Production of Crystalline Urea Phosphate using the Untreated Jordanian Wet Process Phosphoric Acid

Yousef A. Mubarak *

ABSTRACT
Relatively pure and large crystalline urea phosphate of 17-44-0 (N-P₂O₅-K₂O wt%) grade has been obtained from untreated Jordanian wet process phosphoric acid of about 50 % P₂O₅ content. The modified procedure involves the addition of a certain percentage of mother liquor to the urea and untreated wet process phosphoric acid in the reaction vessel. The preferred reaction temperature was found to be 45°C, and the reaction and nucleation (crystallization) time is 2 to 3 hr. The slurry must be pumped to the cooled crystallizer at 15°C to allow further growth of the urea phosphate crystals and increase product recovery. The urea phosphate crystals produced contain about 80 % of the urea, and phosphoric acid feeds and almost free of the impurities present in the wet process phosphoric acid. This modified procedure has some advantages over the conventional procedure in many aspects such as easy agitation and pumping, less cooling, easy separation of the urea phosphate crystals from the mother liquor, efficient drying, and low energy consumption.

Keywords: Urea phosphate, Crystals, Growth, Wet Process Phosphoric Acid, Crystallization.

INTRODUCTION

Chemical fertilizers are used to supply the plants with the required primary nutrients (nitrogen, phosphorus, and potassium) in addition to secondary nutrients (calcium, magnesium, and sulfur). Normally plants can obtain these nutrients from the rich soil in order to grow and increase crop. Chemical fertilizers are necessary for most types of agriculture and especially in intensive systems from which high yields are sought and where the unsupplemented soil cannot supply nutrients quickly enough or insufficient quantities to meet the requirements of the crops (Jones, 1987).

Urea phosphate is an organic compound composed of carbon, hydrogen, nitrogen, oxygen and phosphorus. Its formula is CO(NH₂)₂.H₃PO₄. It is a dry, white crystalline material that melts at 117.3°C and contains 17.7% nitrogen (N) and 44.6% P₂O₅. Urea phosphate is acidic, very soluble in water (960 g/l at 20°C) and has a specific gravity of about 1.76. The critical humidity of the material is 75 to 80% at 30°C and is similar to urea. Agronomic tests of the material have shown that it is an efficient source of nitrogen and phosphate for plant growth (Gasser and Penny, 1967). Urea phosphate is a valuable product with great potential as a finished fertilizer, and as an intermediate in the production of solid and liquid fertilizers containing polyphosphate; it is often used in drip irrigation to clean the pipe system (Wilbanks and Faulkner, 1980). Urea phosphate was also successfully used as a specialty cleaner and as an active ingredient in some detergent compositions. It is also used as a food additive mainly for cattle (Kiiskinen, 1983).

One of the main raw materials used to produce urea phosphate is phosphoric acid (H₃PO₄) which has different impurities commonly found in the wet process phosphoric acid. These impurities include dissolved and suspended materials, both organic and inorganic in nature. Sources of these contaminants come from phosphate rock, the sulfuric acid, and processing equipment that is physically and chemically attacked during the manufacturing steps (Feki et al., 1987). The relative amounts of these impurities vary considerably among producers who use different raw materials and production methods.

Excessive amounts of impurities can have several adverse effects on the phosphoric acid produced. Among these include the impartation of undesired color or turbidity, change of physical characteristics such as viscosity and
density and sludge formation (El-Asmy et al., 2008). Actually the major problem faced the producers of urea phosphate is the availability of a constant source of the wet process phosphoric acid. For example, the acid produced in Aqaba by the Jordan Fertilizers Company suffers from the variation of the P$_2$O$_5$% from batch to batch. In the mean time, the percentage of solid materials and the impurities level present in the acid varies and makes it impossible to produce any stable product. The presence of these solids and impurities in the acid when used in the production of the urea phosphate crystals, as an example, makes the color of the final product light green, and when the urea phosphate is dissolved in water it makes water turbid which does not suit the customers. The other major problem is the physical appearance of the final product: oily, sticky and requires long time in the dryer and the final dryness is not satisfactory.

Nowadays, locally and globally there is an increasing demand on fertilizers especially crystalline urea phosphate for its valuable nutrients. Hence; the main objective of the present work was to find a suitable way in which a crystalline and clear urea phosphate without impurities is produced locally and in many other countries using the conventional method illustrated in Figure 1. It has been noticed that this method faces the following problems and difficulties:

- **a) Dissolution Time:** since the reaction between urea and phosphoric acid is exothermic, the conventional method excludes the heating step at the beginning which takes very long time to dissolve the urea prills. A liquid mixture (free of any solid urea prills) of urea and phosphoric acid never obtained without the aid of extra heating; a solid urea free mixture is a very important step in the production of crystalline urea phosphate.

- **b) Continuous Cooling:** production of urea phosphate according to the conventional production method requires the cooling water to flow in the cooling jacket of the reactor during the whole process (reaction, nucleation, crystallization, and growth) which means extra cost for pumping of cold water and then refrigerating the cooling medium to keep it within a suitable temperature.

- **c) Transferring:** pumping the urea phosphate slurry from the reactors to the collecting tanks above the centrifuges via pipe lines by the aid of a pump is considered a very slow step in the production process. The low fluidity of the slurry makes it hard and takes long time to pump and transfer the very viscous and thick slurry.
Figure 1: Schematic diagram for the urea phosphate production by the conventional method.

d) **Centrifuging:** due to the presence of the urea phosphate fine particles produced by the conventional method, an appreciable amount of these fine particles comes out with the filtrate, which reduces the recovery and makes it necessary to leave the mother liquor to settle down for another day to collect the escaped urea phosphate fine particles in another cycle.

e) **Drying:** as a result of the high percentage of impurities within the wet process phosphoric acid, it is not easy to produce large crystals of urea phosphate in a low fluidity medium; a very fine and almost oily or sticky product is obtained and makes it very hard to be dried even with a high air temperature and long residence time inside the dryer.

f) **Recovery:** in the conventional production method, two cycles are required for each batch to obtain the required urea phosphate recovery, and again this is considered as a waste of time and power. The mother liquor leaving the centrifuge contains a large amount of fine urea phosphate particles so it is necessary to leave this liquor to settle and continue the crystallization process, which may require another cycle of cropping to increase the recovery.

g) **Fuel Consumption:** due to the oily, sticky appearance, and the very fine crystals of the urea phosphate powder produced, a high temperature medium is used to dry the product. In order to get this high medium temperature, more fuel is burned to raise the temperature of the air to almost 80–90°C, which means a high consumption rate of fuel. On exit from the drying process, the product still suffers the sticky and oily appearance.

To overcome all the above mentioned problems and produce a crystalline urea phosphate free of impurities, the present work was carried out and the results seem very promising.

### EXPERIMENTAL WORK

**Materials:**

Urea in the prilled form is obtained from the local market with a nitrogen content of 46%. Table 1 presents the prilled urea specifications. Wet process phosphoric acid produced by Jordan Phosphate Mines Company is used without any treatment. Table 2 shows the chemical analysis of the wet process phosphoric acid.

<table>
<thead>
<tr>
<th>Total nitrogen (wt %)</th>
<th>46 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biuret content (wt %)</td>
<td>1 max</td>
</tr>
<tr>
<td>Formaldehyde (HCHO) (wt %)</td>
<td>0.45 min</td>
</tr>
<tr>
<td>Crushing strength (kg)</td>
<td>2 min</td>
</tr>
<tr>
<td>Moisture (wt %)</td>
<td>0.5 max</td>
</tr>
<tr>
<td>Particle size (wt %)</td>
<td>2-4 mm……90% min</td>
</tr>
<tr>
<td></td>
<td>&gt; 4 mm ………7% max</td>
</tr>
<tr>
<td></td>
<td>+2.8 mm……60%min</td>
</tr>
</tbody>
</table>

**Table 2: Chemical analysis of Jordanian wet process phosphoric acid**

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>S.G. at 20°C</td>
<td>1.632</td>
</tr>
<tr>
<td>P₂O₅ (wt %)</td>
<td>50 - 52</td>
</tr>
<tr>
<td>SO₃ as H₂SO₄ (wt %)</td>
<td>3.05</td>
</tr>
<tr>
<td>Solids (wt %)</td>
<td>0.74</td>
</tr>
<tr>
<td>CaO (wt %)</td>
<td>0.08</td>
</tr>
<tr>
<td>Cl ppm</td>
<td>89</td>
</tr>
<tr>
<td>F (wt %)</td>
<td>0.51</td>
</tr>
<tr>
<td>Al₂O₃ (wt %)</td>
<td>0.39</td>
</tr>
<tr>
<td>Fe₂O₃ (wt %)</td>
<td>0.43</td>
</tr>
<tr>
<td>MgO (wt %)</td>
<td>0.41</td>
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**Procedure:**

Figure (2) presents a schematic diagram for the procedure followed in the present work to obtain the urea phosphate crystals.

Wet process phosphoric acid and solid urea are weighed in an eqimolar ratio and added to the reactor vessel at room temperature. The mother liquor is added to the mixture, and the whole mixture is brought to the required temperature.
using a heating element; the temperature of the mixture should be enough to melt the urea prills and get a liquid mixture free of any solid particles. After a specified time, the mixture is transferred from the reactor to a controlled temperature crystallizer, where the mixture is agitated at a slow speed of about 80 rpm to keep the growing crystals suspended within the mixture.

Upon completion of the crystallization step, a centrifuge, at a speed of 1200 rpm, is used to separate the urea phosphate crystals from the mother liquor. The urea phosphate crystals are then dried at a temperature of 40°C for enough time until they get dry. The mother liquor is stored and used as a recycle. The wet process phosphoric acid, dry urea phosphate crystals, and the mother liquor was analyzed for each run to determine their N and P₂O₅ contents.

Figure 2: Schematic diagram for the crystalline urea phosphate production by the suggested method.

The studied parameters:
There are many factors affecting the production process and the quality of the urea phosphate. In the present work, the following parameters have been studied: recycled mother liquor/H₃PO₄ ratio, nucleation temperature, nucleation time, crystallization temperature, and crystallization time.

Recovery of urea phosphate crystals calculation
The recovery of urea phosphate crystals is calculated by using the following equation:

\[
\text{Recovery (wt %)} = \frac{\text{UP crystals obtained experimentally}}{\text{UP crystals obtained theoretically from the chemical reaction}}
\]

According to the chemical reaction equation (1), a reaction of 1 mola of H₃PO₄ (98 g) with 1 mole of urea (60.05 g) will produce 1 mole of urea phosphate (158.05 g). This theoretical value (158.05) was used in the calculation of the recovery of urea phosphate crystals once they are produced experimentally and weighed after the drying process.

Measuring urea phosphate crystals size
To obtain the urea phosphate crystals size, few crystals (at least 10) were measured under an optical microscope with a magnification of 190X for each run. The measured crystals were then averaged; the obtained value is used as an average value for the crystals size.

RESULTS AND DISCUSSION
1. Fluidity of the medium in which urea phosphate crystals nucleate and grow
Increasing the fluidity of the mixture (represented by
different weight ratios of recycled mother liquor to $\text{H}_3\text{PO}_4$ has some advantages over the reaction of reactants without the mother liquor; some of these advantages are (Lewis and Dillard, 1984):

- Easily agitates and reduces in the power required to keep the slurry moves and prevents the crystals from settling at the bottom of the vessel.
- Prevents the build up of a urea phosphate layer on the inside wall of the reactor and crystallizer which reduces the heat transfer between the coolant and the slurry.
- Increases the available space which urea phosphate crystals need to grow up and give large size.
- The resulted urea phosphate crystals can easily be separated from the mother liquor due to the large amount of liquid.
- Most of the mineral impurities accompanying the wet-process phosphoric acid remain in the mother liquor.

On the other hand, high recycled mother liquor to $\text{H}_3\text{PO}_4$ ratio has some disadvantages such as the size of the equipments and the required time for the production process. Larger reactor and crystallizer sizes are required to give a reasonable production rate because most of the equipment’s volume will be occupied by the recycled material. In addition to that longer reaction and crystallization time are needed to allow the urea phosphate crystals to nucleate and grow, increasing the recycled mother liquor to $\text{H}_3\text{PO}_4$ ratio will delay the nucleation and slow up the growth of the crystals.

Recycled mother liquor/$\text{H}_3\text{PO}_4$ ratios of 0, 0.5, 1.0, 1.5, and 2 have been tried in this work. Figure-3 shows both urea phosphate recovery and the required dissolution temperature of the urea prills as a function of recycled mother liquor/$\text{H}_3\text{PO}_4$ ratio. The used mother liquor contains 8.5 wt% N and 20.5 wt% $\text{P}_2\text{O}_5$. It is clearly seen from Figure 3 that increasing the recycled mother liquor/$\text{H}_3\text{PO}_4$ ratio over a range of 0 to 2 caused progressive decreases in the dissolution temperature from 88 to 50°C. This reduction in the dissolution temperature will also reduce the cooling duties for both the reactor and the crystallizer. Lewis et al. (1983) reported a dissolution temperature of 76°C for mixtures of urea and $\text{H}_3\text{PO}_4$ without a recycled mother liquor and a dissolution temperature of 37°C for mixtures with a recycled mother liquor to $\text{H}_3\text{PO}_4$ ratio of 4. It is also noticed that increasing the mother liquor/$\text{H}_3\text{PO}_4$ ratio up to a certain value, the recovery will increase, and beyond this value the recovery will decrease again. From the results a mother liquor/$\text{H}_3\text{PO}_4$ ratio of 1:1 was found to be the most suitable ratio.

2. Reaction temperature

The modified process includes a reactor and a crystallizer separated from each other compared with the conventional process which has a recator crystallizer in one vessel. A source of heating is required as well to raise the mixture temperature to the required reaction temperature and to erase the history and melt all fine urea particles present in the solution. To overcome the problem of the presence of fine particles that resulted in very fine product, the temperature of the solution must be raised to a proper value at the beginning of the reaction only (Lewis et al., 1983). Once the mixture become clear of any solid urea, the mixture temperature is brought back to the required reaction temperature by the aid of the cooling/heating media through the jacket of the reactor.

The effects of the reaction temperature on the urea phosphate recovery and crystals size are presented in figure (4). It is obvious that the optimum reaction temperature is around 45°C; below this temperature the recovery was slightly reduced slightly, and the size of the obtained crystal was smaller. On the other hand, at 50°C the nucleation step took longer time to start, and there were only few crystals but the final size of the crystals was larger.

3. Reaction time

It is important to keep the agitation speed low, otherwise, excessive stirring may cause abrasion and cleavage of crystals which are detrimental to crystal growth. It is recommended to leave the mixture without cooling for the period of nucleation to permit only small number of urea phosphate crystals to nucleate and grow. Cooling the system at this stage will allow more urea phosphate crystals to nucleate and so increasing the number of nuclei which will not allow the crystals to grow up and give large sizes. Large urea phosphate crystals could be only obtained if the cooling step starts after enough nucleation time (Lewis and Dillard, 1984).

Figure 5 presents the effects of the reaction time on the recovery and final crystal size of the urea phosphate product. The recovery of urea phosphate does not change after 2 hours and remains at about 80% which means that there is no need to leave the mixture in the reactor more than 3 hours. It is also noticed that below 2 hours of reaction time, only small number of urea phosphate crystals nucleated in the reactor, these crystals continued to grow in the crystallization step resulted in large crystals size but most of the urea phosphate crystals were excessively nucleated in the crystallizer which was maintained at low temperature (15°C). With this large temperature difference ($\Delta T = 30^\circ C$)
between the reactor (45°C) and the crystallizer, excessive nucleation occurred in the crystallizer, and this resulted in a relatively small size product crystals.

4. Crystallization temperature

Increasing the crystallizer temperature reduces the urea phosphate recovery but increases the size of the final crystals. Figure 6 shows the effects of the crystallizer temperature on the recovery and the final crystal size of the urea phosphate product. It is clearly seen that decreasing the crystallizer temperature will increase the recovery of urea phosphate crystals, about 95% could be reached at a crystallizer temperature of 5°C but the crystals were fine (size \( \cong 0.48 \text{ mm} \)) and the product was white and shiny (see Figure 7a). Larger urea phosphate crystals were obtained at 25°C but with less urea phosphate recovery (about 55%), which is a very low value and might not be economical for the producers. Hence, it is believed that 15°C might be a suitable crystallizer temperature at which about 80% of the urea phosphate was recovered as white, shiny, and larger in size (\( \cong 0.72 \text{ mm} \)) crystals (see Figure 7b).

5. Crystallization time

The effects of crystallization time on the recovery and the size of the urea phosphate crystals are shown in Figure 8. As the crystallization time increases, both the recovery and the size of the crystals increase up to a crystallization time of 2 hours after which there was no appreciable effect was noticed. As a result, a crystallization time (2 – 3 hours) is considered to be a sufficient crystallization time for this process. It is recommended to crystallize the urea phosphate mixture for a period of 2 to 3 hours and recover 80% of the urea phosphate as crystals and leave the remaining 20% in the mother liquor which will be used as a recycle stream or can be used to produce clear liquid fertilizer (Wilbanks and Faulkner, 1980, Herman et al., 1987, and Hodge and Motes, 1994).

The effect of crystallization time on urea phosphate recovery was carried out at some specified operating conditions, see Figure 9. About 80% recovery was obtained in the first 2-3 hours, while a recovery of 96% could be reached after 24 hours. This means that it might be a waste of time and energy to recover this additional 16% over a period of time of 21-22 hr.

6. Cooling time

Lastly, one more trial was carried out to obtain urea phosphate crystals by leaving the mixture to cool down from a temperature of 45°C to ambient temperature (30°C) naturally without the aid of any cooling medium. Figure 10 shows a graphical representation of the recovery of urea phosphate crystals as a function of the cooling time. The obtained crystals were very large in size (\( \cong 0.9 \text{ mm} \)), white, and very shiny (see Figure 11b) as compared with those obtained by the conventional method (see Figure 11a). It should be mentioned that the recovery of the urea phosphate product was 80% after the first 12 hours and became 85% after 24 hours. This means that it might not be feasible to wait extra 12 hours to get 5% additional recovery.

Table 3 shows a chemical analysis for the urea phosphate crystals obtained at best conditions (reaction temperature of 45°C, reaction time of 2 hr, crystallization temperature of 15°C, crystallization time of 2 hr, and a mother liquor/H\(_3\)PO\(_4\) ratio of 1:1). The analysis reveals that most of the mineral impurities accompanying the wet-process phosphoric acid remains in the mother liquor.

Table 3: Chemical analysis of urea phosphate crystals obtained at best conditions

<table>
<thead>
<tr>
<th>Element</th>
<th>(wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>17.1</td>
</tr>
<tr>
<td>P(_2)O(_5)</td>
<td>44.5</td>
</tr>
<tr>
<td>SO(_4)(^{-2})</td>
<td>0.02</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>0.06</td>
</tr>
<tr>
<td>F</td>
<td>0.09</td>
</tr>
<tr>
<td>Fe(_2)O(_3)</td>
<td>0.07</td>
</tr>
<tr>
<td>MgO</td>
<td>0.05</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.30</td>
</tr>
</tbody>
</table>

CONCLUSIONS

- According to the present work the nucleation step must be separated from the growth step to obtain crystalline urea phosphate with less impurities. Two separate equipment (a reactor and a crystallizer) should be used instead of one equipment (reactor-crystallizer).
- The best operating conditions to produce crystalline urea phosphate according to the present work are: urea/untreated acid H\(_3\)PO\(_4\) mole ratio of 1:1, mother liquor/H\(_3\)PO\(_4\) weight ratio of 1:1, reaction temperature of 45°C, reaction time of 2-3 hr, crystallization temperature of 15°C, crystallization time of 2 hr, agitation speed of 90-100 rpm, drying temperature of 40°C, and a centrifuging speed of 1200 rpm.
- According to the suggested procedure there is no need for high drying temperature. The urea phosphate produced will have large size and non-sticky surface crystals, which means low drying temperature and less residence time are needed in the dryer. Definitely, this will reduce the amount of fuel burned in the drying step.
A maximum yield is obtained using the suggested procedure without the need for a second cycle, and the resulted mother liquor is much more stable and does not precipitate crystals in contrary to what happens in the conventional procedure followed by many urea phosphate producers.

The experimental results of this work indicated that increasing the retention time in the reaction and crystallization stages caused progressive increase in the crystal size and impurity reduction of the final urea phosphate product.

Increasing the fluidity of the mixture will result in the production of large urea phosphate crystals almost free of impurities. Most of the mineral impurities accompanying the wet-process acid remains in the mother liquor that leaves the centrifuge.

Experimental work showed that the fluidity of the mixture, and the nucleation temperature are the most important factors that affect the quality and the size of the urea phosphate crystals.

Figure 3: Effect of recycled mother liquor/H3PO4 ratio on the required temperature to dissolve urea prills and urea phosphate recovery at a reaction temperature of 45ºC, reaction time of 2 hr, crystallization temperature of 15ºC, and crystallization time of 2 hr.

Figure 4: Effect of the reaction temperature on the urea phosphate recovery and crystals size at constant reaction time of 2 hr, crystallization temperature of 15ºC, crystallization time of 2 hr, and a mother liquor/H3PO4 ratio of 1:1.
Figure 5: Effect of the reaction time on the urea phosphate recovery and crystals size at constant reaction temperature of 45°C, crystallization temperature of 15°C, crystallization time of 2 hr, and a mother liquor/H3PO4 ratio of 1:1.

Figure 6: Urea phosphate recovery and crystals size as a function of crystallization temperature at a reaction temperature of 45°C, reaction time of 2 hr, crystallization time of 2 hr, and a mother liquor/H3PO4 ratio of 1:1.
Figure 7: Photographs of urea phosphate crystals obtained (a) at crystallization temperature of 5°C (crystals size 0.48 mm) (b) at crystallization temperature of 15°C (crystals size 0.72 mm).

Figure 8: Effect of the crystallization time on the urea phosphate recovery and crystals size at constant reaction temperature of 45°C, reaction time of 2 hr, crystallization temperature of 15°C, and a mother liquor/H₃PO₄ ratio of 1:1.
Figure 9: Recovery of urea phosphate crystals as a function of crystallization time at constant reaction temperature of 45°C, reaction time of 2 hr, crystallization temperature of 15°C, and a mother liquor/H3PO4 ratio of 1:1.

Figure 10: Graphical representation of urea phosphate crystallization when the reaction mixture is naturally cooled from a reaction temperature of 45°C to ambient temperature (30°C) over a 24 hr period of time for a mother liquor/H3PO4 ratio of 1:1.
Figure 11: Photographs of urea phosphate crystals obtained (a) by the conventional method (crystals size < 0.1 mm) (b) naturally cooled from a reaction temperature of 45°C to ambient temperature of 30°C (crystals size 0.90 mm).

REFERENCES


انتاج فوسفات اليوريا المبلور باستخدام حامض الفسفوريك الأردني غير المعالج

يوسف احمد مبارك

ملخص

لقد امكن الحصول على بلورات فوسفات اليوريا (0-44-17) ذات نقاء عالية واحجام بلورات كبيرة وذلك باستخدام حامض فوسفوريك أردني غير معالج وذي محتوى 50% P2O5. تتضمن طريقة الحصول على بلورات فوسفات اليوريا إضافة نسبة معينة من السائل الأم المتفاعل الذي يحتوي على اليوريا وحمض الفوسفوريك غير المعالج. وقد وجد ان أفضل درجة حرارة لتشكل بلورات فوسفات اليوريا تتم عند 45 درجة مئوية و زمن تفاعل يتراوح بين 2 الى 3 ساعات.

يصبح الخليط بعدما الاحجادات على درجة حرارة 15 درجة مئوية استكمال عملية نمو البلورات وزيادة المحصول. تتضمن طريقة الإنتاج المحترمة استرجاع ما يقارب 80% من اليوريا و حامض الفوسفوريك المضاربين إلى المفاعل كما ان نسبة الشوانج في المنتج النهائي تكون محترمة جدا، و تمتلك الطريقة المحترمة بعض الميزات عند مقاربتها بالطريقة التقليدية والمعتمدة حاليا لإنتاج فوسفات اليوريا مثل: سهولة التحريك والتحليق في المفاعل والمزلاج، سهولة نقل الخليط بواسطة المضخات، وقصر زمن التبريد، وسهولة فصل بلورات فوسفات اليوريا عن السائل الأم في عملية الطرد المركزي، والحصول على جفاف مقبول في زمن أقل و على درجة حرارة ادنى.

الكلمات الدالة: فوسفات اليوريا، بلورات، النمو، حامض الفسفوريك المصنع بالطريقة الوطنية، التبتور.