A Production Process for Specialty Field Fertilizers

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Introduction on Plant Nutrition

- Plant nutrients are essential elements for plant growth
- Nitrogen (N), phosphorus (P) and potassium (K) are required in high quantities relative to the other nutrients and are designated as macronutrients
- Calcium (Ca), magnesium (Mg) and sulfur (S) crop demand is similar to that of N, P and K, however they are often referred to as secondary nutrients.
- The elements boron (B), zinc (Zn), cooper (Cu), iron (Fe), manganese (Mn), chlorine (Cl) and molybdenum (Mo) are required in significant smaller quantities by crops and are known as micronutrients.
- Micronutients are also essential for plant growth and must be available in sufficient quantities to secure high crops yield and quality.

Introduction on Plant Nutrition

Average concentration of mineral nutrients in plant shoot dry matter (Marschner, 2002).

Macronutrients	%	Micronutrients	mg kg^{-1} (ppm)
Nitrogen	1.5	Iron	100
Potassium	1.0	Chlorine	100
Calcium	0.5	Manganese	50
Magnesium	0.2	Boron	20
Phosphorus	0.2	Zinc	20
Sulphur	0.1	Copper	6
Molybdenum	0.1		
Nickel	0.1		

Introduction on Plant Nutrition

- Fertilizers restore available nutrients in the soil profile to levels that are compatible with high crop yields and quality
- Higher yields, improved crop varieties, high rates of application of NPK fertilizers, and better crop management practices have increased the need for secondary and micronutrients in crop production
- The secondary elements Ca, Mg and S are included in some fertilizers that supply the macro elements N, P and K or can be supplied to the soil through specific fertilizer products, such as Calcium Nitrate, Magnesium Carbonate or Magnesium Sulfate.
- Micronutrients B, Zn, Cu, Fe, Mn and Mo are rarely present in significant quantities in fertilizers carrying primary or secondary nutrients, mainly because of the generalized use of high-analysis fertilizers.

Introduction on Plant Nutrition

- The concentration of micronutrient in the soil solution that is beneficial to crops is smaller than the concentration of macro nutrients. The difference between a deficient and a toxic concentration in the soil solution is rather narrow.
- The narrow "window of effectiveness" associated with micronutrients create special fertilizer application problems. The relatively small rate to be applied needs to be evenly distributed over the complete area of application.
- One alternative is to include the micronutrient fertilizer in a bulk-blend of macronutrient fertilizers. The final blend must be highly homogenous and be kept in that condition until it is spread in the field. Segregation will concentrate the micronutrient fertilizer in certain areas of the blend resulting in uneven application. While some areas in the field will receive less than the needed micronutrient rate, other areas may receive toxic levels of application.
- Compound fertilizers offer a better alternative than bulk blend fertilizer mixes. If minute fractions of the micronutrient fertilizer can be attached to each granule of the compound fertilizer, then the even application of the compound fertilizer will secure an even application of the micronutrient over the whole area of application.

Process Alternatives for a Compound Fertilizer

- The goal of this work was to design a process to produce granules containing sodium nitrate and urea, allowing also for incorporating small amounts of other compounds; with the purpose of satisfying specific plant nutrition needs
- A granulation and two fattening processes were evaluated to achieve this objective
  - Granulation is a process where small particles are gathered into larger ones by the action of a binder
  - Fattening of a granule is a process for layering a granule with the liquid of the same or another material

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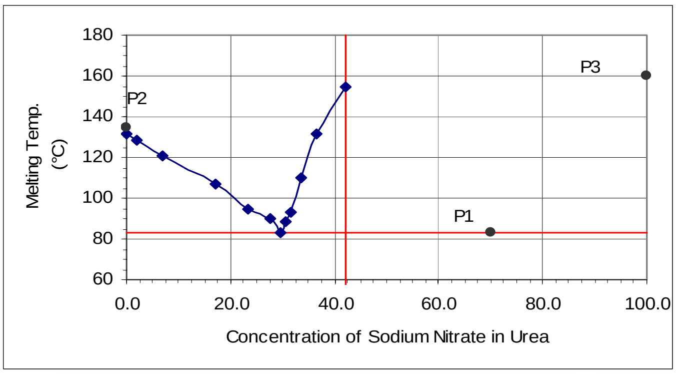
Process Design

- Phase equilibrium for the Sodium Nitrate – Urea system has an eutectic point
- The eutectic mixture is a good candidate for binder material and may allow for an energy efficient process



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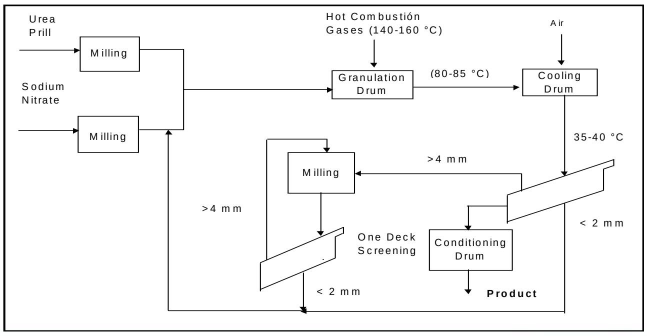
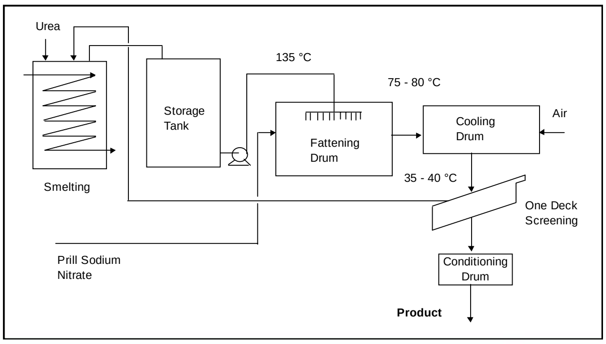
Process Alternatives

1. Wet Granulation:
   – 70% sodium nitrate and 30% urea prills are crushed and fed into a heated granulation drum at 90°C
   – In equilibrium conditions at 90°C, 42% of the mixture would be melted at the eutectic composition (30% $NaNO_3$, 70% urea), acting as binder for the granulation
   – Pilot plant test results were not satisfactory, rendering soft and easy to break granules



Process Alternatives

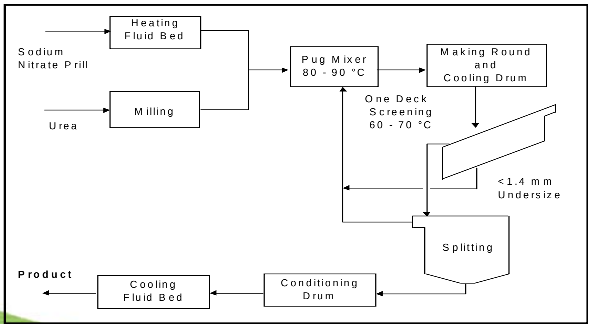
2. Fattening of sodium nitrate prills with melted urea
   – Sodium nitrate prills at room temperature are covered with melted urea (135°C) to form eutectic mixture at the surface of the $NaNO_3$ prills when cooling of urea occurs
   – Bench scale test results showed that the urea outer layer was weak and became loose after a short period of time, detaching from the $NaNO_3$ prill. Heat transfer from the urea to the $NaNO_3$ prills was inefficient, resulting in poor eutectic mixture formation.

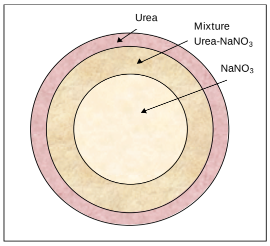


Process Alternatives

3. Fattening of preheated NaNO3 prills with urea

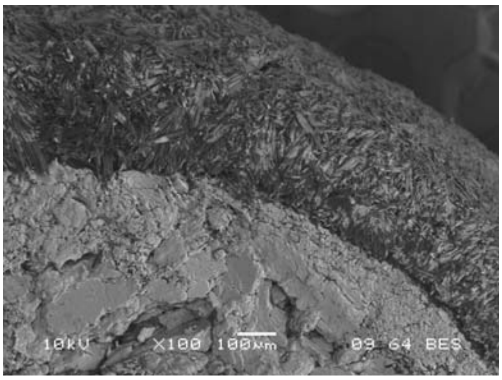
– $NaNO_3$ prills are heated to 160°C and are mixed with crushed urea; 70% $NaNO_3$ and 30% urea
– The heat transfer from the prill to the urea allows for the eutectic mixture formation on the prill surface
– This process was selected for an industrial plant, currently in operation





Industrial Plant Results

- A compound urea-sodium nitrate granule obtained from the industrial plant production, evaluated with Scanning Electron Microscopy (SEM-EDX)
- The different shades of grey relate to different chemical compositions



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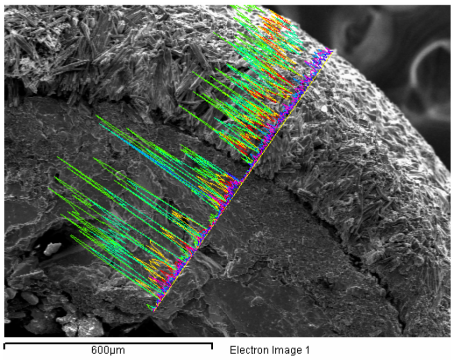
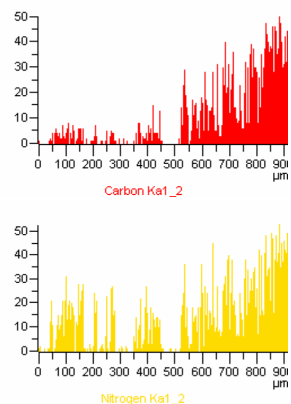
Industrial Plant Results

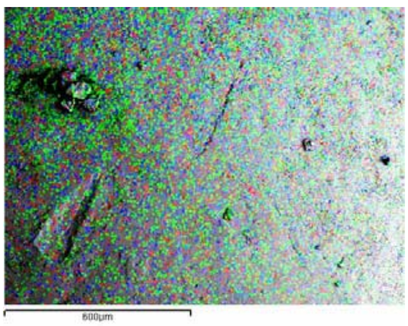
- Chemical profile analysis

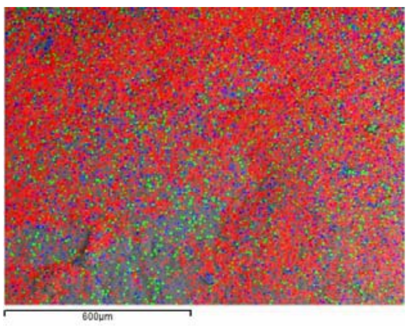




Industrial Plant Results

- Chemical mapping on the surface of a granule produced from a potassium nitrate prill covered with an urea-MgO mixture (2% MgO).
- The rich Mg layer is about 100 µm thick





■ Magnesium ■ Nitrogen ■ Carbon

Conclusions

- A process was designed and an industrial plant was built by using solid-liquid phase equilibrium information for urea and sodium nitrate.
- Currently, this plant is operating and producing different compound products of the type urea-sodium nitrate and urea-potassium nitrate.
- A variety of minor components can be added to this type of products, allowing for secondary and micronutrients incorporation into the granules, giving opportunity to design a product for satisfying specific plant nutrition needs required by the costumers.
- Compound products with the three primary nutrients: nitrogen, phosphorous and potassium (NPK) also could be produced with the process developed in this work, combining raw materials such as urea, ammonium nitrate, monoammonium phosphate, sodium nitrate, potassium nitrate, calcium nitrate, and potassium chloride