Assuring premium urea product quality

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Summary
This technical paper starts with introducing the various finishing technologies in use worldwide and the various forms of urea available in the market. Then it will discuss the critical urea product quality parameters like Caking, Strength, Contamination, Segregation and Dust. The paper will conclude following: As the urea market becomes tighter and competition will increase, urea producers need to assure top quality product to become or stay ahead in this competition. Moisture content is key to minimize / avoid caking problems and top quality product pays back in premium prices and less product losses. This paper also provides a recommended urea granule quality when one likes to export urea.

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1. Introduction

About 75% of all 500+ urea plants worldwide produce prilled urea. Prill quality urea suit quite well when applied locally and when not transported in bulk. Prills typically have an average diameter of 1.7 mm, although in the CIS countries the average diameter is 1.9 mm. Prills have a relatively low crushing strength of some 1 kg/cm². The figure below shows left a natural draft prilling tower located close to Urumqi, Xinjiang province in the People’s Republic of China and on the right side a rotating prilling bucket in operation.

Figure 1: A natural draft prill tower and a prilling bucket in operation.

Most other urea plants operate a fluid bed granulation, which typically produces a larger size urea product (average diameter is 3 mm) with a significant higher crushing strength (typical 3 kg/cm²). Granules are very well suited to ship in bulk and granules are produced in urea plants, which produce product for export purposes.

In mostly North America one can find still several drum granulation lines in operation in some urea plants. Drum granulation is an older technology (1960-1980) and typically one line can produce some 500 mtpd urea. The product quality of a drum granulation resembles the product quality from a fluid bed granulation.

Please note that in certain areas like North and South America, urea granules are used in bulk blending plants producing mixed fertilisers like NPK and NPKS. To avoid segregation problems it is important that the urea granules particle size distribution is minimum and matches closely with the other fertilizer P, K and S granules.

The figure below shows a Yara fluid bed granulation in China and a drum granulation (location unknown).

Figure 2: A fluid bed granulation and a drum granulation
Another upcoming finishing technology is the Sandvik Process Rotoformer, where urea melt is sprayed on a rotating cool steel belt. The resulting urea pastilles are very uniform with a crushing strength close to granules. Furthermore the diameter of the pastilles can be freely chosen, the required energy figures are very low and also the emission figures are very low. The figure below shows two Sandvik Process Rotoformer lines (skid mounted including a hood).

**Figure 3: Two Sandvik Process Rotoformer lines**

The Sandvik Process Rotoformer is an excellent finishing technology to produce technical urea or urea plus ammonium sulphate, urea plus sulphur or urea plus other nutrients.

In the market one can find various forms of urea besides the fertilizer grades. Technical urea is urea without any additives, which is used for urea formaldehyde (plywood), melamine and nowadays more and more for AdBlue, also called DEF (NOx reduction). Further one can find feed grade urea (1 mm size) and urea briquettes in the market. The IFDC (International Fertilizer Development Corporation) from the US is promoting urea briquettes for rice production as it reduces the nitrogen losses to air and water during application. This is called Urea Deep Placement as each urea briquette is placed in between 4 rice plants deep in the soil of the paddy. Refer to the figure below.

**Figure 4: Urea Deep Placement of a Urea Briquette developed by IFDC**
2. Urea Product Quality

**Strength**

Strength is a very important quality parameter as sufficient strength will avoid dust and fine formation during transportation and reduce caking problems.

One can distinguish three strength parameters:
1. Crushing strength: the static weight a urea particle can handle before it crushes. This parameter is of importance when storing urea in bulk.
2. Impact resistance: the dynamic force a urea particle can handle when bouncing with a certain velocity on a surface. This parameter is of importance when poring urea in a ship or warehouse.
3. Abrasion resistance: the tendency that particles creates dust when these are rubbed against each other. This parameter is of importance when transporting urea for example on a conveyor belt.

Typically only crushing strength is a requirement when urea is traded in the market. But the other strength parameters can also cause complaints from a client.

It is good practice to “teach” all parties in the logistic chain the best practices how to handle urea. Therefore many urea producers issue urea handling recommendations.

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**Caking**

Caking is the quality parameter causing most complaints from customers. Caked urea product is causing loss of product and fines and dust when these lumps are broken loose again. Below find examples of caked urea product.
What is caking?
Caking of urea is caused by the formation of crystal bonds between urea particles. When one presses two urea particles against each other, after some time these two particles form a bridge between each other. Refer to the figure below.

![Figure 7: The formation of crystal bonds between two particles.](image)
The figures below show the bridge diameter and strength versus storage time: The bridges are formed quickly but its strength increases in time.

![Figure 8: Bridge diameter and strength in time](image)
So one can distinguish loose and strong caking depending on the strength of the bridges. Also note the strength of these bridges is stronger for bridges, which are formed when moisture migrates from inside the granule to outside than vise versa. So it is recommended to keep the moisture level in the granules at a minimum level.

Now lets have a look which factors influence caking behavior. Moisture and moisture differences between particles or batches of urea product is the most important factor causing caking. Related to this also the relative humidity of the air in which the urea product is stored is important.
Second factor is temperature and temperature differences between particles or batches of urea product or between urea product and the surrounding air. Then the other factors influence caking behavior like free ammonia (and differences), formaldehyde content (differences, nota also that the formaldehyde content varies in granule itself), coating, particle size distribution (Size Guide Number, Uniformity Index), dust and fines content and storage pressure and time. But again moisture is the key parameter.

The graph below shows the relation between relative humidity and temperature and one can see a line where above caking occurs. This is the so called the Critical Relative Humidity (CRH).

![Figure 9: CRH of urea versus temperature (urea and air have same temperature)](image)

In case the relative humidity of the surrounding air is above the CRH, moisture will be picked up by the urea product from the surrounding air and caking will occur. At even higher levels of relative humidity urea particles will start to dissolve. For urea having higher contents of formaldehyde, the CRH curve will be somewhat lower, resulting in a somewhat more hygroscopic behavior of Urea containing more formaldehyde. Further the graph shows that the higher the product temperature the lower the CRH. This means it is important to produce urea granules with a low and constant temperature.
But this is not always easy as ambient conditions can be tough and temperature and relative humidity levels vary during day-night and throughout the year. For example storage of a warm product in a relatively cold environment is a situation that occurs often. Urea product is produced with a relatively high temperature and is transported at this temperature to the storage. The average temperature in the storage is somewhat lower. The water vapour pressure of the warm urea product is higher than the water vapour pressure of the surrounding air, therefore some water will evaporate from the urea product into the air. At the same time the top layer of the urea heap will cool down to the lower temperature in the storage leading to a lower water vapour pressure of the urea product. Thus a moisture gradient is formed between the center of the heap and the top layer and moisture will migrate from the center to the top layer, which is supported by the air movement through the heap. As the temperature in the storage will vary somewhat due to day-night cycles, in the top layer of the heap continuous transport of moisture occurs, liquid bridges are formed leading to caking of the top layer. Note that this temperature dependence is less critical when moisture content of the urea product is already lower. And therefore we like to repeat our recommendation to keep the moisture content of the urea product minimum.

How one can influence the moisture content in the urea granules?
First of all it is very important to feed the fluid bed granulation with the right urea melt concentration. The right urea melt concentration again is determined for a significant part by operating the vacuum section at the right design pressures and temperatures as indicated in the figure below.

![Figure 10: Influencing moisture content in the urea melt](image)

In case you have problems to realise the design conditions, be advised companies like GRAHAM ([www.graham.com](http://www.graham.com)) do provide troubleshoot services.

Also in the granulation section itself several parameters can be adjusted to improve the moisture content as indicated in the following figure.
Figure 11: Influencing moisture content in the fluid bed granulation

One and maybe the most important parameter to influence the moisture content in the urea granules is the level in the fluid bed granulator. One needs to assure that one operates with a bubbling bed and by that assures that there is sufficient movement of the granules through the spraying zones. Only then one creates the right circumstance and surface area to evaporate water from the urea melt and thus assure a sufficient low moisture level in the granules.

Even when a urea plant delivers a perfect product, it is still possible that during storage and in the logistic process the product is mistreated and its perfect quality is destroyed. Refer to figure below for some examples.

Figure 12: Urea product mistreated during storage and further logistic steps
This brings us back to our earlier recommendation to issue urea handling procedures for all parties involved in the logistic chain and of course your customer. This is already good practice in many areas worldwide.

**Contamination**
Find in the below figure some examples of contamination when using bulk carriers. Good inspection of cleanliness and covering the urea heap with a polyethylene sheet is good practice to avoid contamination and customer complaints.

![Contamination of urea during logistics](image1)

**Figure 13: Contamination of urea during logistics**

**Segregation**
As granules are produced in a certain particle size range, segregation will occur during the several logistic steps as is shown in the figure below. Also this is a point of attention when discussing logistic handling procedures.

![Segregation](image2)

**Figure 14: Contamination of urea during logistics**

In case one faces complaints from customers one can perform a product quality assessment and thus assess the product quality at each step of the logistic process between producer and customer. This assessment enables one to find the logistic step(s), which mostly deteriorate the quality and where certain countermeasures need to be implemented. Refer to the figure below.
The figure shows that after taking the right measurements one is able to assure an acceptable product quality at the customer.

**Dust**

When one cannot solve dust problems for one or the other reason, UreaKnowHow.com can offer a so-called "end of pipe" solution: The Van Bommel Dedusting Technology (VBDT) removes all dust from your urea product when one fills a bulk carrier for example. This is thus a de-dusting technology capable to de-dust a bulk flow capacity of for example 500 tons per hour. Refer to the figure below for an impression of the Van Bommel Dedusting Technology. More information one can download via: 

![Figure 15: Urea product assessment](image)

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![Figure 16: Impression of the Van Bommel Dedusting Technology](image)

**Figure 16: Impression of the Van Bommel Dedusting Technology**
3. Conclusions

- The urea market becomes tighter and competition will increase
- Urea producers need to assure top quality product to become or stay ahead in this competition
- Moisture content is key to minimize / avoid caking
- Top quality product pays back in premium prices and less product losses

Let’s also summarize the recommended urea granule quality when one likes to export urea:

- **Moisture**: max 0.3 wt%
- **Biuret**: max 1 wt%
- **Nitrogen**: min 46.0 wt%
- **Crushing strength**: 3 kg on 3.15mm granule
- **Size distribution**: min 90 wt% in the requested particle size range
  
  (2-4 mm is preferred in case of bulk blending at customer)
- **Fines smaller than 1.25 mm**: max 1 wt%
- **Formaldehyde**: as specified by the customer
- **Free ammonia**: max 150 wt-ppm
- **No caking / free flowing**

Besides adhering to these urea product quality parameters also note our recommendation to issue urea handling procedures to all parties involved in the logistic chain and to your customers.