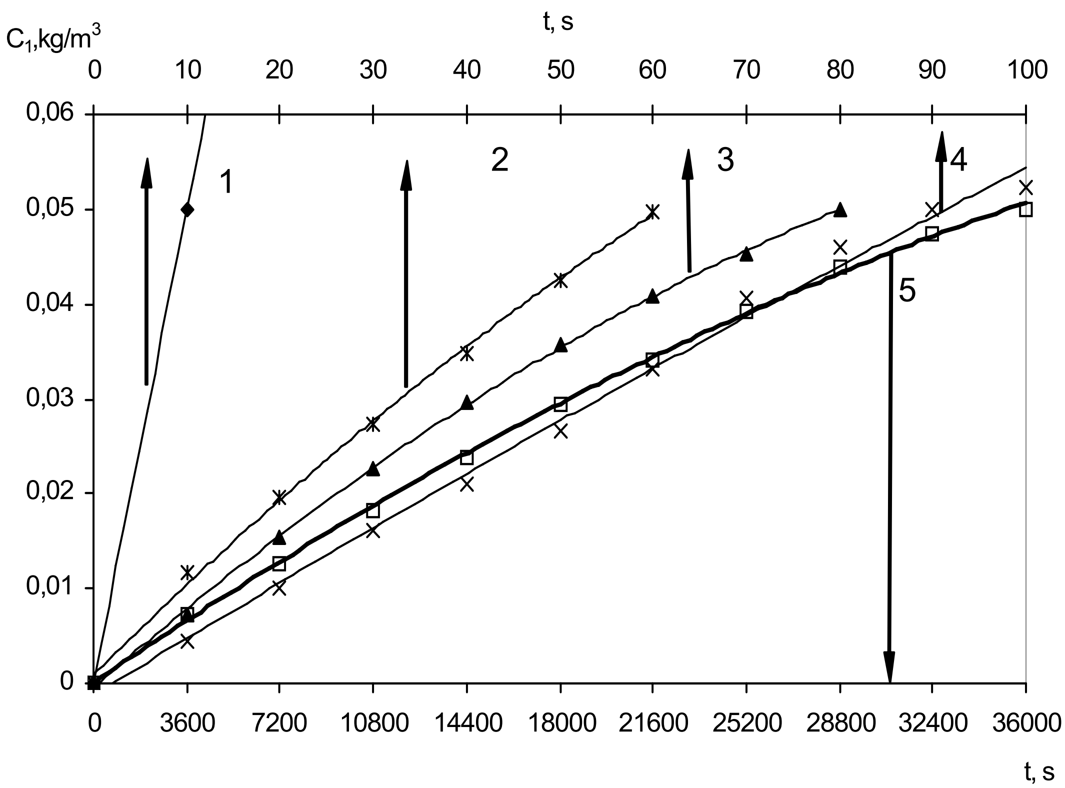


Figure 3. Comparisons of solubility granulated and encapsulated fertilizers in damp environment at humidity of environment W=25 of %: ■ - encapsulated fertilizers covered by the polymeric shell d=20 micron; ♦ - humidity of environment; ▲-granulated fertilizers.

For comparison investigated granulated and encapsulated by polystyrene NH_4NO_3. As it is visible from a fig. 3, granulated fertilizer in identical conditions (constant temperature and the humidity) was dissolved for few seconds, while the encapsulated fertilizer is dissolved much longer. Achievement of the same concentration C_1 in environment continued approximately ten hours. In comparison, the uncovered fertilizers were released 12 seconds. It means, that the granulated fertilizer accumulates very fast in a soil, which promotes washing away of fertilizers in to the underground water horizons (fig. 3). Application of encapsulated fertilizers permits to adjust the component release, according to need of plants in nutritional elements, avoiding thus the losses of fertilizers by washing away and destruction.

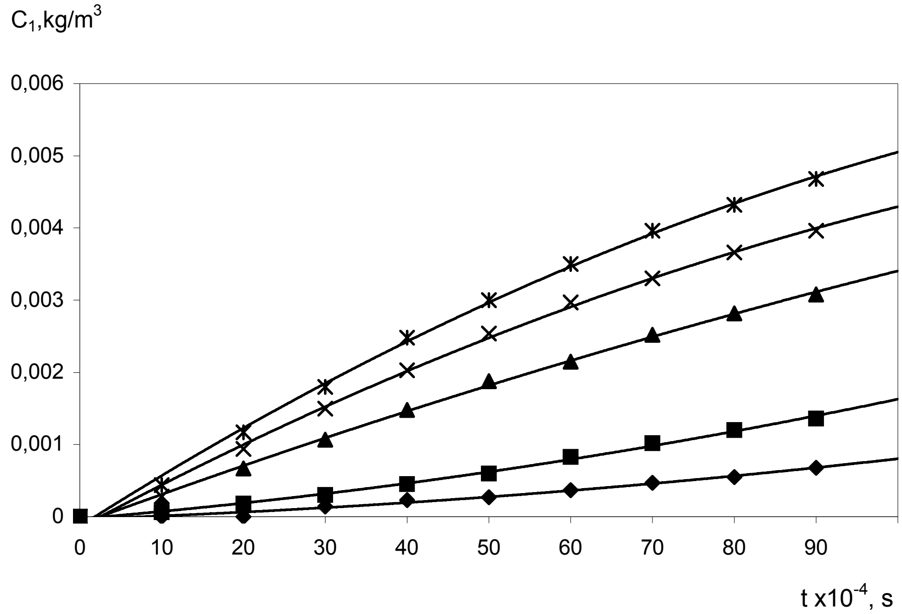


Figure 4. Dependence the velocity of component release of encapsulated fertilizers to humidity of environment: ♦ - 10 %; ■ -15 %; ▲-20 %; x-25 of %; *-30 %.

Solubility of the encapsulated particle in the inert granular environment at its different humidity was investigated. (fig. 4). As it is visible from the diagram at increase of humidity of environment the velocity of fertilizers extraction grows. The tendency to increase of speed of the component release from the polymeric capsule at increase of humidity of the environment is explained to that in liquid environment the shell completely contacts to the solvent. In such conditions the area of the surface of masstransfer is maximal. Besides that in the liquid the released component is transferred by masstransfer. Hence in the environment the uniform distribution of the component and low concentration of released substance on a surface of capsule will be observed, that provides high driving force of the process. Opposite, in inert granular environment, that simulates ground, takes place molecular diffusion of the extracted substance. The process passes something more slowly as a result of smaller value of coefficient of molecular diffusion. On the surface of capsule collects the released substance, that reduces driving force of the process. In the dry environment the masstransfer does not occur because of absence of contact of phases. From here comes up, that at reduction of the mass part of the moisture in environment, the process of extraction will be slowed down.

Therefore for regulation of the velocity of component release it is possible to calculate the thickness of the polymeric capsule of fertilizers, according to needs of agricultural cultures in nutritious elements and physicochemical properties of the environment.

Proceeding from the research data we can see, that the intensity of growth of plants appreciably depends on the doze of nutritious elements (Fig.5).

During the period of vegetation at realization of irrigation the contents of the washed up mineral fertilizers in filtrate were analyzed. Thus the following ratio of the brought in amount of fertilizers to losses of nutritious substances was observed by washing away and assimilation of fertilizers by plants. The analysis of the filtrate explained, that at preplant entering of fertilizers the significant quantity of granulated fertilizers is washed away. In the same time, at application of encapsulated fertilizers is not observed of essential losses of nutritious substances, that provides an optimum nutrition of plants during the period of vegetation.

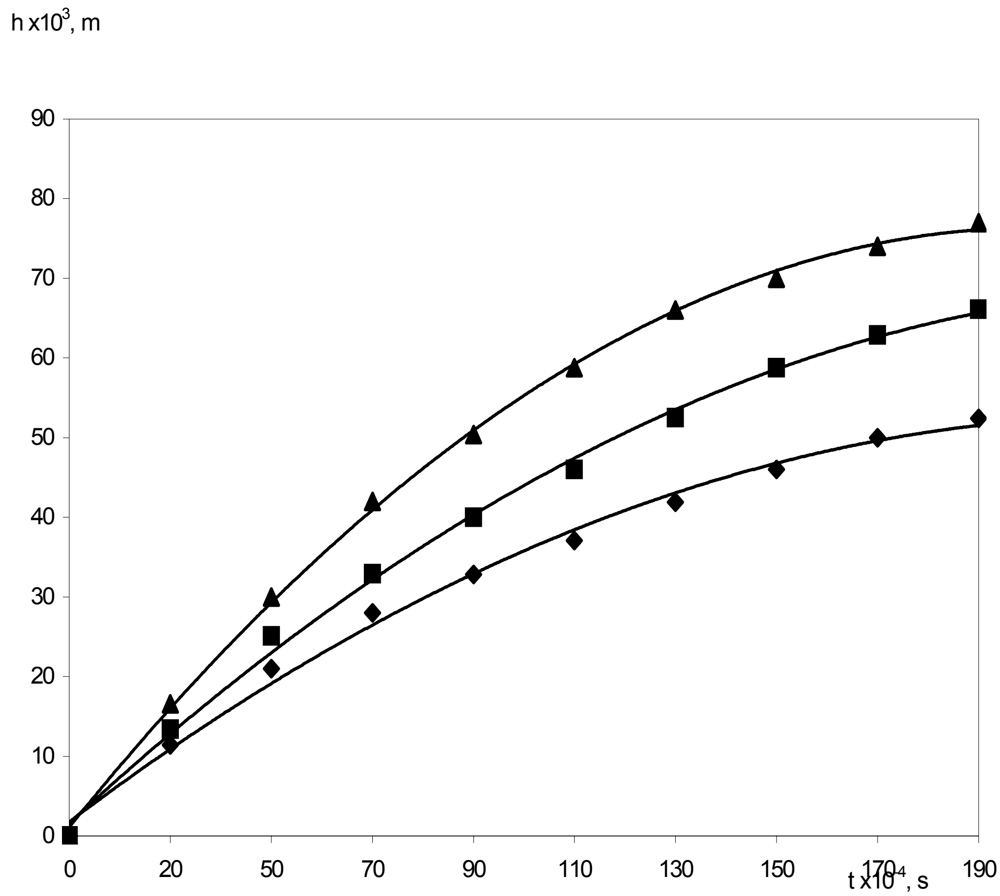


Figure 5. Kinetic of watercress depending on agrotechnics ▲- encapsulated fertilizers,■-classical agrotechnics, ♦-without fertilizers.

In conditions of the given experiments the following dependence of nutritious elements release from encapsulated fertilizers in time, when the periodic humidifying of the soil is applied was observed (fig. 5).

For reduction of expenses by manufacture of fertilizers it is offered to produce capsules from polystyrene wastes. It will permit also polymeric emissions utilization.

With the purpose of reduction of influence by an environment it is offered to use as the shell for encapsulated fertilizers the polymeric composition, that is capable biologically to be decomposed. For this purpose except for high molecular the bases (polystyrene) are offered to be used substances, are capable to accelerate biodegradation of polymer (biodegradable addition).

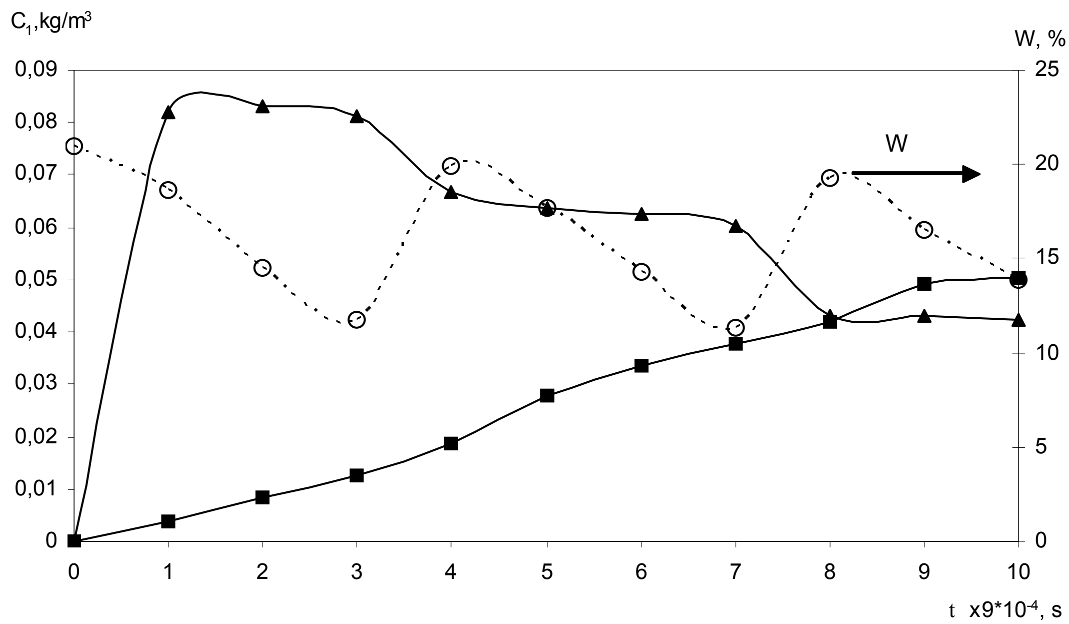


Figure 5. Influences of periodic humidifying of the soil of the target component release from encapsulated fertilizers ♦ - humidity of environment; ■ - encapsulated fertilizers covered by the polymeric shell d=20 micron; ▲-granulated fertilizers.

THE USE OF RESULTS FOR ARRANGE SURFACE COVER

Speed of component release depends from the thickness of polymeric capsule. This fact may be used for regulating the time of component release. According to the value of the process speed may be calculated the thickness of coating. It is very important, because there are a lot of different sorts of soil in accordance to such parameters as acidity, moisture content, ets. Each of them makes a considerable contribution on the speed of component release. That is why carried out experiments are very important for apply capsulated fertilisers with definite thickness of shell in accordance of type of the soil. With the purpose of reduction of influence on the environment is offered to use as an environment for encapsulated fertilizers a polymeric composition, which capable biologically to be displayed. For this purpose except the high-molecular-weight plasticize are offered to be used substances capable to accelerate biodegradation of polymer.

REFERENCES

[1] Городній М.М. Шикула М.К. "АГРОЕКОЛОГІЯ"-К."Вища школа", 1993 р.

[2] Кондратов А.П. Капсулирование в полимерных пленках – М.: Химия 1990, 190 с.

[3] Аскадский А.А. Химическое строение и физические свойства полимеров.-М.:Химия, 1983.-248с.

[4] Аксельруд Г.А., Альтшшулер М.А. Вверение в капилярно-химическую технологию.-М.: Химия.-1983.-264с.

[5] Аскадский А.А. Химическое строение и физические свойства полимеров.-М.:Химия.-1983.-248с.