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Development of the Technology of Capsulated Fertilizers Based on the Composition Natural Sorbent-lignin and Determination of Their Resistance to Attrition

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Abstract: The principal technological scheme of capsulated fertilizers production with use of lignin and natural dispersed sorbents as a film-forming composition has been developed. The process of fertilizers capsulation in conditions of a boiling layer is described. Material balance of capsulation process has been calculated. Resistance to attrition of sample units have been investigated in the laboratory conditions.

Key words: capsulated fertilizers, lignin, natural sorbents.

INTRODUCTION

Nowadays it is hard to imagine the development of agriculture without mineral fertilizers. But together with positive effects (harvest increase, increased quality of food), massive use of mineral fertilizers creates many environmental problems. The biggest problem is environment pollution by residual agrochemicals. Components, which remain unused by plants, leak to water basins and, in case of nitric fertilizers use, also to the atmosphere as nitrogen (I) oxide. The part, which is digested by plants amounts to 0.4÷0.6[1], so roughly one half of distributed synthetic fertilizers becomes a potential environment pollutant. One of the effective methods of avoiding this problem is to create prolonged-action fertilisers, fertilizers capsulated in water-soluble film. Such form allows prolonging the fertilizer action for a significantly longer time, so it allows to decrease the frequency and quantity of their distribution, and also to minimize the dissipation of nutritious elements to the environment. Though, the price of film-forming composition and technological process of film covering is quite significant, so the price of such fertiliser will be much higher comparing with traditional fertilizers. That is why the development and introduction of new technologies of capsulated mineral fertilizers with use of cheap and effective materials for film creation will lead to economically efficient and environment-friendly fertilizers for the agriculture industry.

Critical analysis of the literature and patents for granulated fertilizers have shown that there are 2 main trends among new researches:

1. Prolonged action fertilizers with the regulated release of nutrients;
2. Introduction of microelements, as separate compounds or as the waste product, to the fertilizer content.

Technologies of the first trend can be divided to few groups, depending on the production method of prolonged-action fertilizer:

- high pressure compacting or pelleting in high temperature;
- covering of granules with polymer film, hard-to dissolve or insoluble compounds;
- addition of sorbents of macro- and microelements of natural and synthetic origin.

In order to minimize the water absorbency, caking and fast solving in the soil, the fertilizer granules are covered by films of different content. The authors[2] suggest covering fertilizers by a substance which includes carbamide, partly bound with formaldehyde, humidifier, water and chelate compound of copper. In accordance with the known method[3] the prolonged-action fertilizer is received by combining of ammonia nitrate, carbamide – formaldehyde tar and microelements in mass proportion (1 – 1.2) : 1 : (0.1 – 0.2) under temperature 40 – 60^{0}C with subsequent addition of magnesium salts, polyalkyl siloxane and N-P-K fertilizer in mass proportion (0.01 – 0.02) : (0.01 – 0.15) : 1, which amounts to 85-90% of fertilizer's total mass. The received substance is pelleted under temperature of 70 – 110^{o}C. The disadvantage of this method is a need to use high temperatures and pelleting equipment, which are known for their high

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energy demand. So, the technological process of receiving such fertilizer requires considerable energy resources.

In the experiment[4] the surface of complex fertilizer granules was covered by liquid sulphur, which made it possible to get the prolonged effect and add one more nutrition element to the fertilizer's content. In[5] potassium chloride granules were covered by copper sulphate film with their further thermal treating in 190 – 425ºC. The methods of covering granules by film of organic polymers are still used, which decreases the speed of nutrients release, but also removes water absorbency, caking, improves mechanical characteristics of the granules. In the work[6] it is suggested to cover granules with the layer of polymer film 5 – 110 micrometer thick, which allows cumulative release not more then 10% of the fertilizer during 30 days. A similar effect can be reached by covering the granulated fertilizers with the film of polyurethane[7], thermo reactive[8] or urea-formaldehyde tars[2].

By covering of fertilizer granules with a film, their physical, chemical, mechanical and agro-technical qualities are increased, but the films are partly destroyed in soil, especially salt-based, which decreases the effectiveness of this group of methods of granulated fertilizers production.

Based on the analysis, it can be summarize that the known methods and technologies are multi-stages and high energy consuming, so the net cost of such granulated fertilizer will be quite considerable.

It is suggested to use natural dispersed sorbents – zeolite, glauconite and bentonite – as well as the by-product of paper and cellulose production – liquid soap - as the components for film creation[9]. One of the main reasons for limited use of capsulated fertilizers in the agriculture is their relatively high price. The use of natural materials with minimal added costs as well as industrial wastes will decrease the end-product cost.

The investigations[9] proved that the highest firmness of the samples is reached under minimal use of lignine. It is impossible to decrease the lignine even more, since the blend does not become paste-formed and forming of granules becomes impossible. That is why such blend can not be used for forming of prolonged-action film on fertilizers.

On the other hand, the investigations have proved that the content of lignine in sorbent:lignine mixture higher than proportion 5:4 leads to substantial decrease of firmness, which makes it impossible to use for fertilizer capsulation.

MATERIALS AND METHODS

For determination of the mechanical firmness, a 200 g sample was placed in the device for granulometric content determination РКФ-2У on the top sieve #20, which was installed above the sieve #10, so the particles less then 1mm were separated. The sample mass which was left on sieves #10 and #20 was weighed and placed into cylinder ПКПГ-1 for determination of their dynamical firmness and resistance to rubbing out. Steel balls with the diameter 5 mm were put into the cylinder in quantity corresponding to the mass of the sample. Time of the experiment – 10 minutes.

The device ПКПГ-1 consists of parallelepiped container with the dimensions: $3x3x1{,}25 \cdot 10^{-1}$m. Inside the container there is a diagonal spade: length $2{,}25 \cdot 10^{-1}$ m and width $5 \cdot 10^{-2}$ m, which is used for stirring granules. Front wall of the container is made from an organic glass, which allows observation of the process. Angular speed: 5 radians per second.

After the experiment, steel balls were taken out of the cylinder with the use of magnet and again the particles less then 1mm were sieved out. The particulates that were left on sieves #10 and #20 were weighed.

Dynamical firmness and resistance to rubbing out X is calculated as:

$$X = \frac{m_1}{m} \times 100 \qquad (1)$$

where m – mass after the first sieving out, g;
m_1 – mass after the second sieving out, g.

RESULTS AND DISCUSSION

An important stage of the investigation is capsulation technology development, which will allow to establish production and use of new fertilizer. The production process of N-P-K fertilizer, capsulated by a film from lignine and natural dispersed sorbent, consists of two main technological stages:

1. preparation of film-forming blend;
2. covering of the granulated fertilizer.

Balance scheme for production of 1 tonne of final product, considering that the cover is 20% from the fertilizer mass and assuming 5% loss of film-forming blend, is the following:

- granulated N-P-K fertilizer – 800 kg;
- film-forming blend (dry product) – 210 kg.

For production of 210 kg of film-forming blend, when calculating for dry product, the components and their required quantities for different proportions are presented in the Table 1.

The data from Table 1 regarding water and lignine are calculated with regards of 20% content of free

Table 1: Material balance of prolonged-action fertilizers production

Components	Proportion sorbent:lignine			
	5:1	5:2	5:3	5:4
Sorbent, kg	175.0	150.0	131.3	116.7
Lignine, kg	43.8	75.0	98.5	116.7
Water, kg	102.8	88.2	77.1	68.6

Table 2: Dynamical firmness of N-P-K fertilizer, covered with a mixture natural sorbent – lignine

Cover type	Zeolite: lignine			Bentonite: lignine			Glauconite: lignine		
Components content	5:2	5:3	5:4	5:2	5:3	5:4	5:2	5:3	5:4
X, %	93	94	96	92	95	97	95	95	97

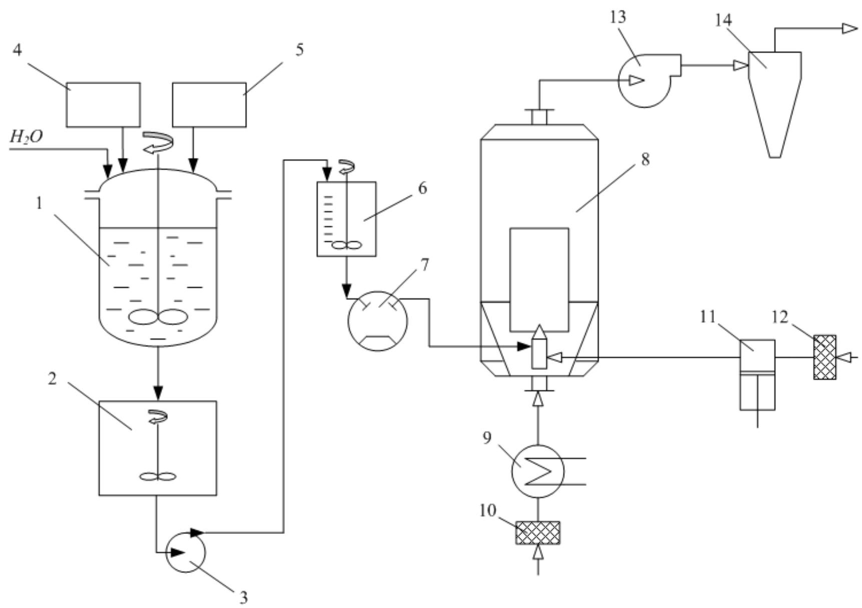

Fig. 1: Technological scheme of capsulation of granulated N-P-K fertiliser:

moisture in lignine. Since different supplies of sulphate soap from paper and cellulose production can differ in their water content, the re-calculation of these figures might be necessary.

The technological scheme developed for the process of capsulation of granulated N-P-K fertiliser is presented on the Figure 1.

Figure 1. Technological scheme of capsulation of granulated N-P-K fertiliser:
1 – container for film-creating suspension; 2 – collector with mixer; 3 – centrifugal pump; 4 – sorbent dosimeter; 5 – lignine dosimeter; 6 – film-creating suspension dosimeter; 7 – dosing pump; 8 – boiling layer apparatus; 9 – heater; 10, 12 – air filter; 11 – compressor; 13 – centrifugal blower; 14 – air cleaning system.

Fluidized bed state in the apparatus is created by transmission of gas with a certain speed through the layer of dispersed material which is placed in perforated diaphragm. During this, the flow of diluting agent is heavier then the layer of the material. Material particulates are intensively mixed in the air flow, bumping against each other and against the device walls. Such conditions require a certain firmness of the material, the particulates and their cover. The base granulated N-P-K fertilizer that is to be capsulated have sufficient firmness qualities. That is why it is required to investigate the mechanical characteristics of film-creating composition, which can limit the firmness of capsulated fertilizer.

For preparation of film-creating suspension the container 1 is used, it is equipped with a mixing device. It is filled with sorbent from dosimeter 4, lignine from dosimeter 5 and water. During 24 hours the sorbent is being saturated with water. From container 1 the ready film-creating composition is transferred to collector 2. Then, gradually, it is transferred to dosimeter 6 by pump 3. Collector 6 and dosimeter 6 are equipped with a mixing device in order to prevent sedimentation of suspended solid phase.

Capsulation of N-P-K fertilizer is performed in the boiling layer apparatus 8 of cylinder-conical type with orienting cylinder of sequenced action. In order to avoid any possible unwanted effects in the layer of solid particles and to organize their circulation the special devices are used, which are equipped with orienting dividers. Vertical dividers have different forms and are used to separate particulates layers onto covering zone and drying zone. In the covering zone a spraying device is installed.

Granules, which enter covering zone through the gap between lower part of the divider and gas-spreading grid, are sprinkled with the suspension and are transferred to the drying zone. The speed of air is low here, so the particles which sink down go to the covering zone again.

The gas-spreading grid has higher percentage of openings surface in the zone of covering than in the drying zone. This allows creating upflow granules movement, delivering more air into the covering zone. The presence of vertical dividers, which break the volume of the apparatus on sections allows not only to arrange the movement of particles but also to increase the quality of fertilizer capsulation thanks to creation of more uniform layer[1].

After loading of fertilizer into the boiling layer apparatus the material is fluidized with the help of centrifugal blower 13. At the same time the particulates are heated to the working temperature while dust-like fertilizer particles are removed, otherwise they decrease the quality of covering.

After working temperature is reached in the apparatus working zone, the film-creating composition is transferred to the apparatus with the use of dosing pump 7. Spraying of film-creating composition is done with the use of pneumatic injector, which is supplied with air from the compressor 11 with the pressure of 2 atmospheres.

In order to avoid any dust-like particles presence in the apparatus, the technological air is previously cleaned in filters 10 and 12.

In the process of dust removal from the fertilizer layer the polluted air if created, which is cleaned at the apparatus exit in the system 14. In order to prevent polluting substances leakage from the system, underpressure is created with the use of the gas blower 13.

For maintaining the technological conditions of work the cover distribution device is equipped with an automatic system of air consumption and temperature regulation.

The proposed scheme described above has been built in the laboratory of Lviv National Polytechnic University. At the laboratory scale installation the proposed technology of fertilizer capsulation has been approbated.

Coefficients of inner diffusion of N-P-K solution in the cover layer, which is made from paper and cellulose production waste – lignine and natural sorbent (zeolite, bentonite and glauconite) in components proportion 1:5, 2:5, 3:5, 4:5 were experimentally determined. The exponential dependences of cover permeability with different proportions of the cover composition components have been got.

Results of experiments with fertilizers cover of 20% from the total fertilizer mass are summarized in the Table 2.

Based on received results, N-P-K capsulation by the mixture of natural sorbent – lignin did not influence on its dynamical firmness and resistance to rubbing out (according to regulations this parameter should not be lower then 80% for granulated fertilizers used in Ukraine). This figure is slightly increasing with the increase of lignine content.

Summarizing the performed investigation it can be concluded that it is possible to capsulate granulated mineral fertilizers by the film which is based on natural dispersed sorbents with use of hydrolysis lignine as a binding component and which is a by-product of a paper and cellulose production. The received cover has good mechanical firmness and low water absorbency, which is proven by the absence of caking indications in the process of capsulated fertilizers storing in an open container.

Conclusions: The use of natural sorbents as raw materials for capsulation of mineral fertilizers increases physical and chemical qualities of the cover and a fertilizer itself. The use of such fertilizers can benefit in prevention of environment pollution by residual mineral fertilizers and solve the problem of long-time preservation of nutrients in soil with their gradual release.

In order to create effective film-creating compositions it is advised to use a binding component, which can be a waste of paper and cellulose production, hydrolytic lignine in particular.

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